THULE, NORTH RIVER BRIDGE

Kjeld Thomsen, Man.Dir., Christian Riis Petersen, Associate
ISC Consulting Engineers A/S, Copenhagen, Denmark.

NSCC, Copenhagen 2004

Summary

The new North River Bridge is supposedly the most northernly built road bridge of that size at the latitude of 77˚N.
The bridge with 60 m span crosses the North River, which runs parallel with the runway in Thule Airport. The bridge replaces a shorter 23m span truss bridge, which was destroyed during a flood in the autumn of 2001.
The arctic climatic condition has influenced the selection of structural system and steel material adequate for application at very low temperatures.
The bridge structure consists of two warren type 5 m tall trusses carrying the 8.4 m wide bridge deck. No lattice bracing is arranged between the top flanges due to client requirement leaving the free compressed top flange length of 54 m only elastically supported by the truss bracing restrained in the transverse floor beams. The bridge deck is timber oak beams transversely prestressed together with dywidag bars forming a homogeneous slab. The timber deck is specially applicable in dry and cool climate.
Only one or two ships arrive at Thule every year and all construction elements have to be packed into the ship in 40 ft. containers. The system was therefore designed with connections for fast assembly on site and thereby avoiding any welding on at low temperatures.

Fig. 1: View of completed bridge

1. Introduction

Thule Air Base is located at the North West Coast of Greenland at about 77˚ latitude in a rocky, high arctic environment. The Airbase is divided by a canyon parallel with the runway in a distance of about 400m to 600m called North River, water filled in the short summer period and a low frozen water level in the long winter season running from October to June.
The North River separates a major tank farm from the main facilities and runway. In August 2001 heavy rain and melted water from the ice cap resulted in a sudden flooding of the river

which eroded the backfill at the abutments and left the existing lattice girder bridge with a span of 23m half way tilted and unstable amid the riverbed. A study showed that it was not feasible to repair the deformed two lane bridge structure not least because safety considerations indicated that the natural riverbed profile should be restored in the bridge line. This required a total length of the bridge of about 60m and removal of the 20m long embankments to restore the original shape of the river cross section. It was therefore finally decided to construct a two lane road bridge with 60m span. The construction season in this arctic region is only 4 month from June to middle September completion work can take place from mid September to October. Snow storms and temperatures below – 20˚C can be expected in October.
Ship arrival season to Thule is limited to 6 – 8 weeks in the summer season July, August and left only 1½-2 months to assembly and erection of the new bridge. These facts influenced the selection of the structural concept for the bridge. Speedy assembly and installation was a mandatory requirement, which means that welding on site should be avoided. Therefore an all bolted steel lattice girder solution with a stress laminated wood bridge deck fulfilling AASHO Specification was proposed as the most feasible and adequate solution.
The detail design phase was carried out in January/February 2002. The construction contracts were entered in May. Construction of abutments started in June and the bridge was opened for traffic in the beginning of October 2002.

2. Conditions for Structures in Arctic Climate

The climatic conditions in the North of Greenland have had a dominating influence on selection of structural concept for the bridge, selection of material and selection of assembly and mounting.
From end of September to end of May the temperature is normally below 0˚C. Snow starts usually in October and the Thule area is covered with snow until mid June. Seaway traffic is only possible in July/August as the Melville Bay is closed by ice. Only one or two cargo vessels arrive from Denmark to Thule in August, where the sea is free from ice.
The soil consisting primarily of weathered rock and gravel is permanently frozen which means that all foundation shall be built on subsoil in permafrost condition and excavation is usually done by use of blasting.
The water level in North River can be high in the summer season but is usually low and frozen from September to June.
Concrete casting can only be carried out in June, July and August.
Cement and aggregates must be available in June, which means that it shall be shipped the year before application. The steel material for fatigue loaded welded structures shall have sufficient ductility at –60˚C and consequently be normalized, killed steel of quality class

- S355J2G3. EN10025. (ASTM A572 Gr 50) for plate thickness t< 30mm and
- S355NL. EN10113. (ASTM A572 Gr 50) for plate thickness t> 30mm

with supplementary requirements regarding Charpy v-notch testing down to –20˚C and –40˚C respectively for ASTM specified steel.
All structural components for the superstructure shall be prefabricated to max 12 m length corresponding to 40 ft. container size and be loaded onto the same ship arriving in August.
The short construction season means that time consuming welding on site shall be avoided.
A steel bridge calls for limited maintenance because the humidity generally is below 40 %. The speed of corrosion is therefore very slow and paint protection of steel has a long life.

3. Hydraulic Considerations

The natural cross section of the North River bed was narrowed in the old bridge line with embankments on both sides of approximately 20 m length. The water flow in the river and the current speed is mostly acceptable adequate also for the narrowed cross section and no severe erosion problems were experienced in more than 40 years. However, a sudden high melt water amount flowed out from under the permanent ice cap in August 2002 with water level in North River reaching the deck level of the bridge and the strong current eroded the embankments and the backfill of the abutments leading to the partly downfall and torsional deformation of the steel bridge superstructure. The evaluation of the accident resulted in a decision to ease the hydraulic flow by removal of the embankments abutting bridge to achieve a long term reliable solution. The bridge length consequently had to be extended to about 60m.

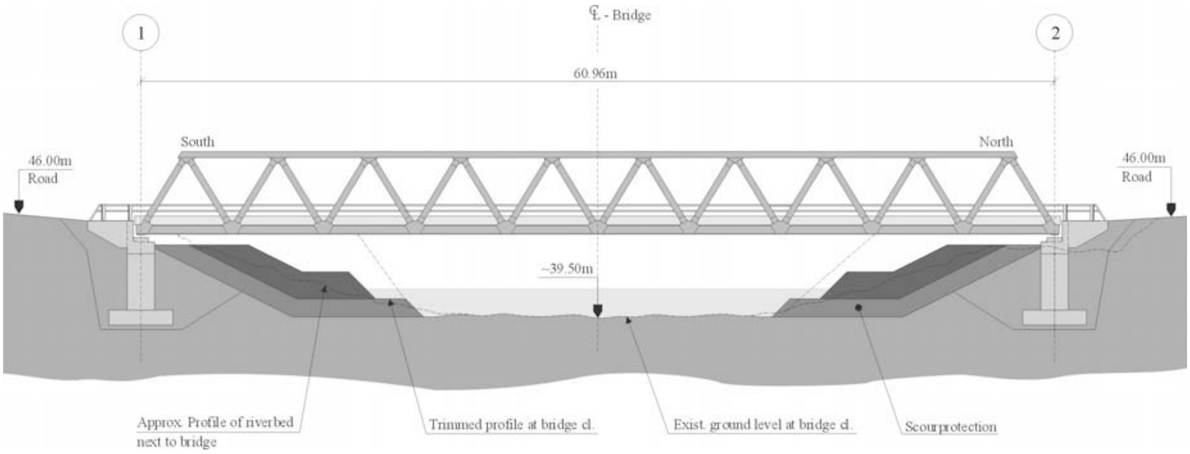

Fig. 2: Bridge elevation

4. Steel Bridge Superstructure

The 200 ft long (60.950 m) free span for the bridge superstructure consists of two 5 m high warren type regular trusses carrying the 27 ft. 8’’ (8.433m) wide bridge deck.
Welded I-shaped bridge floor beams connect the lattice nodes in the bottom flanges by means of rigid HTFG bolted connection thereby forming semi rigid frames at a distance of 20 ft. The open channel shaped cross section of the bridge is made possible due to the elastic horizontal support of the top flange provided by the half frames. A K-lattice bracing in tubular sections 193.3 x 6.3 mm connects the bottom flanges below the bridge floor to a lattice girder carrying the horizontal load to the abutments. *(Figure 3)*

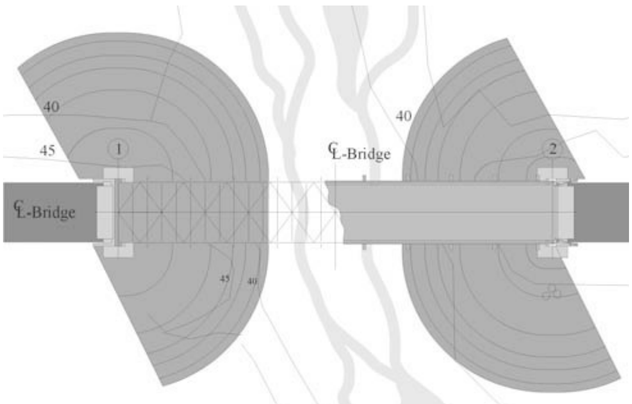

Fig. 3: Bridge plan

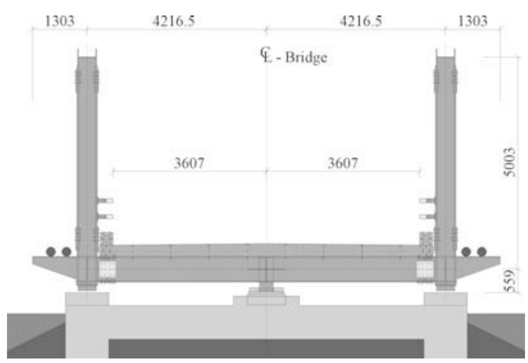

Fig. 4: Bridge cross section

The top and the bottom flanges of the warren type trusses as well as the diagonals are welded H-sections with web depth 16 in, 20 in and 14 in respectively. The flange width is constant 16 in. The flange thickness varies between one inch and two inches. Brackets for support of a fuel pipeline from the tank farm to the airport side of the river and supports of electrical power cables are cantilevered outside the trusses next to every bottom flange node.

The structure is all bolted with HSFG class 10.9 bolts corresponding to ASTM 490 in connections arranged close to the shop welded nodes this keeping the max transport section length under 40 ft for all members in the bridge structure.

A fixed bearing transferring only horizontal load is provided in the centerline at one end of the bridge and a similar bearing carrying only horizontal load transverse to the bridge axis at the other end. Spherical sliding bearings are provided below the outer truss nodes for vertical support of the trusses on the concrete abutments.

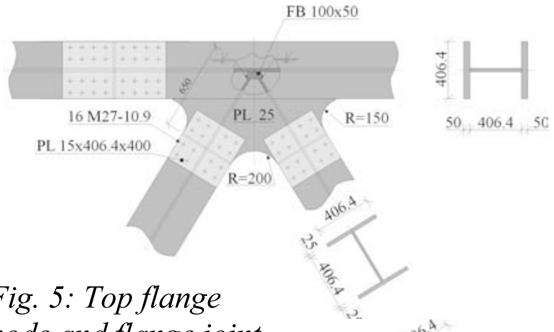

Fig. 5: Top flange node and flange joint

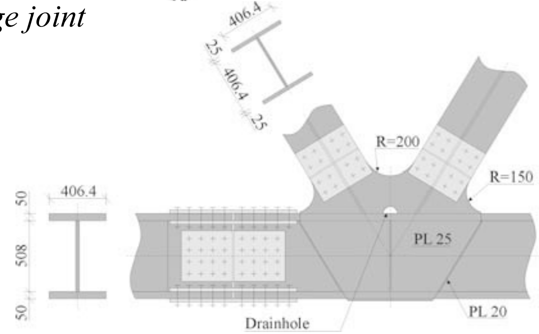

Fig. 6: Bottom flange node and flange joint

Precamber of 150 mm was provided at the centre of the trusses corresponding to the deflection for the dead load and half the distributed load.

An interesting feature was observed in the analyses of the stability and bearing capacity of the horizontally elastic supported top flange of the truss girders.

A conventional analysis of the stability of the top flange in compression with variable axial force was carried out. The static model is shown on figure 7.

The top flange is considered elastically supported in the lattice girder nodes perpendicular to the lattice girder plane.

The elastic support is provided by the lattice members which are restrained in the bridge floor cross beams connecting the bottom flanges of the bridge main girders. However this analysis in the present structural configuration resulted in a conservative lower boundary of the bearing capacity of the top flange.

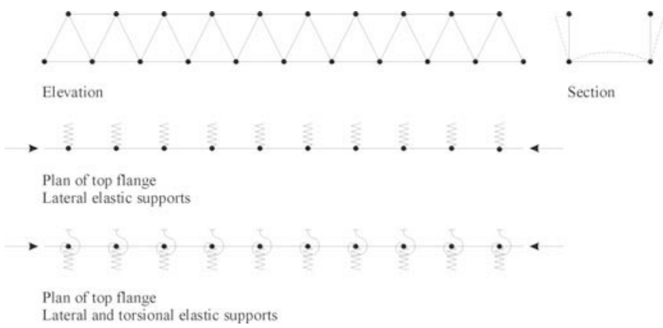

Fig. 7: Static model of top flange

A more accurate analysis was carried out taking into account the rotation restraint in the lattice nodes provided by the torsional rigidity and bending rigidity of the lattice members.

For the simple case with equally distributed load on the bridge an increase of the bearing capacity around 50 % was achieved. This increase was critical for obtaining the required overall stability without arranging a horizontal bracing system between the top flanges.

Omitting bracing was a basic client requirement because an overhead travelling crane is foreseen installed on the top flanges to transport special objects over the bridge.

5. Bridge Deck

The bridge deck consists of German oak timber beams with depth 250 - 300 mm and width 50 mm prestressed transversely to a solid slab by means of 26 mm dia Dywidag bars arranged pr.1.15 m (3ft. 9¼ in.). The transverse prestress is 0.7 Mpa on the gross section. The wood slab is bolted to the cross girders in the bridge floor arranged at a distance of 2,032 (6ft. 8 in.) The wood deck is designed according to the AASHO bridge specifications. Due to shrinkage it is foreseen that the transverse prestress shall be repeated after the bridge has been into service in one year.

The timber is especially suitable for this application compared to an orthotropic steel deck, partly due to the cold and dry climate and partly because time consuming welding is avoided. A timber deck is a durable solution as proven by the service life of more than 50 years in the old bridge.

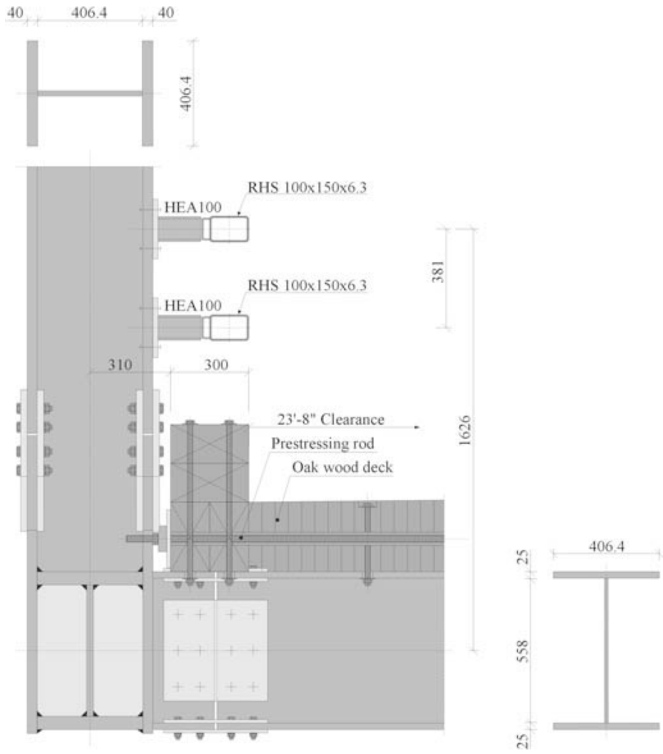

Fig. 8: Timber deck detail

6. Abutments / Retaining Walls

The abutments are constructed in reinforced in-situ cast concrete. They consists of two 1 x 2 m shafts 4.8 m tall each founded on square slabs 4.3 x 4.3 m and 1 m thick. The shafts support an L-shaped 2 m high concrete beam/retaining wall with wings enclosing the road ballast and providing support for the fixed bearing and the two spherical bearings. The shafts and retaining structure are provided with frost heave protection by means of insulation mats and bituminous felt.

The concrete slabs are founded 1 m below riverbed level and approximately 5 m down in the permafrost zone. Excavation was carried out by means of drilling/chiselling, a complex and time consuming method. Thawing of the frozen subsoil shall be prevented.

The excavated surface was covered with a geotextile net and back filled with compacted non frost susceptible NFS fill.

The scour protection around the abutments consists of a 1.2 m thick filter layer with stone size 200-400 mm and a 1.8 m thick armour layer with stone size 1.0 - 2.5 tonnes. Armour stones and filter stones are produced from non weathered sound rock (basalt) found.

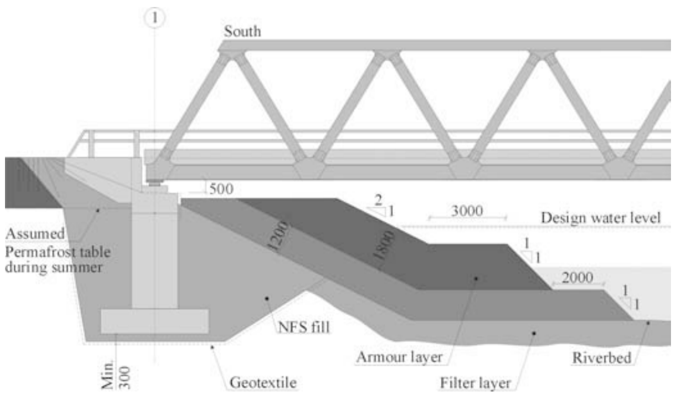

Fig. 9: Abutment detail

7. Construction diary

The excavation for the concrete abutments was carried out in June 2002 and the first concrete casting took place July 10th. Both concrete abutments and execution of backfill and scour protection were completed mid August. The steel superstructure was fabricated in North West of Finland. All the I-sections were fabricated by means of an automatic cutting / welding plant followed by computer aided drilling of bolt holes and lap plates. Accuracy of manufacturing was controlled by a trial assembly of part of the bridge. The steel sections were sandblasted to Sa 2½ and coated with a paint system before leaving the workshop.
Fabrication of steel took place in June/July and all steel members and bolts of class 10.9 and Dywidag prestressing bars were shipped to the port of Ålborg in Denmark arriving July 28th.
The whole bridge structure incl. timber, bearings and bolts left Ålborg August 6th in 40 ft flat rack containers arriving at Nuuk in the Davis Strait on the West coast of Greenland 7 days after.
In Nuuk the cargo was unloaded and further loaded onto another ship crossing the Baffin Bay and arriving at Thule in Northwest Greenland August 17th. The 3 km transfer of the bridge components from the harbour to the site was carried out on lorries. The assembly of the steel structure with around 10.000 bolts was completed in 2 weeks on the Southern shore. The steel bridge superstructure was launched into the final position over two provisional supports placed in the frozen riverbed in only one working day. The precalculated camber was met with an accuracy of 2 mm which underlined the fabrication accuracy for the steel elements achieved in the workshop.
The timber deck was mounted continuously over the cross girders with lamella length of about 5m in a way that only one butt joint occurred in any four adjacent beams within 1220 mm distance. The transverse prestressing was done with 26 mm dywidag bars at a distance of 1.14 m. All holes for the dywidag bars were predrilled before shipment. The prestressing will be adjusted after one year service to compensate for transverse creep. The bridge was completed and opened for traffic in the beginning of October only 8 month after design start.

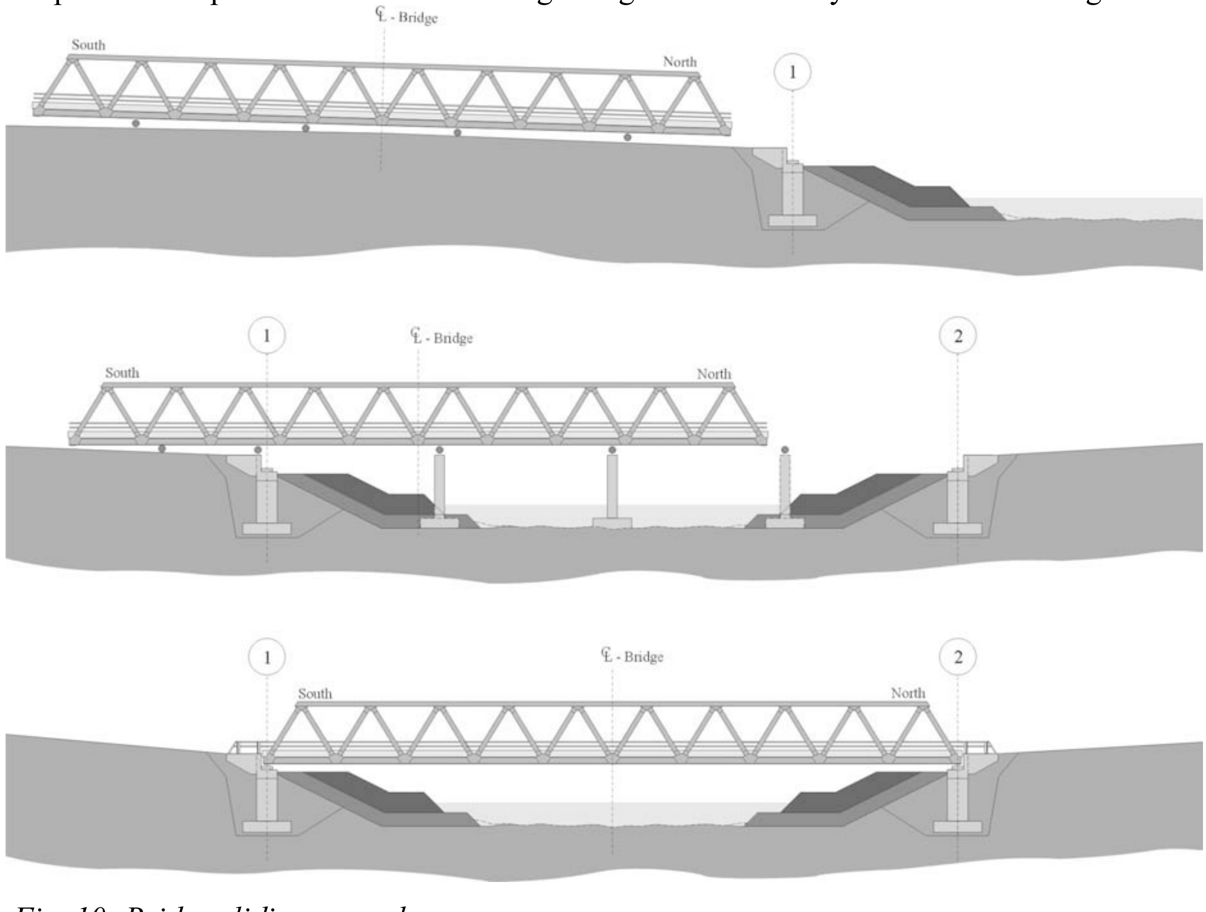

Fig. 10: Bridge sliding procedure

8. Lessons learnt

A number of Danish construction companies have a long standing experience in planning of constructions of buildings and infrastructure works on Greenland going back to World War two.
All material and building components have to be transported to this arctic ice covered island with only 45,000 inhabitants living along the coastline.
The weather window for casting of concrete in the northern region is limited to July and August and all foundations in the Thule region shall be casted on perma frozen soil.
The transport of the whole bridge superstructure contained in only one ship transport required design of a system built up of straight steel members of max 40 ft. length prepared for easy bolted assembly in temperatures down to – 200 C in August, September. Similarly the timber deck was built up of pre-cut and predrilled oak beams. A thorough marking and numbering was mandatory for easy identification and mounting speed on site.
A preassembly in the workshop was also a prime requirement to assure that no site adjustment was needed which would be prohibitive in adhering to the tight construction schedule limited to only a few weeks. A detailed logistic planning is mandatory to achieve a successful termination of construction within the time schedule under the conditions.

9. Conclusion

Successful construction of major structures in remote polar environments call for consideration of climatic conditions, transportation possibilities, adequate weather windows and knowledge of crane equipment on site already at the design stage. Planning of schedule for tender, fabrication, preassembly, transport and construction on site must therefore be precise and comprehensive and adhere to the above mentioned conditions if a successful result shall be achieved. Any error will easily result in one year delay. The design planning and construction of the Thule Bridge adhered to these basic requirements and the bridge went into service according to schedule.

Fig. 11: Inside view of completed bridge

Fig. 12: Front view of completed bridge

10. Data Block

Owner / Client:	United States Air Force
Consulting Engineer:	ISC Consulting Engineers A/S, Copenhagen, Denmark
Main Contractor:	Adserballe & Knudsen, Smørum, Denmark
Subcontractors:	PPTH Kliavieski, Finland, fabrication of steel structures MTHøjgaard A/S, Denmark, assembly and erection of the bridge Enemærke og Petersen A/S, Denmark, concrete structures and earthworks.
Steel (t):	240
Structural bolts:	10,000
In-situ concrete (m3):	175
German oak timber (t):	155
Scour protection stones (m3):	8,500
Service date:	October 2002