**Appendix to report:**

SBJ-33-C5-OON-22-RE-018

DESIGN OF PONTOONS AND COLUMNS

**Appendix title:**

# APPENDIX C – BOLTED COLUMN CONNECTION

| | |
|---|---|
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CONCEPT DEVELOPMENT FLOATING BRIDGE E39 BJØRNAFJORDEN

HEYERDAHL ARKITEKTER AS

# Table of Content

# 1 GENERAL

In order to reduce the time consumed for assembling the brige girder onto the pontoons, a bolted solution is recommended. This solution requires flanged interface between the column and bridge girder. This technical note concerns the dimensioning of the connection and the practical aspects of the assembly.

This bolted connection requires machining of the connecting surfaces after welding. Because this is a large steel structure, the use of mobile machining equipment will be required. Also the bridge girder will need to be machined. This will be done in the factory by a specially designed machining cell.

It is planned to use 2 bolts per 100 mm of the column circumference. This gives a total of approx. 740 bolts distributed around a circumference of approx. 37 m (including transverse flanges). This may seem like a high amount of bolts, but the mounting time is estimated to 2-3 days.

**Time schedule for bolted solution**

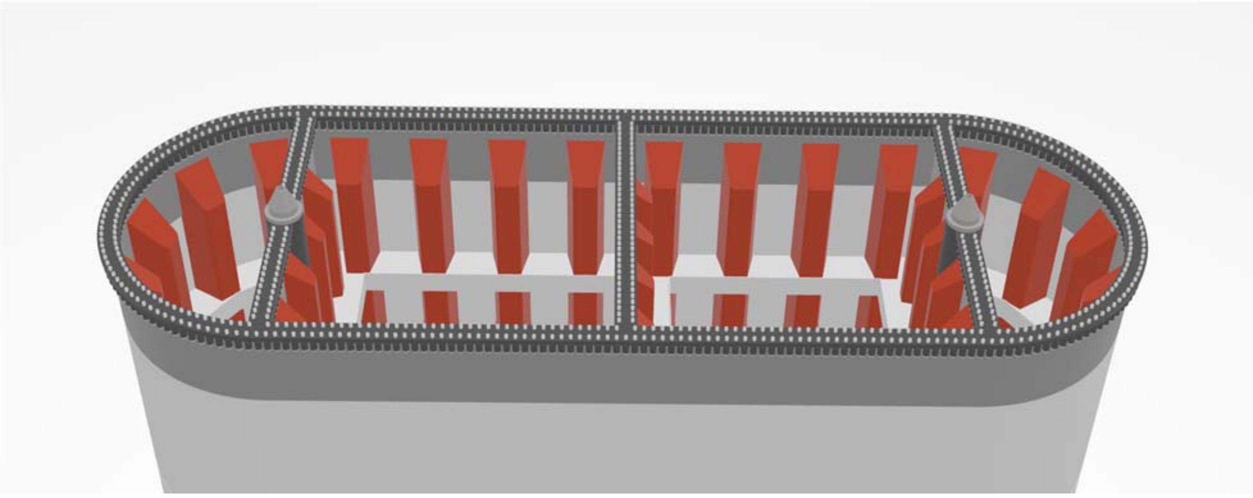
| Description | Number of days |
|---|---|
| Position pontoon (floating pontoon) | 2 days |
| Scaffolding (simpler than for welded solution) | 3 days |
| Position bridge gireder | 1 day |
| Mounting of bolts | 3 days |

The total time for bolted connection between four columns and 480 meters of bridge girder is estimated above. This is a total of 9 days. For mounting of 10 bridge elements the time is estimated to 90 days, or approx. 3 months.

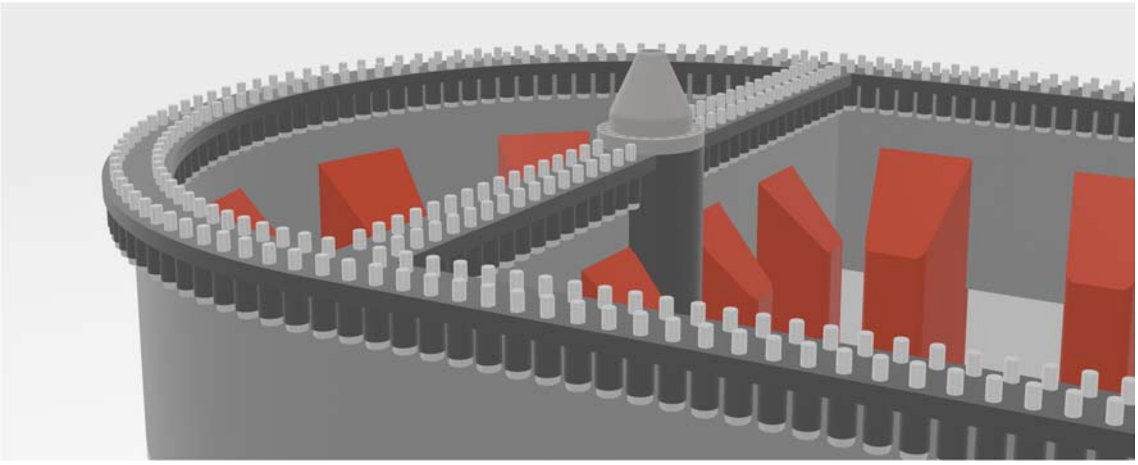
## 1.1 Connection properties

The connection between the column and bridge girder will be flanged type, connected with bolts. The strength of the bolted connection will depend on the bolt dimensios and number of bolts. For pretensioning of the bolts, distance sleeves must be installed.

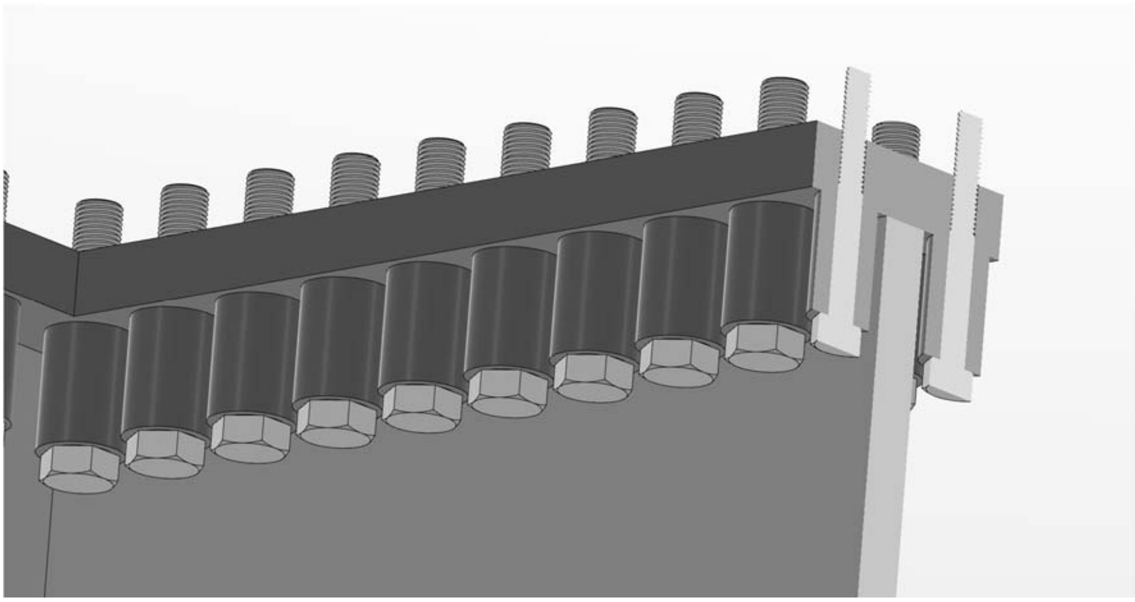
Two guide conic guide pins are to be mounted on the column, and corresponding slots on the bridge girder.



> *Figure 1-1: Bolted connection*



> *Figure 1-2: Bolted connection column*



> *Figure 1-3: Bolted connection – section*

## 1.2 Material properties

This chapter concerns the different materials assessed in this note. The table below shows the properties for plates and bolts which are analyzed.

| Property | Yield stress |
|---|---|
| Yield strength 8.8 bolt | 640 N/mm$^2$ |
| Yield strength 10.9 bolt | 900 N/mm$^2$ |
| Yield strength plate S355 @ t=50 mm | 335 N/mm$^2$ |
| Yield strength plate S420 @ t=50 mm | 390 N/mm$^2$ |

# 2 DIMENSIONING

## 2.1 Strength requirement

In order to satisfy strength requirements, the bolted connection is required to have equal or higher strength than the conventional welded connection:

$F_{bolt} \geq F_{plate}$ ,where

| | |
|---|---|
| $F_{bolt}$ | Maximum force before bolt material yield. |
| $F_{plate}$ | Maximum force before plate material yield (benchmark). |

## 2.2 Calculations

### 2.2.1 Benchmark

For the benchmark calculation, the analysis assumes a column plate thickness of 50 mm $(t)$, and a bolt pattern of 2 bolts per 100 mm $(l)$ along the column circumference.This gives the following stress area, $As_{plate}$:

$$\boldsymbol{As_{plate} = l \cdot t = 50\,mm \cdot 100mm = 5000mm^2}$$

Maximum force before yield will be calculated for two plate material qualities; S355 and S420. The benchmark for both qualities is calculated below:

$$F_{plate} = \sigma_{yield} \cdot As_{plate}$$

| $\sigma_{yield}$ | $F_{plate}$ |
|---|---|
| 335 N/mm$^2$ | 1675 kN |
| 390 N/mm$^2$ | 1950 kN |

### 2.2.2 Bolt dimensioning

As mentioned in ch. 2.1, the strength of the bolts must be equal or greater than the benchmark in order to satisfy the strength requirement. Also for the bolts the stress area $(As_{bolt})$ must be calculated by the following formula:

$$As_{bolt} = \frac{\pi}{4} \cdot \left(\frac{d_2 + d_3}{2}\right)^2 = \frac{\pi}{4} \cdot \left(\frac{d_2 + \left(d_1 - \frac{H}{6}\right)}{2}\right)^2$$ where,

| | |
|---|---|
| $d_1$ | the basic minor diameter of external thread |
| $d_2$ | he basic pitch diameter of the external thread |
| $d_3$ | the minor diameter of external thread |
| $H$ | the height of the fundamental triangle of the thread |

As there are two bolts per 100 mm of the column circumference, the bolt stress area is multiplied with 2.

| Bolt dimension | $As_{bolt}$ |
|---|---|
| M36 | 1674.82 mm$^2$ |
| M40 | 2210.70 mm$^2$ |
| M42 | 2296.26 mm$^2$ |
| M45 | 2670.75 mm$^2$ |
| M48 | 3012.93 mm$^2$ |

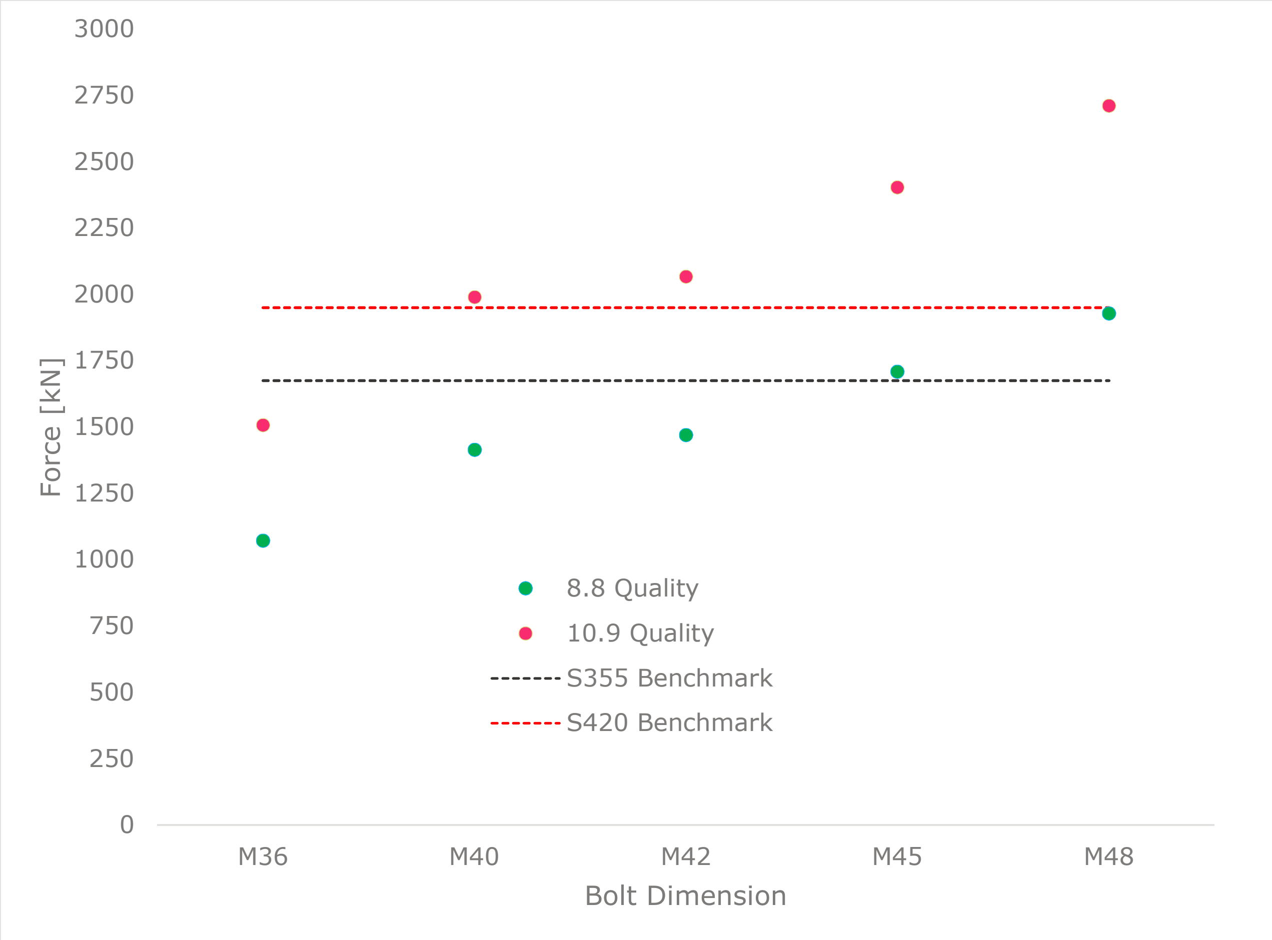
Thus, the maximum force before yield for the various bolt dimensions are calculated:

$F_{bolt} = \sigma_{yield} \cdot As_{bolt}$

| Bolt dimension | $F_{bolt}$ | |
|---|---|---|
| | 8.8 Quality | 10.9 Quality |
| M36 | 1071.89 kN | 1507.34 kN |
| M40 | 1414.85 kN | 1989.63 kN |
| M42 | 1469.61 kN | 2066.63 kN |
| M45 | 1709.28 kN | 2403.67 kN |
| M48 | 1928.27 kN | 2711.64 kN |

## 2.3 Comparison

With the maximum force before yield calculated for both the welded and bolted connecton, the values can be compared in order to propose a suitable bolt dimension.




The diagram above shows which bolts satisfies the strength requirement. Forces above 1.5 x Benchmark is considered overdimensioned. The table below shows which bolts that are applicable for both plate material types:

| | S355 | | S420 | |
|---|---|---|---|---|
| | **8.8** | **10.9** | **8.8** | **10.9** |
| **M36** | 1072 kN | 1507 kN | 1072 kN | 1507 kN |
| **M40** | 1415 kN | 1990 kN | 1415 kN | 1990 kN |
| **M42** | 1470 kN | 2067 kN | 1470 kN | 2067 kN |
| **M45** | 1709 kN | 2404 kN | 1709 kN | 2404 kN |
| **M48** | 1928 kN | 2712 kN | 1928 kN | 2712 kN |

Red = Not Accepted
Green = Accepted