Appendix to report:

SBJ-33-C5-OON-22-RE-019

DESIGN OF CABLE STAYED BRIDGE

Appendix title:

APPENDIX E – FATIGUE DESIGN

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CONCEPT DEVELOPMENT FLOATING BRIDGE E39 BJØRNAFJORDEN

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Table of Content

1 INTRODUCTION

FLS design has traditionally not been a design driver for stay-cable bridges with traffic loading. But this is not a traditional stay-cable bridge. This report summarizes the FLS-design of the stay cable bridge parts that is not been taken care of in the FLS-design rapport [1]The following parts is included:

- Cable to tower connection
- Cable to girder connection
- Cables/sockets of the cables

2 FLS DESIGN

2.1 Analysis method

The analysis method used in this section is according to the analysis method of the fatigue design rapport [1]. In summary:

1. Environmental load response is calculated in DynNo
2. Static variable load response is calculated in Sofistik
3. Time-realizations of the stresses has been generated using Cholesky decomposition.
4. RainFlow-counting and combination according to DesignBasis to get the stress-cycles and lifespan

2.2 Fatigue prone elements

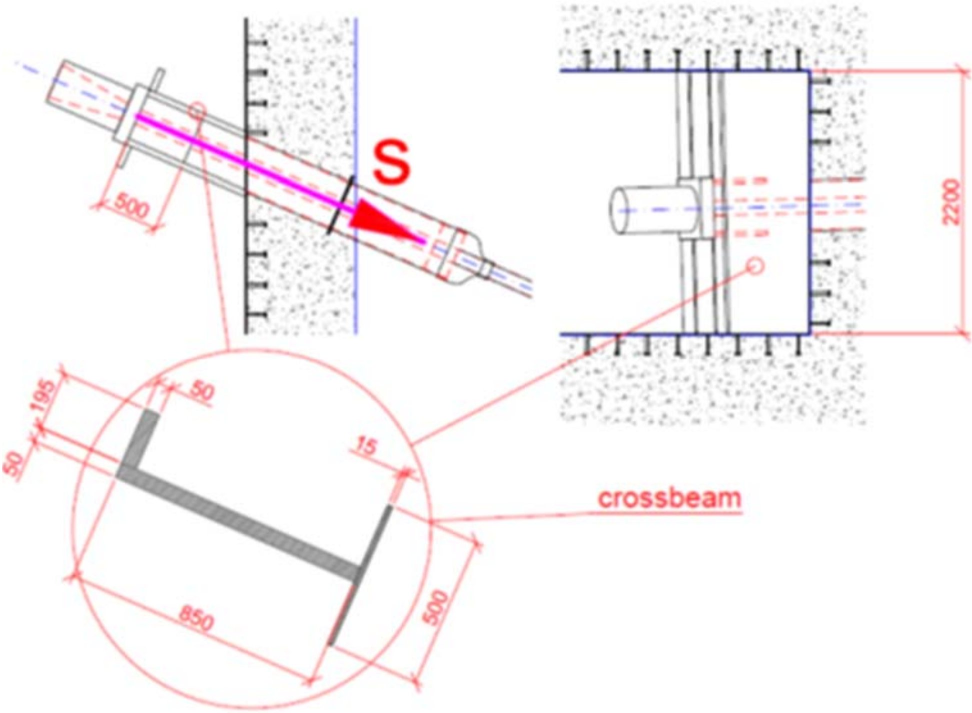
Note that the girder is not considered here, this is addressed in the fatigue design rapport. The remaining fatigue prone elements is:

- Cable to tower connection
- Cable to girder connection
- Cables/sockets of the cables

All the stresses in these elements can be directly related to the cable axial force.

2.2.1 Cable to tower connection

The figure below this the cable to tower connection. For more detail se the design of this point in report [2].

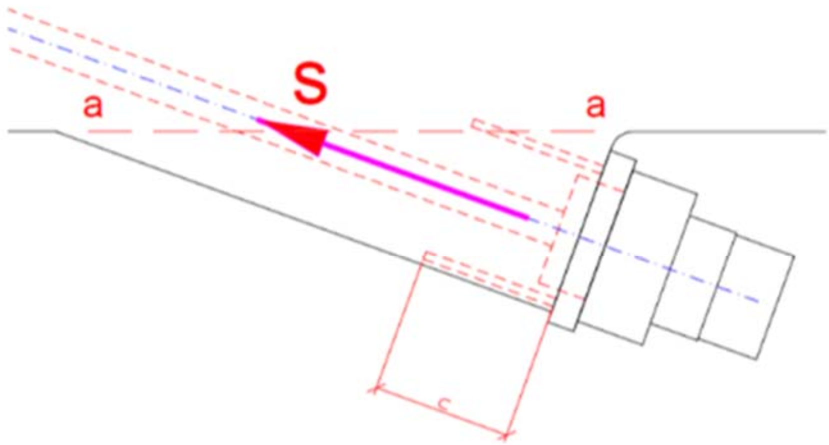


As can be seen there is 3 critical points of this connection:

- Web and upper flange, stress range of 19,56MPa (Ignored due to lower stress range but same category)
- Web and lower flange, stress range of 26,4MPa (point P1)
- Web and the side wall, stress range of 15,8MPa (point P2)

2.2.2 Cable to girder connection

The detailed geometry of the cable to girder connection can be found in appendix [2]. The figure below shows show the geometry:



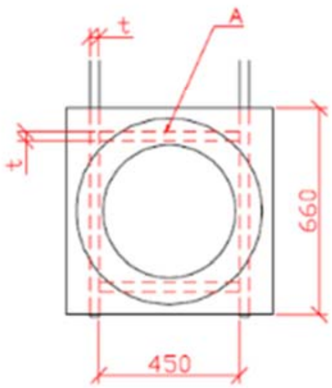


Plate C has the most critical stress-point for this connection(C=500mm) where the maximum axial stress-point is <u>16Mpa</u> for 1000kN cable tension.

2.2.3 Cables and sockets

NS-EN1993-1-11 [3] 9.2 gives rules for fatigue assessment of cables. The cable and socket quality are well within the demands of (2) and the aerodynamic oscillations is reduced due to external damping of cables. The sockets are deemed not fatigue sensitive.

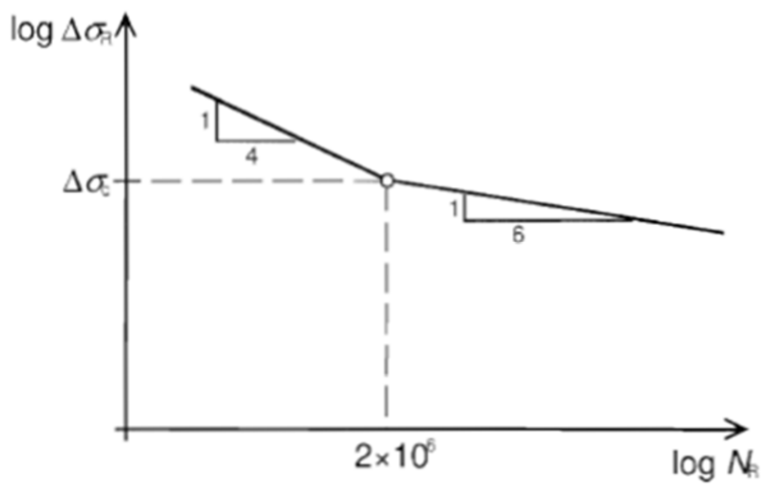
2.3 Standards and coefficients

The rest of the project, including stress-point A-C is according to DNVGL-RP-C203 [4], but cables is not included in this recommendation. The fatigue design for the cables is according to NS EN1993-1-9 [5]/11 [3].

Safety principle: The Stay-cable bridge is design to withstand the loss of a single stay-cable. The stay-cable/attachment fatigue failure is therefore defines as low-consequence loss according to EC3-1-9 table N.A.3.1. The partial factor becomes = 1,35.
The DFF used in the DNVGL-components are set to 2,5.

Stress-point	Detail category
P1, tower	C2
P2, tower	W2
Girder	E
Cable	B2(EC3-1-11) table 9.1 $\Delta\sigma_c$=150N/mm2

For the cables the fatigue strength curves for tension components follow figure 9.1 EC3-1-11:

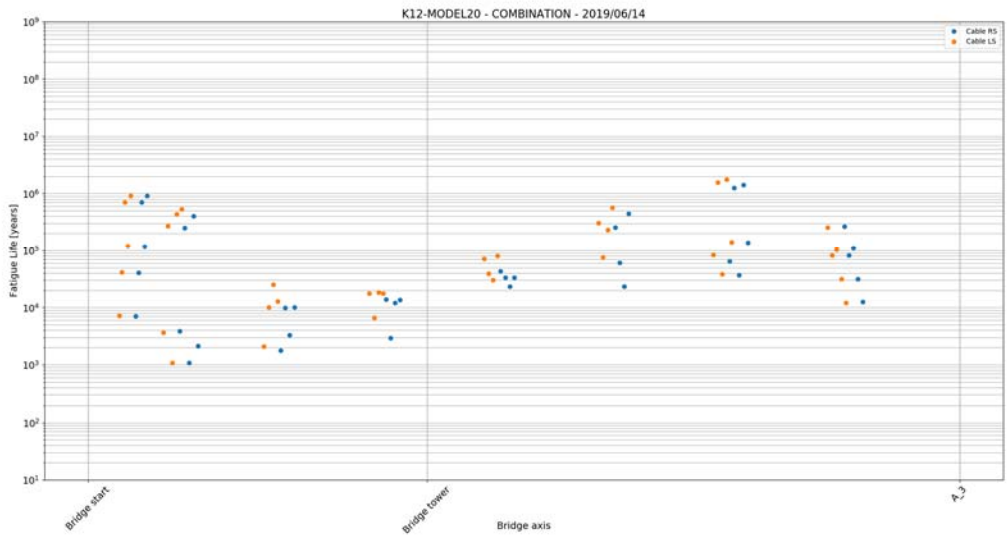


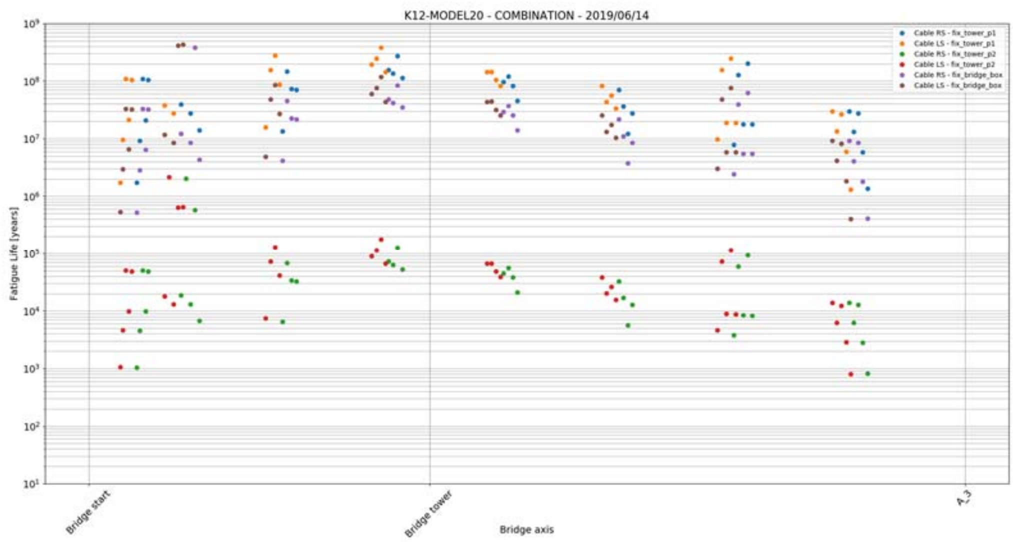
> Figure 1 Fatigue strength curve for cables EC3-1-11 figure 9.1

3 RESULTS

3.1 Full combination

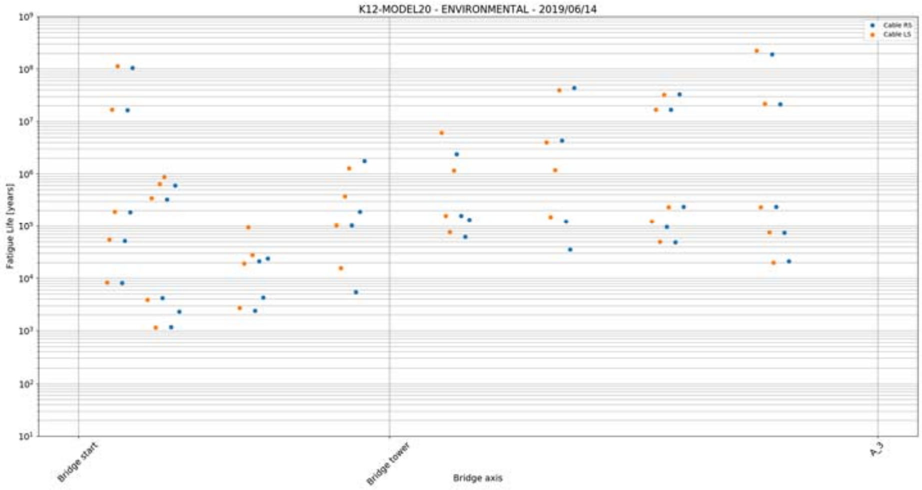
From the next two figures you could see that the fatigue life of cables, connection of girder and connection to the tower is acceptable with good margins.

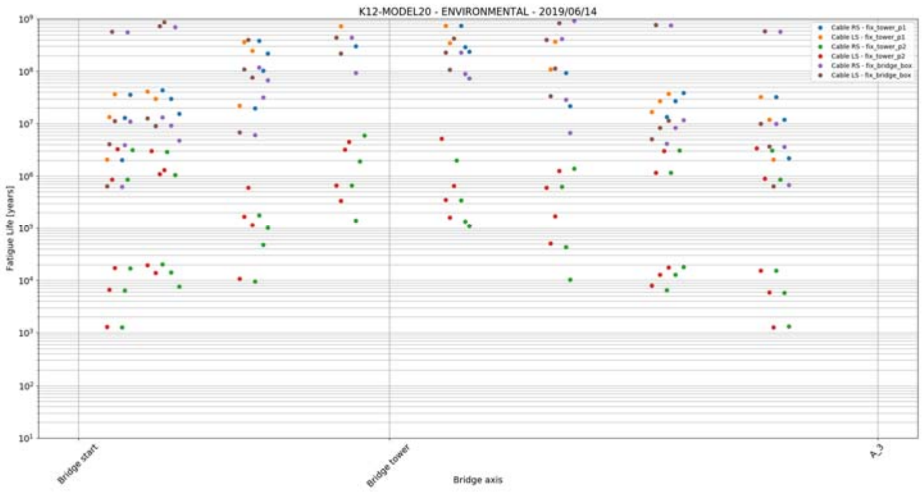


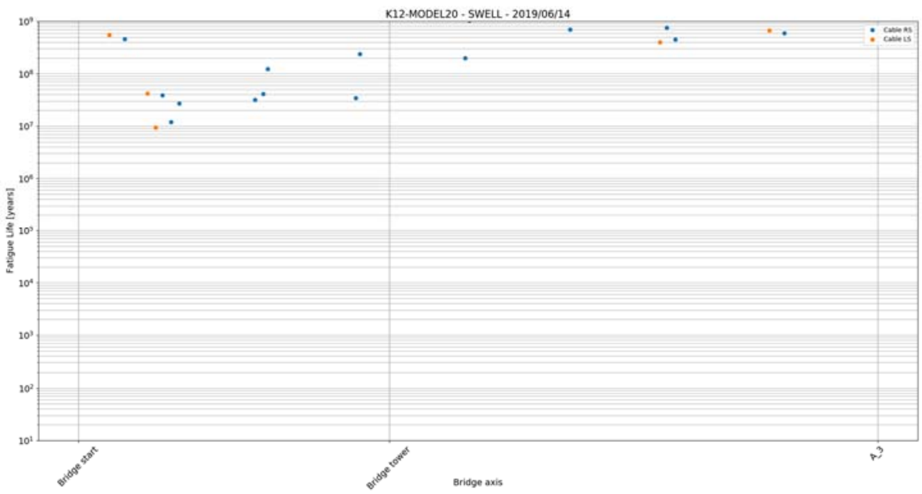


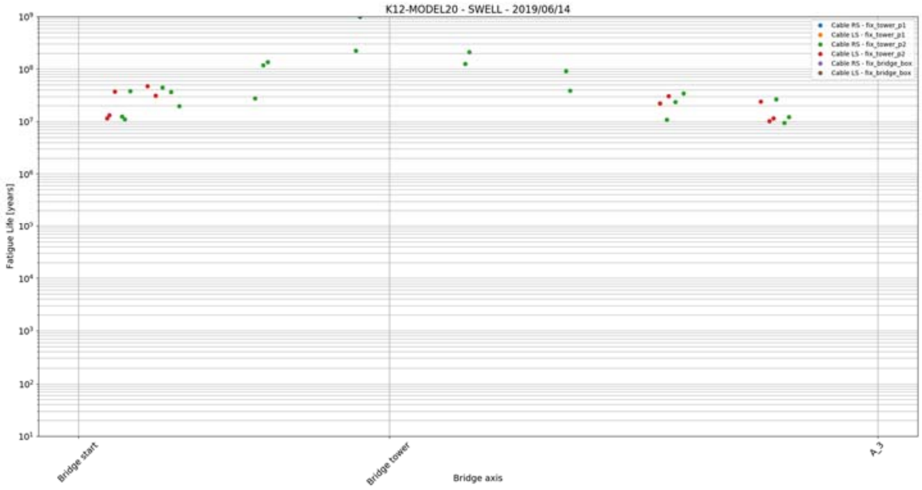
Note that the cables changes size, but not the connection. That's why the fatigue life of the cables and the connection do not follow the same trends.

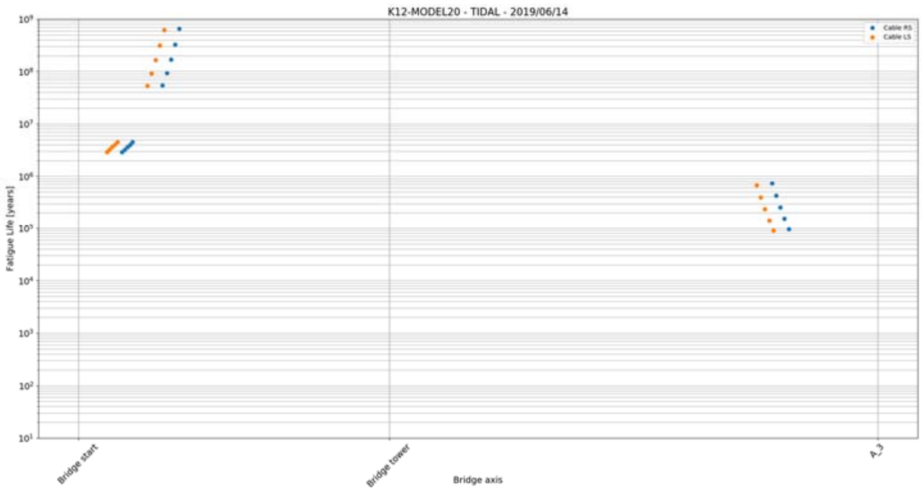
3.2 From single load component

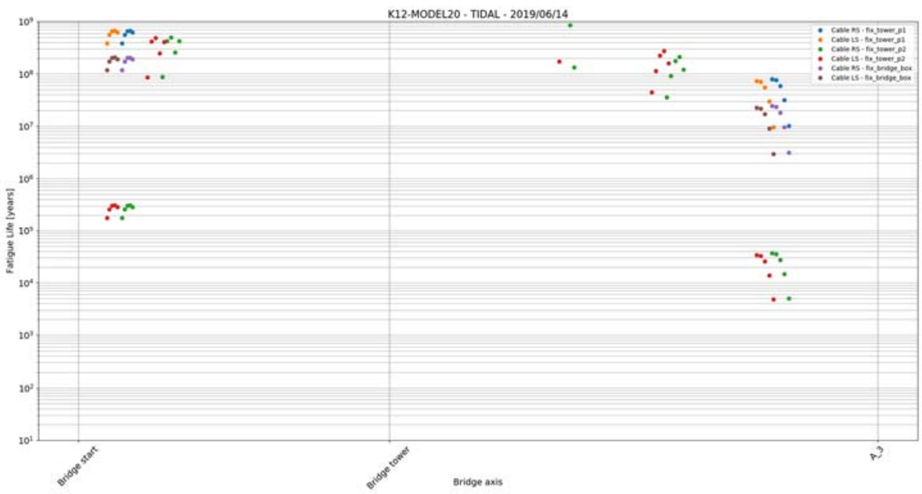


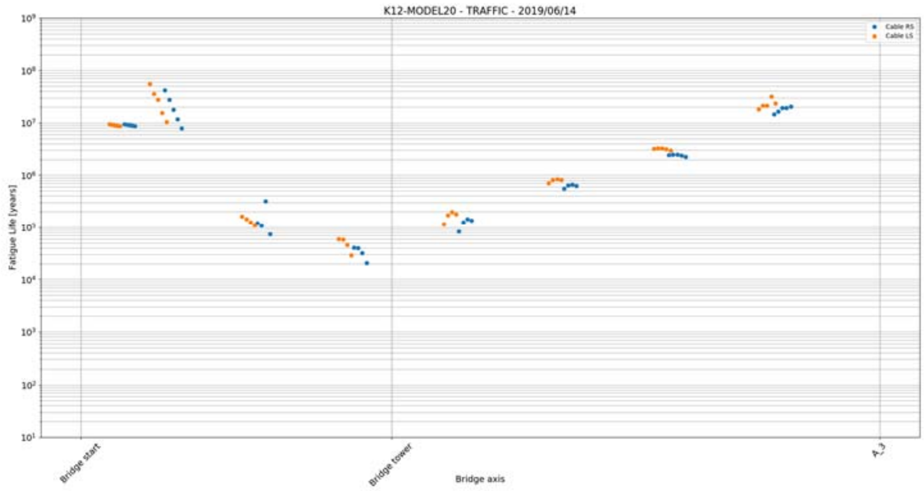


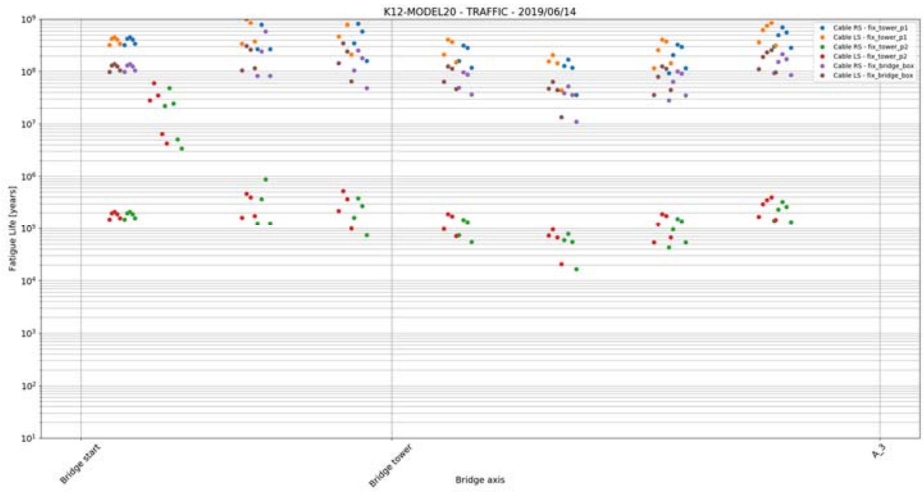


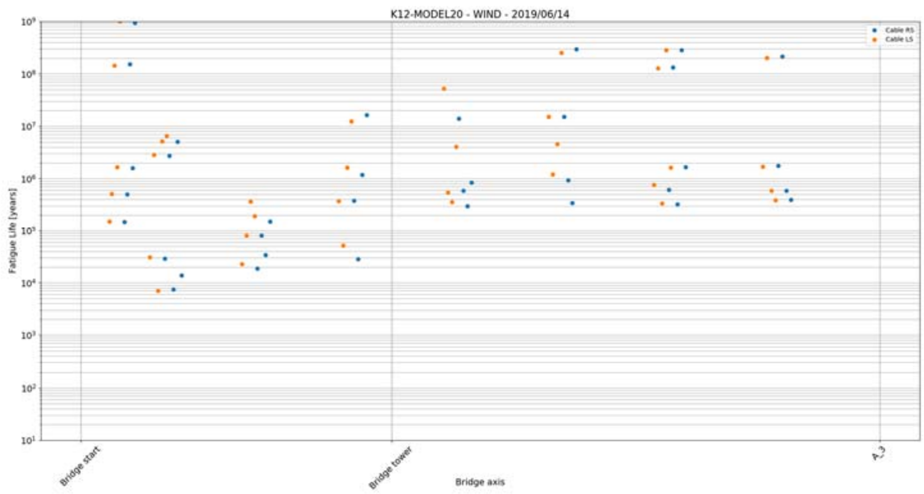

K12-MODEL20 - SWELL - 2019/06/14
Cable RS - fix_tower_p1
Cable LS - fix_tower_p1
Cable RS - fix_tower_p2
Cable LS - fix_tower_p2
Cable RS - fix_bridge_box
Cable LS - fix_bridge_box
Fatigue Life [years]
Bridge start
Bridge tower
A3
Bridge axis

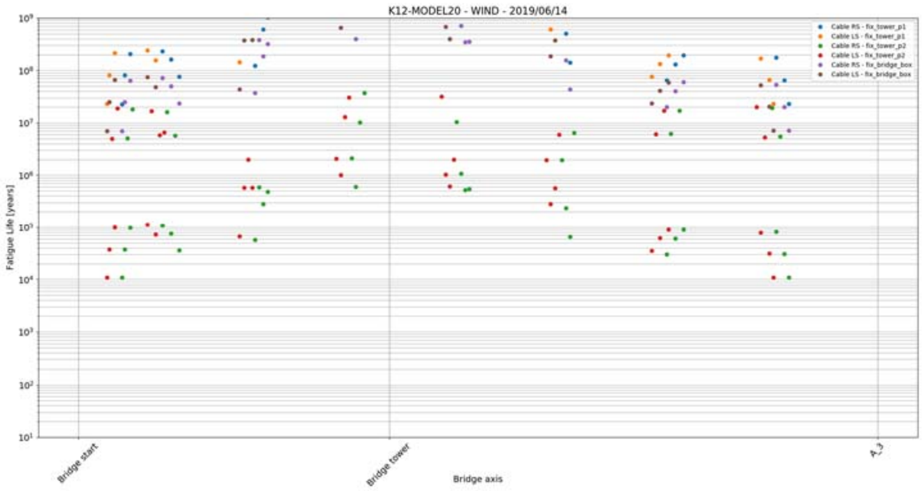

K12-MODEL20 - TIDAL - 2019/06/14
Cable RS
Cable LS
Fatigue Life [years]
Bridge start
Bridge tower
A3
Bridge axis

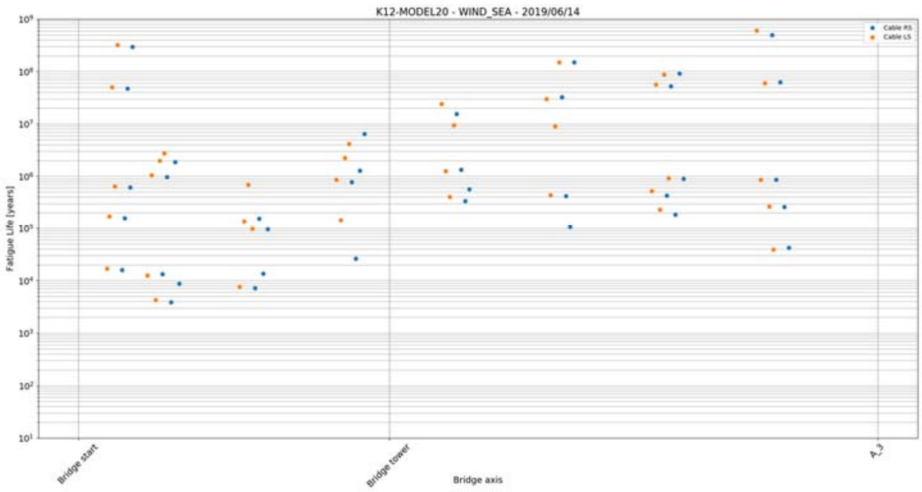

K12-MODEL20 - TIDAL - 2019/06/14
Cable RS - fix_tower_p1
Cable LS - fix_tower_p1
Cable RS - fix_tower_p2
Cable LS - fix_tower_p2
Cable RS - fix_bridge_box
Cable LS - fix_bridge_box
Fatigue Life [years]
Bridge start
Bridge tower
A3
Bridge axis

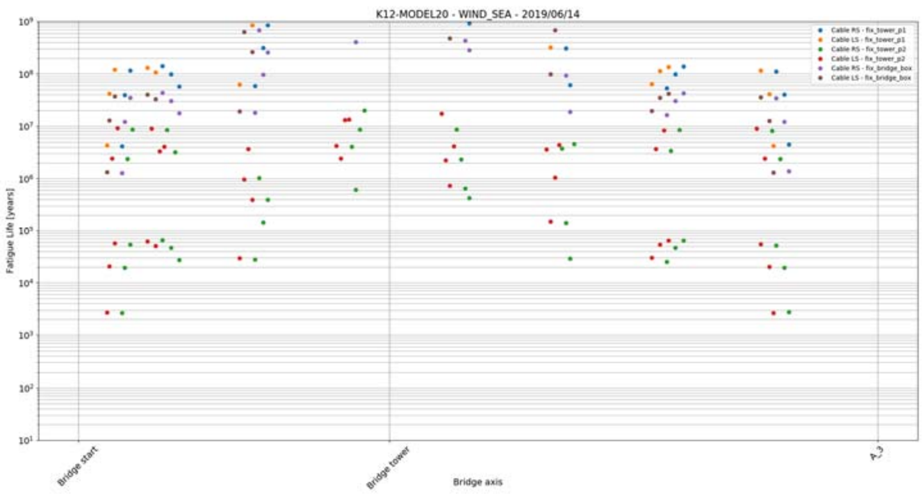

K12-MODEL20 - TRAFFIC - 2019/06/14
Cable RS
Cable LS
Fatigue Life [years]
Bridge start
Bridge tower
A-3
Bridge axis


K12-MODEL20 - TRAFFIC - 2019/06/14
Cable RS - fix_tower_p1
Cable LS - fix_tower_p1
Cable RS - fix_tower_p2
Cable LS - fix_tower_p2
Cable RS - fix_bridge_box
Cable LS - fix_bridge_box
Fatigue Life [years]
Bridge start
Bridge tower
A-3
Bridge axis


K12-MODEL20 - WIND - 2019/06/14
Cable RS
Cable LS
Fatigue Life [years]
Bridge start
Bridge tower
A-3
Bridge axis


K12-MODEL20 - WIND - 2019/06/14
Cable RS - fix_tower_p1
Cable LS - fix_tower_p1
Cable RS - fix_tower_p2
Cable LS - fix_tower_p2
Cable RS - fix_bridge_box
Cable LS - fix_bridge_box
Fatigue Life [years]
Bridge start
Bridge tower
A-3
Bridge axis


K12-MODEL20 - WIND_SEA - 2019/06/14
Cable RS
Cable LS
Fatigue Life [years]
Bridge start
Bridge tower
A-3
Bridge axis


K12-MODEL20 - WIND_SEA - 2019/06/14
Cable RS - fix_tower_p1
Cable LS - fix_tower_p1
Cable RS - fix_tower_p2
Cable LS - fix_tower_p2
Cable RS - fix_bridge_box
Cable LS - fix_bridge_box
Fatigue Life [years]
Bridge start
Bridge tower
A-3
Bridge axis

4 CONCLUSION

The fatigue assessment of the stay-cable bridge proves that the stay-cable parts of the bridge is not critical when it comes to fatigue life.

REFERENCES

[1] OON, «SBJ-33-C5-OON-22-RE-016-K12-Fatigue assesment,» 2019.

[2] OON, «SBJ-33-C5-OON-22-RE-019-K12 Design of cable stayed bridge Appendix B Technical note stay cables».

[3] NS-EN1993-1-11:2016+NA:2009, «Prosjektering av stålkonstruksjoner - Del 1-11: Kabler og strekkstag».

[4] DNV GL, «RP-C203 Fatigue design of offshore steel structures,» 2016.

[5] NS-EN 1993-1-9:2005+NA:2010, «Eurocode 3: Design of steel structures - Part 1-9: Fatigue design of steel structures,» Standard Norge, 2005.

[6] Håndbok N400 , «Bruprosjektering,» Statens vegvesen Vegdirektoratet, 2015.

[7] SBJ-32-C4-SVV-90-BA-001, «Design Basis Bjørnafjorden floating bridges,» Statens Vegvesen, 2018.

[8] NS-EN 1993-1-1:2005+A1:2014+NA:2015, «Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for buildings,» Standard Norge, 2005.

[9] ASTM E1049:85, «Standard Practices for Cycle Counting in Fatigue Analysis».

[10] SBJ-01-C4-SVV-01-BA-001, «MetOcean Design Basis,» Statens Vegvesen, 2018.

[11] OON, «SBJ-33-C5-OON-22-RE-019-K12-Design of cable stayed bridge».