FACULTY OF SCIENCE AND TECHNOLOGY

# MASTER THESIS

Study programme / specialisation:
Master thesis Mechanical and Structural Engineering and Materials Science – Civil Engineering Structures

The spring semester, 2022

Open

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Thesis title:

Analysis of field measurement data from the Lysefjord bridge in relation to main cables wire fracture

Credits (ECTS): 30

Keywords:

Suspension bridge
Steel bridge
Field mesurment data
Structural engineering

Pages: 62

+ appendix: 98

Stavanger, 15/07/22

# Preface

This master thesis is the final part of my Master degree in Mechanical and Structural Engineering and Materials Science at the University of Stavanger. As part of the thesis, field measurement data on the Lysefjord bridge's main cables are collected, discussed, and a FE model of the bridge is developed, which can be used to analyze the bridge under various load conditions and to compare and validate the FE model with the recorded sensor data over the previous years. The data from the Norwegian Public Roads Administration and the previous models are incorporated into this model. Finally, the results from the FE model and cable-wire breakage scenario are compared and discussed. Weather data has been downloaded from different Weather Stations through https://seklima.met.no.

The thesis consists of;

- An overview of a suspension bridge's structural health monitoring system
- Analysis of field measurement data at the time of the wire fractures Data analysis of wire fractures on the Lysefjord Bridge
- Modeling a suspension bridge using finite elements
- Verification of the existing ABAQUS finite element model Discussion of the results and future works

# Contents

# ACKNOWLEDGMENTS

It is with great gratitude that I acknowledge Professor Jasna Bogunovic Jakobsen's guidance throughout this thesis. Additionally, I would like to thank Professor Jonas Snaebjornsson for his comments and suggestions.

As a final note, I want to acknowledge the support I have received throughout this research from my family.

# Abstract

A 637-meter suspension bridge located in Rogaland county, Norway, which connects the two municipalities of Strand and Sandnes, is known as the Lysefjord Bridge. The bridge is located in Rogaland county, and the bridge stretches for 637 meters. With two lanes for vehicles, one lane for pedestrians, and a clearance of 50 meters for ships sailing , the main span is 446 meters long, with side spans of 34.5 meters and 156.5 meters. As a part of the construction, concrete towers and closed steel bridge girders have been used to construct the bridge. As part of the main cable, there is one layer of six locked coil cables that are arranged in a single layer, which is then anchored to rock on either side of the main cable in the form of an anchor. On the side spans, there are no hangers because they are concrete viaducts, and as a result there are no hangers on the side spans. [1-3]

In the years since the bridge opened in 1997, over 900 wires have broken. A real-time acoustic monitoring system was installed on the bridge to detect any cable breaks. Each fracture is manually registered in the outer thread layers during the visual inspection in order to determine, based on the comparison, whether it is a fracture in the outer thread layers or a fracture in the layers. [4, 5]

In this study, field measurements from the bridge are collected in relation to cable wire fracture, discussed, and a FE model is developed to analyze the bridge under different loads, as well as to compare and validate the FE model with sensor data recorded over the previous years. Data and information from the Norwegian Public Roads Administration and previous models are incorporated into this model. A comparison and discussion of the results of the FE model and cable-wire breakage scenario is presented as a final conclusion.

# 1 Introduction

A characteristic that makes cable-supported bridges stand out from other bridge systems is the fact that they can extend to cover large spans of land. A cable-supported bridge consists of the following main components as shown in Figure 1 [6]:

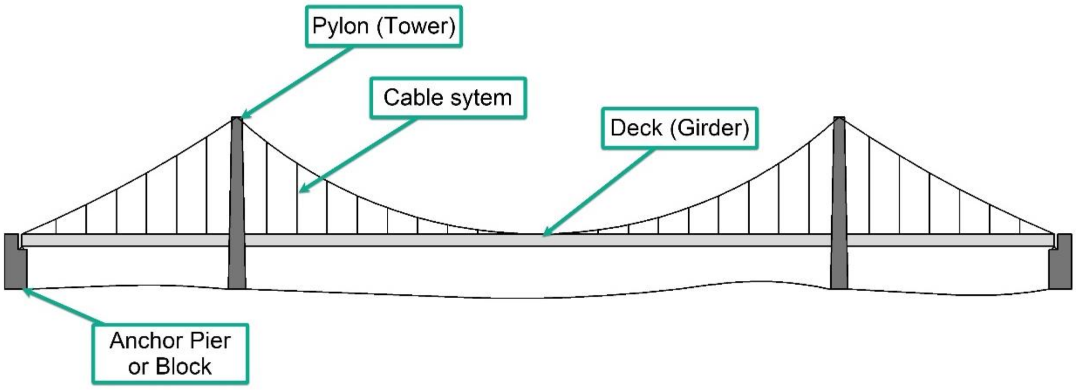


Figure 1. Bridge components supported by cables [6]

(1) The deck (or the stiffening girders);

(2) The cable system that supports the deck;

(3) The towers (or pylons) that support the cable system;

(4) Anchor blocks (or anchor piers) provide structural support to the cable system vertically and horizontally at its ends, or just vertically [6].

Different types of cable-supported bridges are distinguished by the way in which the cable system is configured. The figure below shows how a suspended system is constructed from the main cable and vertical hanger cables. It is most common to find suspension bridges with three spans having a large main span and two smaller side spans that are flanked by the main span. It is usually the case that three-span bridges are symmetrical with equal span lengths on both sides, but there are some cases where the side spans may differ depending on special circumstances. Only one span of a suspension bridge might be cable-supported when there is only one large span to be supported. There is a need to continue the main cable as a free backstay to the anchor blocks as a means of transmitting the horizontal component of the pull of the main cable occurring at the top of the pylons [6].

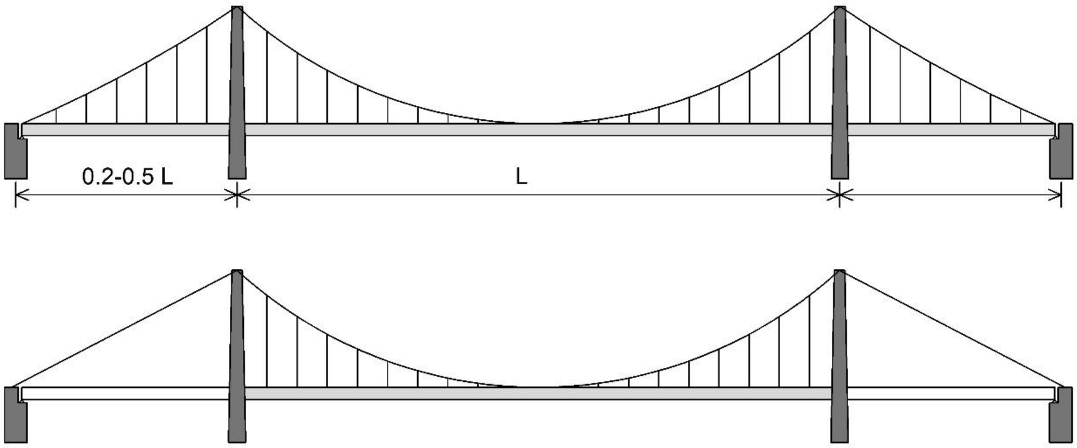


*Figure 2. Three span suspension bridge system with vertical hangers and cable supports (top) or only the main span suspension bridge system (bottom) [6]*

The Lysefjord Bridge is a 637-meter-long suspension bridge located in Rogaland county, Norway, and the two municipalities of Strand and Sandnes are connected by this bridge. The main span is 446 meters long, along with side spans of 34.5 meters and 156.5 meters with two lanes for vehicles, one lane for pedestrians, and a clearance of 50 meters for ships sailing (Figure 3). The bridge is constructed by the use of concrete towers and an aerodynamic closed steel bridge girders. A single layer of six locked coil cables is organized in a single layer along the main cable and is anchored in rock on either side of the cable. Due to the fact that the side spans are concrete viaducts, there are no hangers on the side spans. [1-3]

It is estimated that over 900 wires have broken since the bridge opened in 1997. In order to detect any breakage in the cables, an acoustic monitoring system has been installed on the bridge in order to record the breakage in real-time. During the visual inspection, each fracture is manually registered in the outer thread layers so that, based on the comparison, it can be determined whether it is a fracture in the outer thread layers or a fracture in the layers. [4, 5]

It is the purpose of this research to collect field measurement data from the bridge in relation to main cables wire fracture and discuss them and then develop a FE model of the bridge that can be used to analyze the bridge under different load conditions and to compare and validate the FE models of the bridge with the recorded sensor data over the previous years. In this model, the data and information from the Norwegian Public Roads Administration and the previous models are taken into consideration. As a final conclusion, the results from the FE model and cable-wire breakage scenario are compared and discussed.

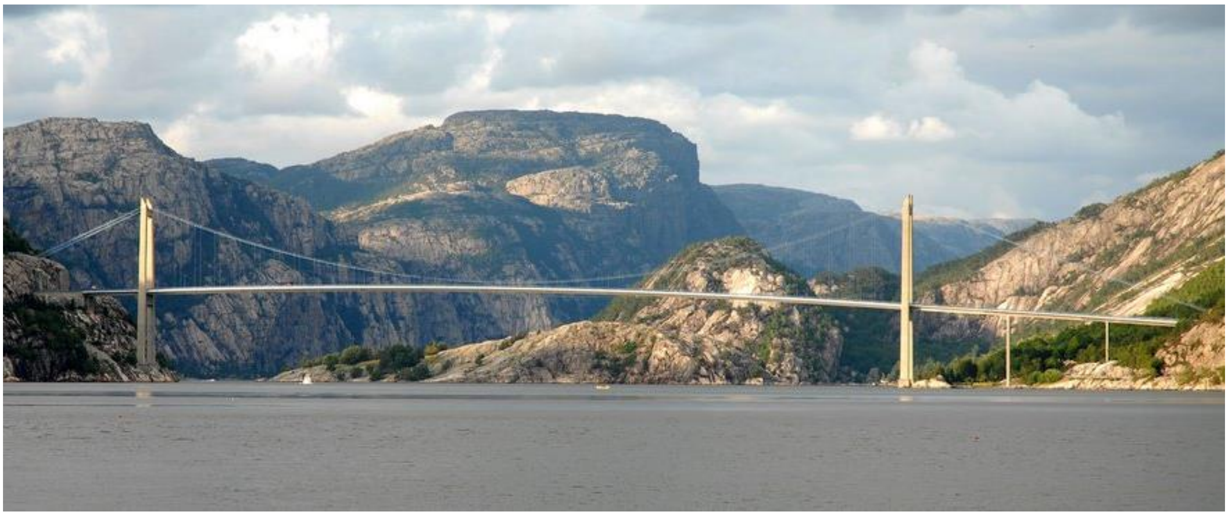

*Figure 3. Lysefjord Bridge [7]*

In order to obtain a better understanding of the acoustic monitoring system on the Lysefjord Bridge, the monitoring system of structures is introduced prior to the analysis of cables' wire fractures.

# 2 Monitoring system of strucures

Structures and mechanical systems play an extremely vital role in modern society, such as "aircraft, bridges, power generation systems, rotating machinery, offshore oil platforms, buildings and defence systems" [8]. In many of these existing systems, there's a danger of their original design life coming to an end in the near future. It is necessary to develop and implement damage detection techniques in order to make sure that these systems continue to function safely even after their service lives exceed their design-based life. Additionally, when the development and introduction of new engineering systems are carried out, these are frequently made with novel materials whose long-term degradation processes are not well understood. As a result of the development of more cost-effective designs, the new designs may have lower safety margins, which may make them less safe. Therefore, in order to prevent failures that can result in life-threatening situations and considerable financial losses, it is crucial to be able to detect damage immediately in new systems so that this can be prevented [8].

Damage detection is typically accomplished through one or more disciplines that are closely related to one another, including but not limited to [8]:

- Structural health monitoring (SHM),
- Condition monitoring (CM),
- Nondestructive evaluation (NDE) – also known as nondestructive testing (NDT),
- Health and usage monitoring system (HUMS),

- Statistical process control (SPC)
- Damage prognosis (DP).

The concept of structural health monitoring (SHM) is defined as a way of assessing the condition of a structure and estimating its remaining lifespan. Developing and implementing SHM processes successfully requires knowledge of multiple disciplines, including sensor technology, materials technology, modeling aspects, and computing technology [9].

There is no distinction between the condition monitoring process and the SHM process, the primary difference being that condition monitoring is applicable to rotating and reciprocating machines, such as those used in manufacturing and energy production [10].

The SHM and CM methodologies can be used to apply more efficient processes to systems and structures in real-time, that is, during operations. NDT (nondestructive evaluation) is normally performed off-line after identifying the possible damage site and subsequent identification of the likely damage. Despite this rule, not all NDE applications rely on technology to detect leaks, as NDE is also able to assist in monitoring in situ structures like pressure vessels and rails from hidden leaks. The application of NDE is therefore primarily to characterize and assess the severity of damage when it is known a priori where the damage will occur [11].

The term health and usage monitoring system (HUMS) is synonymous with condition monitoring system (CM) and can be used interchangeably although it has been primarily used to refer to damage detection in the motors of rotorcrafts [12]. Based on that model, the health monitoring component of the process leads to the identification of damage, while the usage monitoring process counts the number of load cycles the system has experienced in order to calculate how much fatigue life it consumes [8].

It has been established that the purpose of statistical process control (SPC) is to monitor changes in a process and damage to the structure is one of the factors that may contribute to that change [13].

In DP, the system performance (or the failure probability) can be forecasted by evaluating the current damage state of the system (or the SHM), estimating future load loads on that system, and estimating the remaining system life through simulation and past experience. It will be necessary, in order to develop DP capabilities to a level of success, to develop and integrate a number of technologies including hardware capabilities for measuring, processing, and telemetry as well as deterministic and probabilistic modeling in order to quantify uncertainty [14].

The three most mature disciplines of damage detection are without a doubt condition monitoring, non-destructive evaluation, and statistical process control, having made the transition from being research topics to actual engineering practices across a wide range of engineering applications. While SHM has been viewed as a utility, it has widely been believed that it is moving into a more application-oriented domain [8].

## 2.1 Structural health monitoring of bridges

The oil industry, large dams, and bridges are some of the areas where there has been a great deal of research done on SHM applications. Residential and commercial buildings have received comparatively little attention in comparison to residential and commercial buildings [15].

Offshore platforms are designed to operate in deep water and they are exposed to severe environmental conditions. The cost of inspecting offshore structures has resulted in vibration-based methods of damage detection being used for the last two decades because of the high cost associated with inspection. Over the course of seven months, researchers from Duggan et al. [16] collected ambient vibration measurements on a number of offshore platforms in the Gulf of Mexico in order to monitor structural integrity [17]. Generally, tower and building monitoring is intended to better understand the load on the building and how it responds to earthquakes and high winds, among other stresses. There is a discrepancy observed between the wind tunnel simulations and the simulations made by using finite element models and their wind-induced responses measured by Kijewski-Correa et al. [18] on tall buildings in Chicago. Brownjohn and Pan [19] analyzed data taken from the monitoring of a 280 meter high office tower in Singapore over a ten year period and concluded that the wind and seismic standards are extremely conservative. A number of buildings in California, Japan, and Taiwan have been installed with motion monitoring systems in order to collect data, which can then be used to estimate the local earthquake damage after an earthquake, for the purpose of making local earthquake damage assessments. [17, 20-22].

A bridge monitoring program was initiated in the United States in the 1930s, involving the construction of the Golden Gate and Bay Bridges, which evaluated the dynamics of the bridges. As a result of the collapse of the Tacoma Narrows Bridge in 1940, other suspension bridges, including the Golden Gate Bridge, were inspected and modified to ensure they remained safe. The catastrophic collapse of a bridge in West Virginia, USA, in 1967 led directly to the widespread establishment of systematic inspection programs at bridges throughout the United States [15]. It is currently the policy of the department of transportation to inspect bridges every two years, primarily using visual inspection methods and some non-destructive methods such as ultrasonic and acoustic testing. On the other hand, there is always a possibility that damage may occur between the inspections [17].

The use of vibration data for the detection of structural damage over the past three decades has been an area of intense research with various attempts in the time domain and in the frequency domain [15, 23]. It has been observed that vibration-based methods have achieved some success in mechanical and aerospace engineering as a result of the unique nature of civil structures, uncertainties inherent in structures, and the complex nature of the environment. In spite of this, the application of these principals to large-scale civil structures is relatively restricted [24].

Over the past few decades, monitoring major bridges has been widely implemented in China, Japan, the United States, and Europe. In Hong Kong and mainland China alone, more than 40 long-span bridges had been equipped with long-term monitoring systems as of 2005 [25].

## 2.2 Acoustic monitoring system of Lysefjord Bridge

The acoustic monitoring system on the Lysefjord Bridge has been operating continuously since 2009. As shown in the following figures, the system is comprised of 60 acoustic sensors placed over 12 main cables. [4]

### 2.2.1 Location of sensors

Sensors are located along each main cable as follows [26]:

- There is one sensor per cable at each anchor.

At a distance of 4.50 meters from the anchoring chambers, these sensors were positioned.

*Figure 4. Postion oof sensor along each main cable at each anchor [26]*

- On the backstay side of each pylon, 4.5 meters before the upper room (the saddle) of the cable is a multiplexed sensor per cable.

*Figure 5. Postion oof sensor along each main cable on the backstay side of each pylon [26]*

- On Hangers 6, 11, 16, 22, 27 and 32 there are six sensors spread between the two pylons

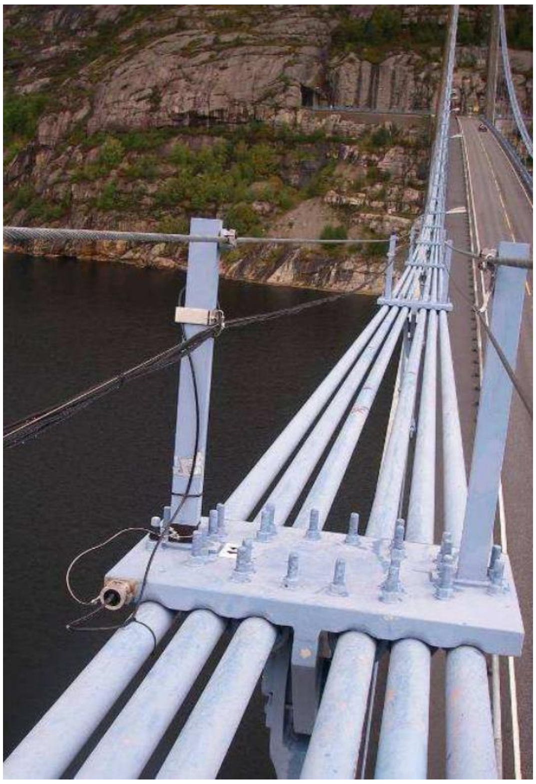

*Figure 6. Postion oof sensor along each main cable on hangers [26]*

- One data acquisition unit for collecting and storing data

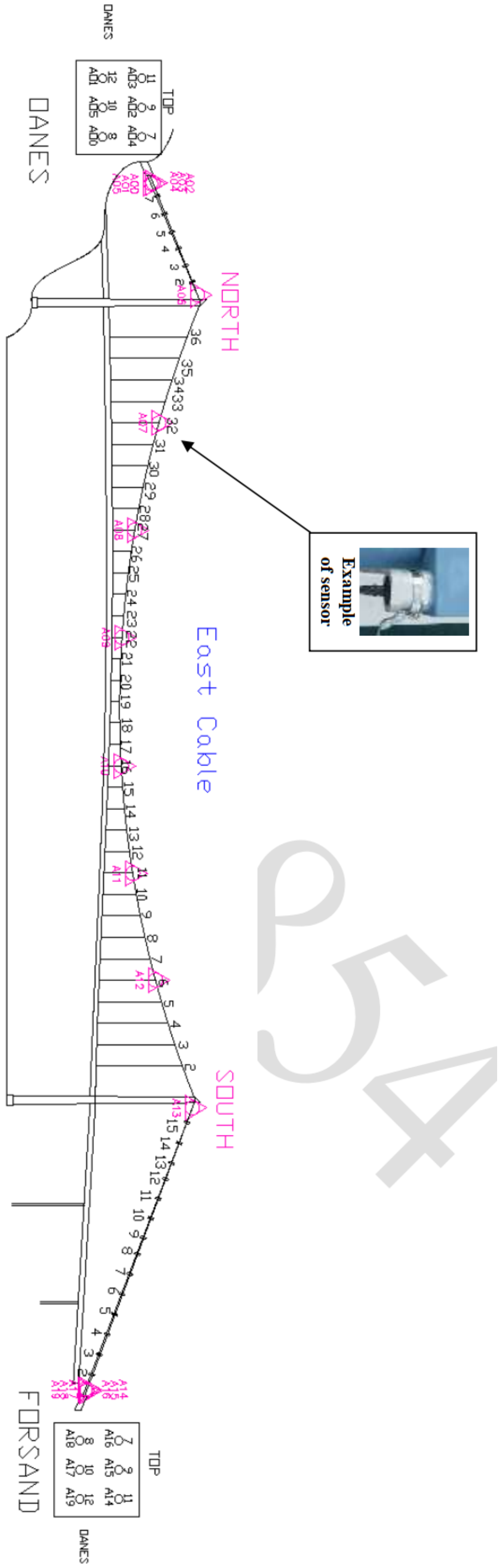


*Figure 7. Location of installed sensors A00 to A19 on East Side [4]*

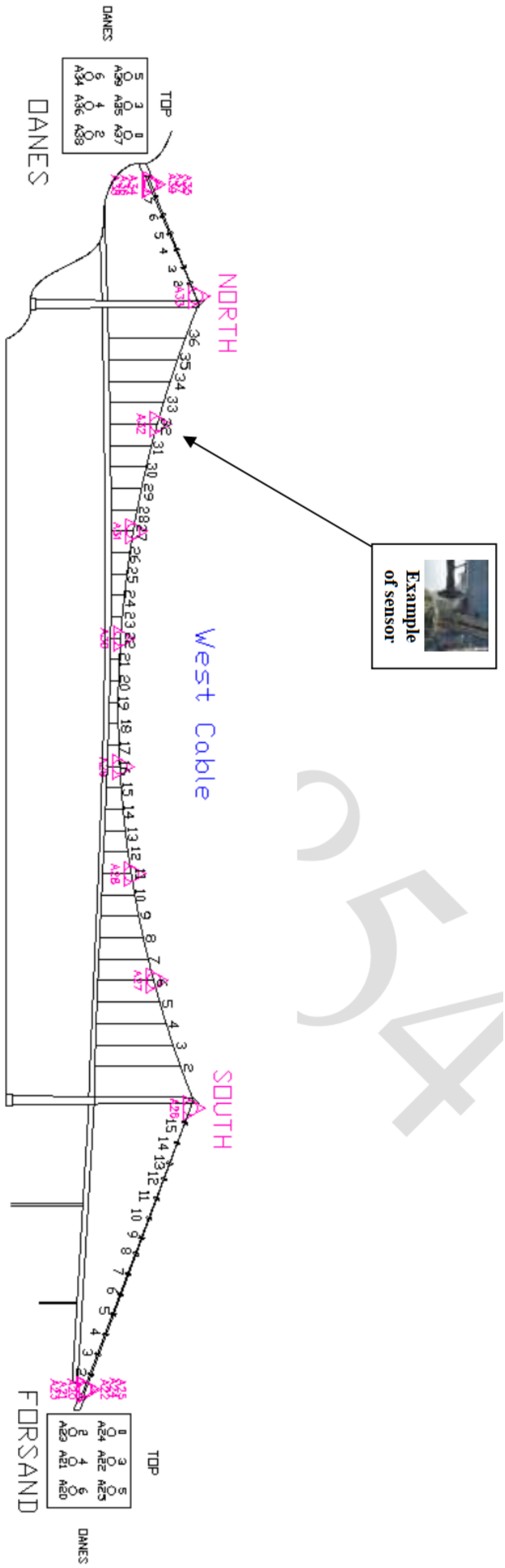


*Figure 8. Location of installed sensors A20 to A39 on West Side [4]*

### 2.2.2 System uptime

In accordance with [4] the table below shows the amount of uptime for the period and since the migration to EverSense Acoustics in 2014:

*Table 1. The amount of system uptime*

| Element | Uptime on the period from 01/04/2019 to 30/06/2019 | Cumulated uptime since 09/09/2014 until 30/06/2019 |
|---|---|---|
| PC | 100% | 90.47% |

# 3 Cables wire breakage data

All acoustic events are monitored and reported by Sixense Systems Company from 2009 to 2019. The probale wire breakages events, date and their locations are listed by the company which are used in this research [4]. All data are presented in Appendix A.

## 3.1 Analysis on wire breakage data

The first step involves categorizing the breakage data based on the followoing groups:

- The number of reports per each sensor (Figure 9)
- The number of breakages per each month (Figure 10)
- The location of breakages per each side (Figure 11)
- The location of breakages on each side during different periods of each year (Figure 12 - Figure 22)
- The location of breakages during different periods of a year (Figure 23)
- The location of breakages on each side during different periods of a year (Figure 24 & Figure 25)

The MATLAB code used for this purpose is attached as Appendix B to the following document.

Feb.

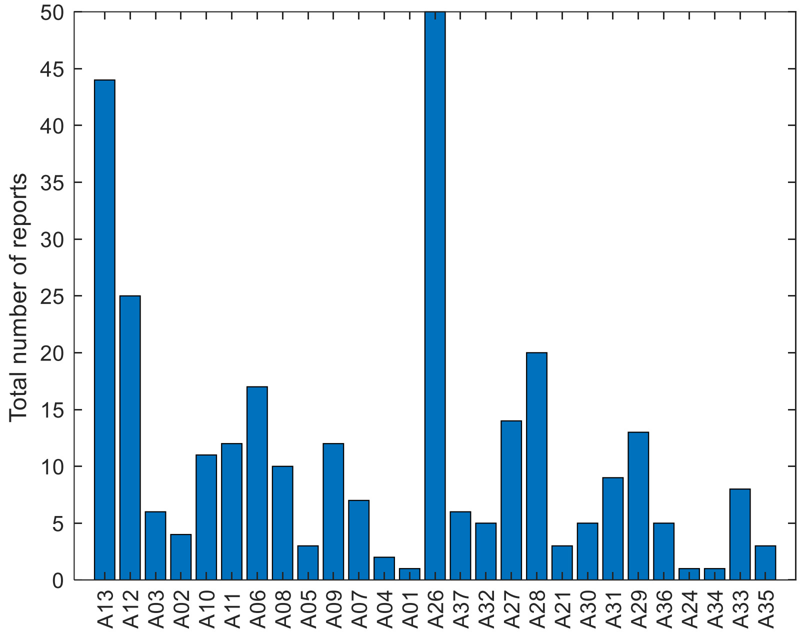


*Figure 9. The number of events per each sensor during 2009-2019*

It can be deduced from the figure above that the majority of reports come from sensors A13 in the southern area of the eastern cable and A26 in the southern area of the western cable.

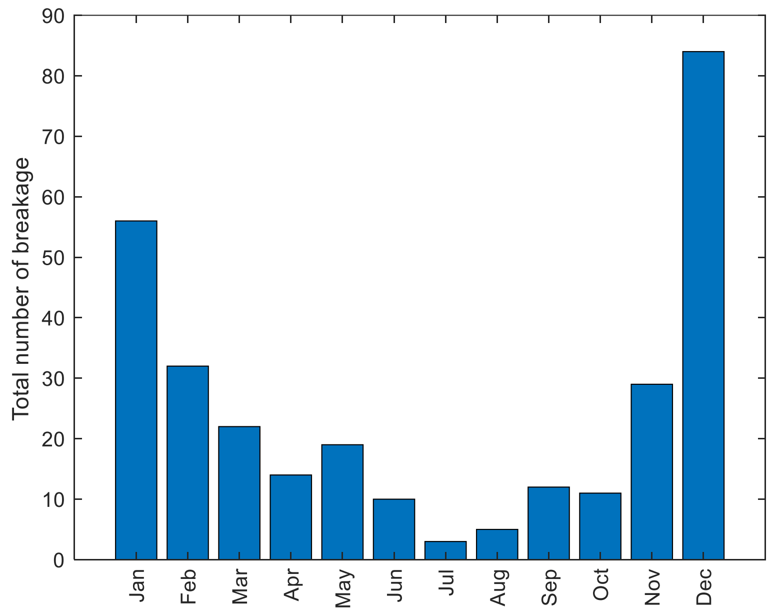


*Figure 10. The number of breakages per each month during 2009-2019*

It can be deduced from the figure above that the majority of breakages occur from Nov to Feb.

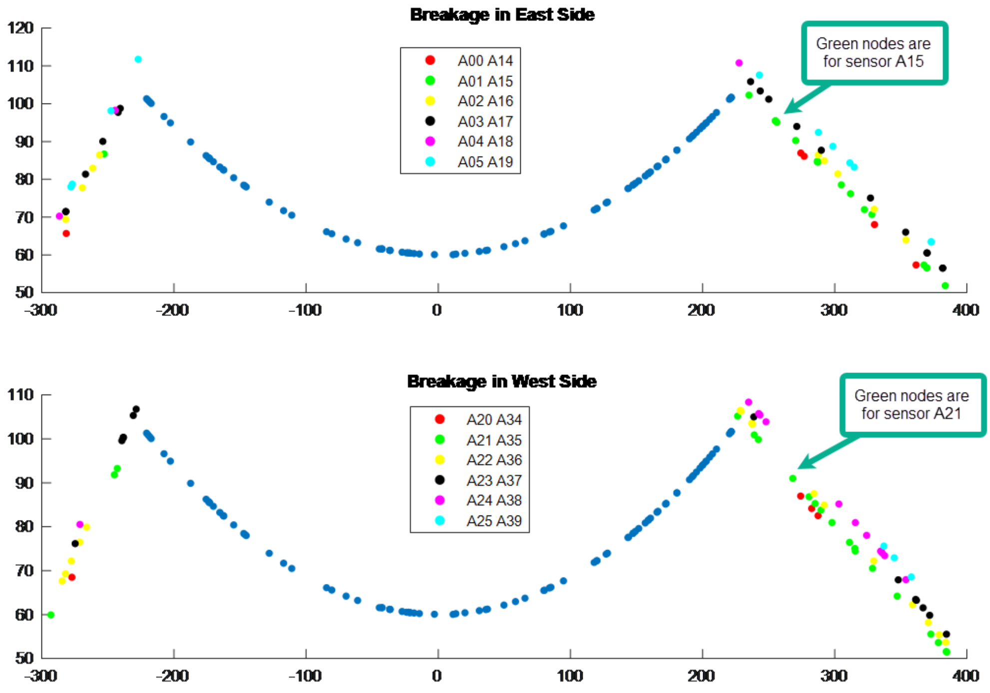


*Figure 11. The location of breakages per each side*

The figure above indicates that there are more breakages on each side of the bridge in the southern part, and the cables with A15 and A21 sensors have the most reports between the backstay cables.

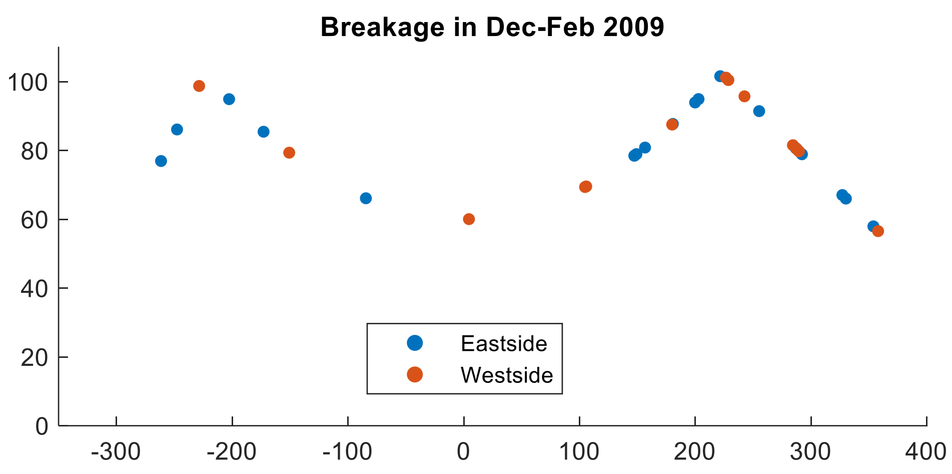


*Figure 12. The location of breakages on each side during different periods of the year 2009*

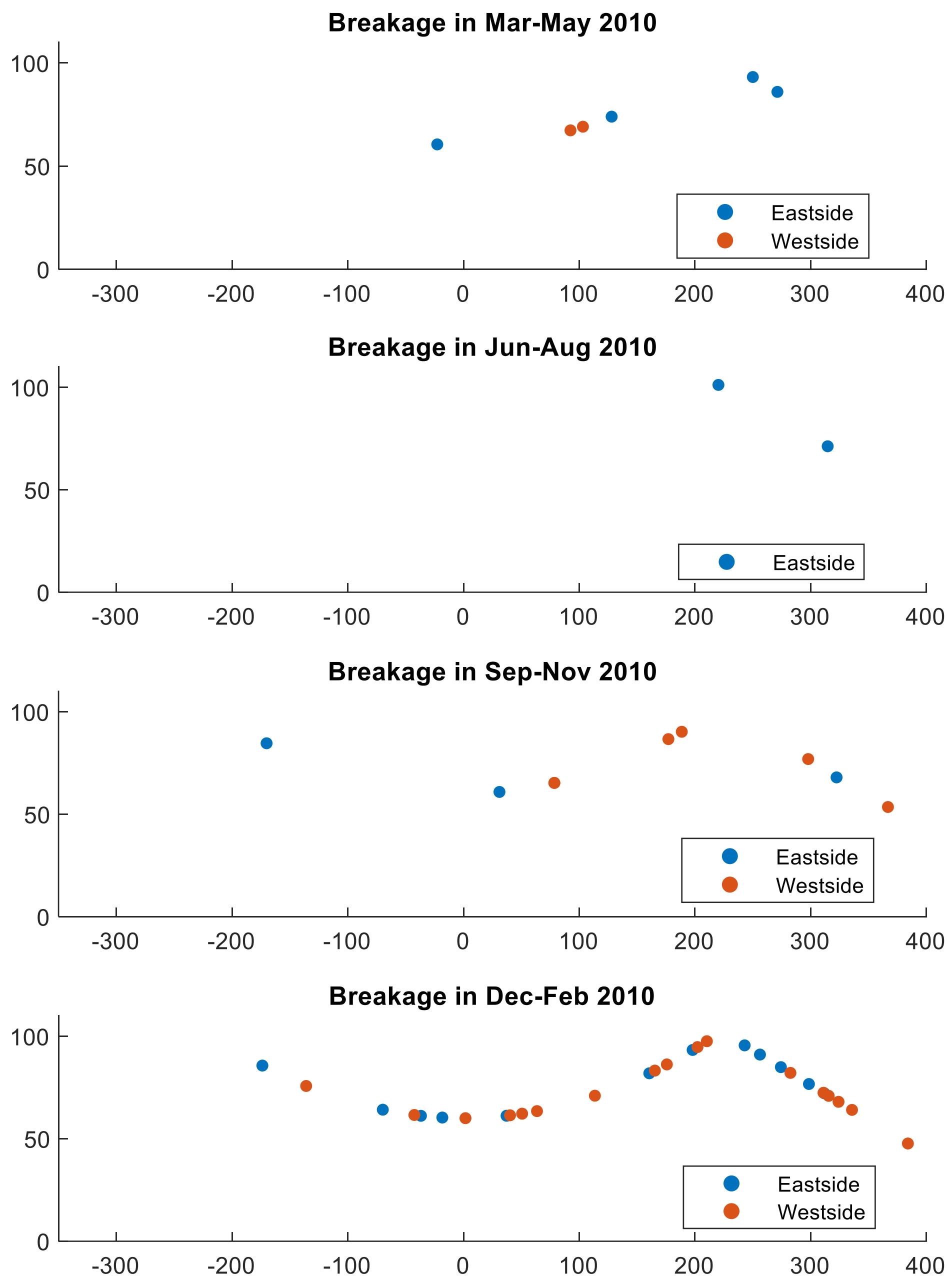


*Figure 13. The location of breakages on each side during different periods of the year 2010*

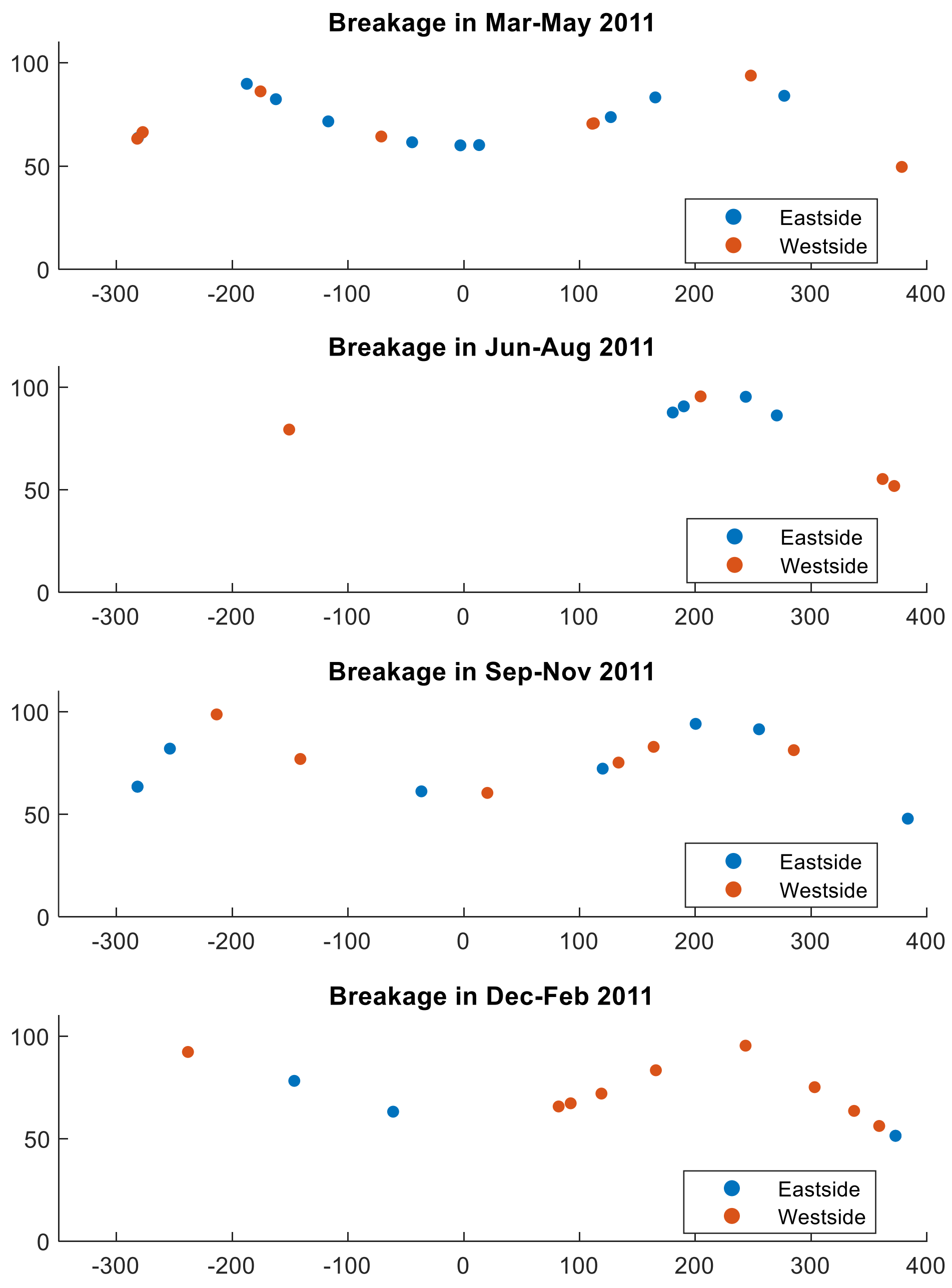


*Figure 14. The location of breakages on each side during different periods of the year 2011*

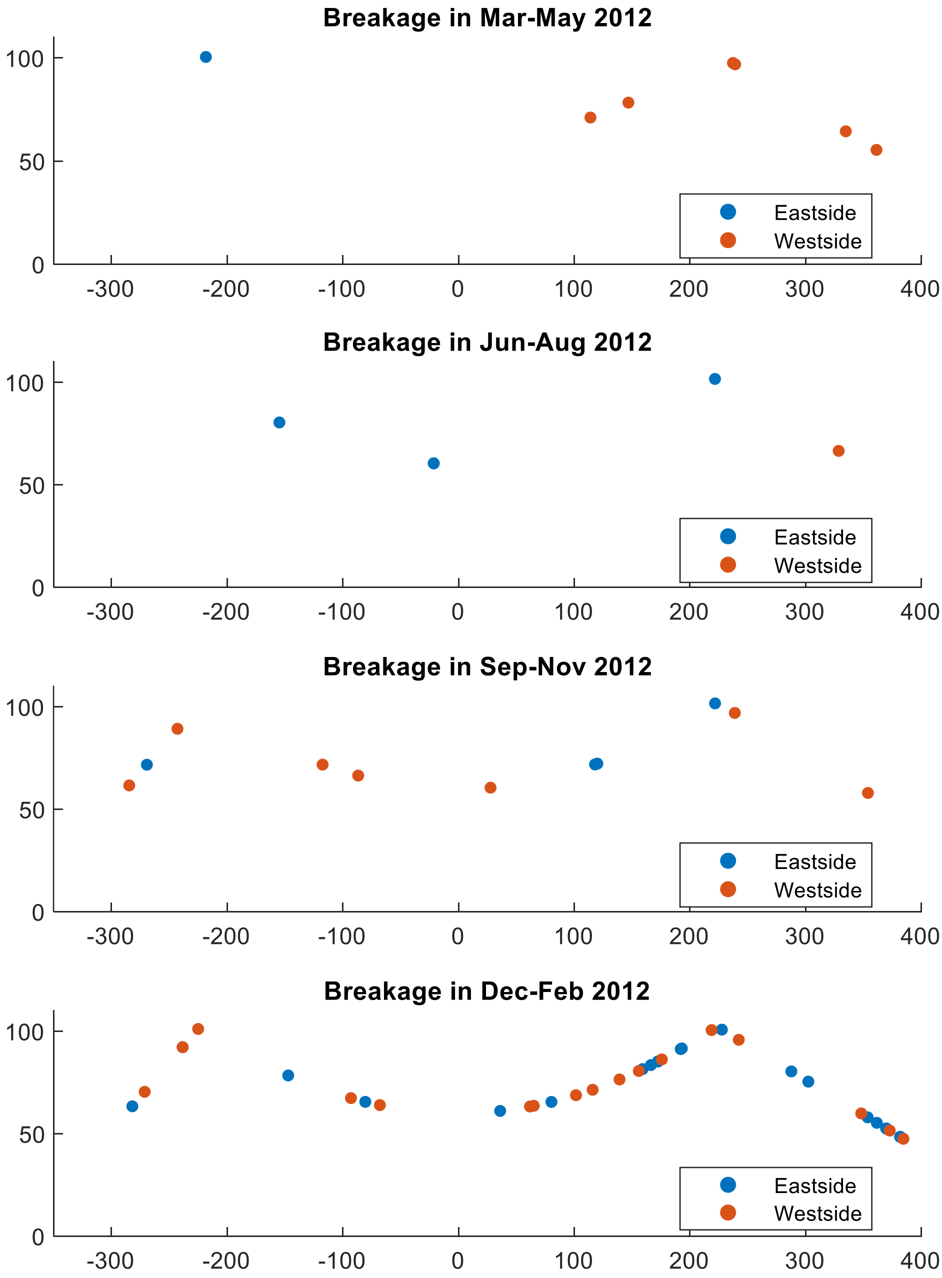


*Figure 15. The location of breakages on each side during different periods of the year 2012*

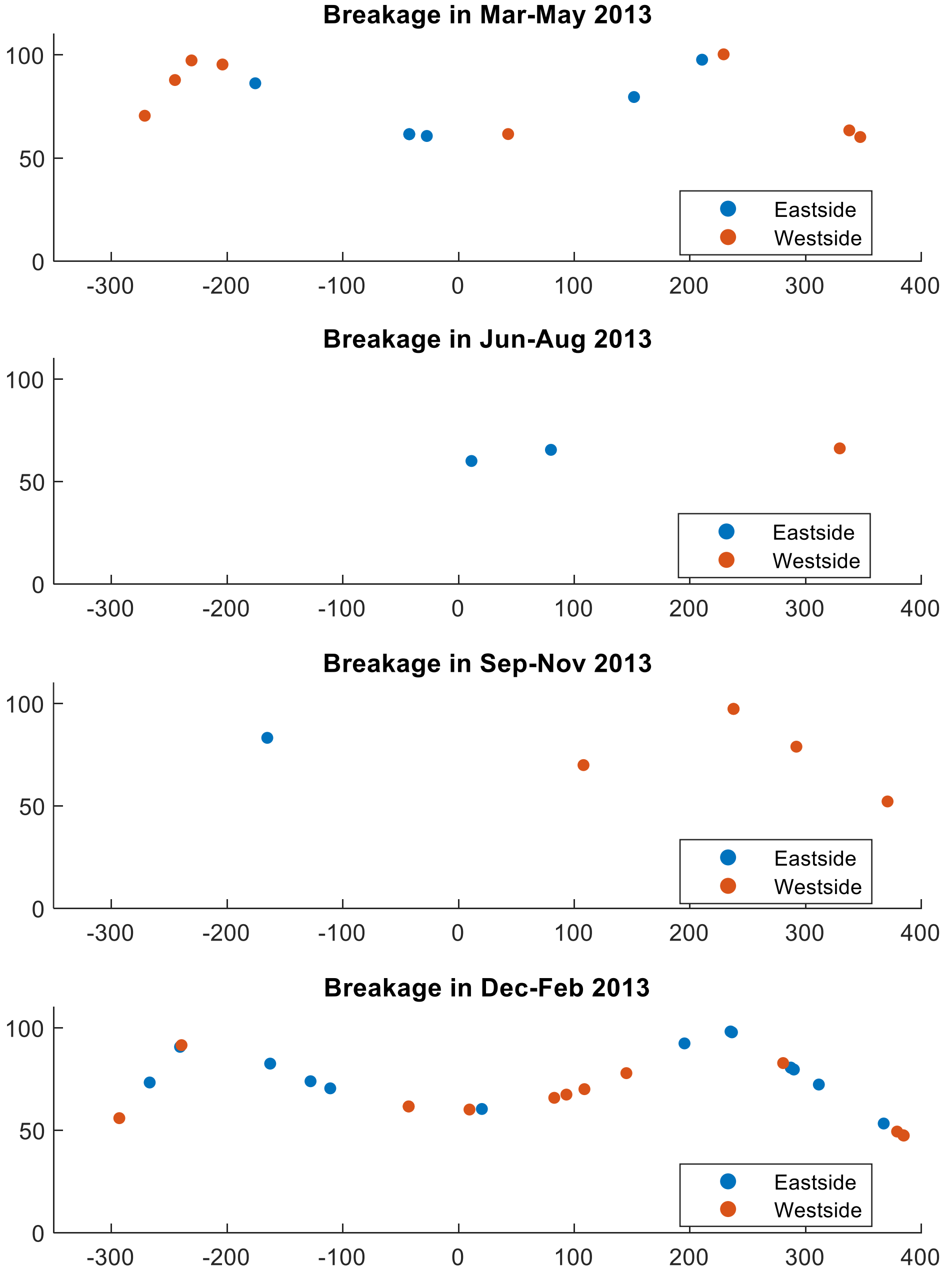


*Figure 16. The location of breakages on each side during different periods of the year 2013*

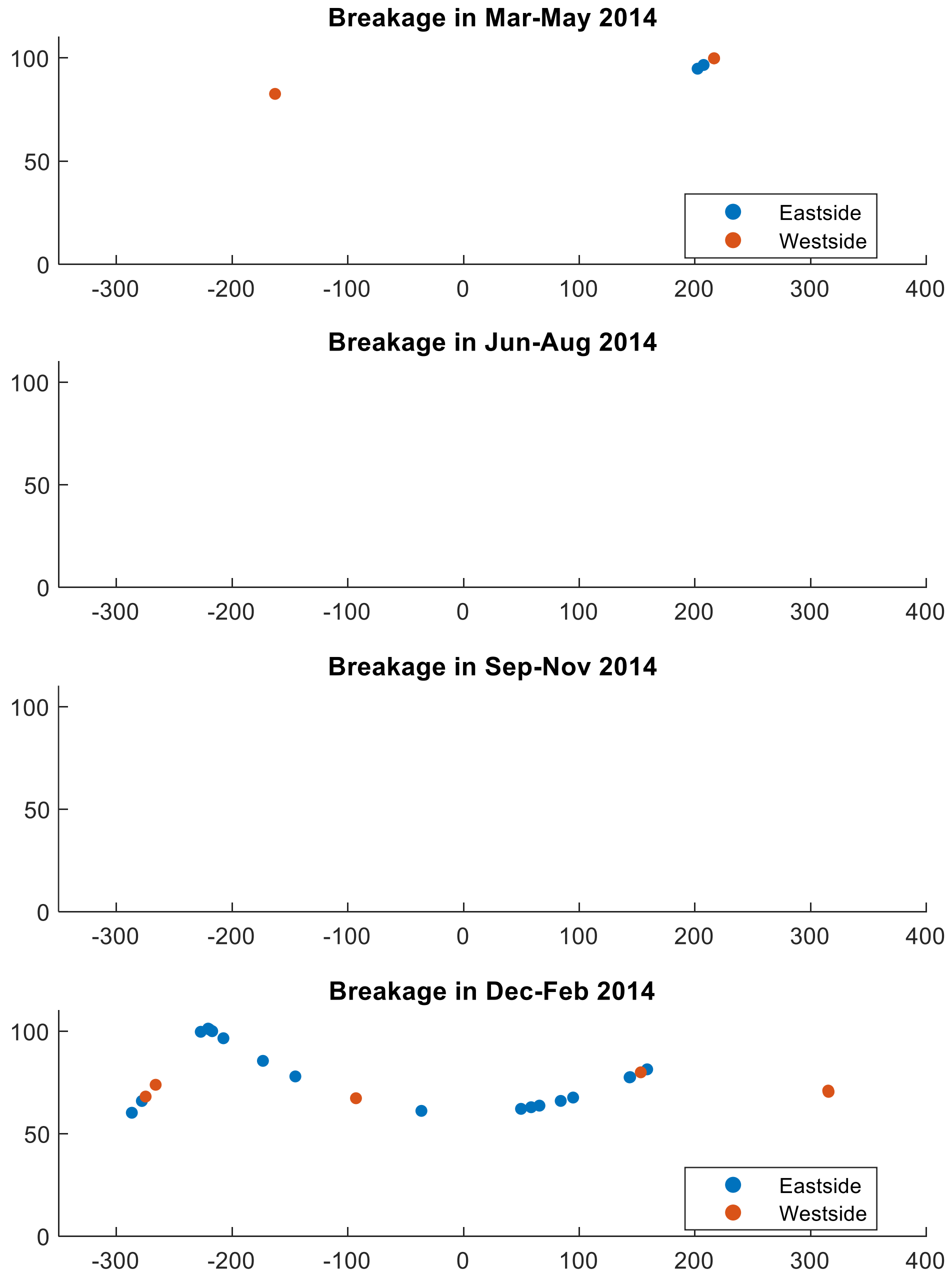


*Figure 17. The location of breakages on each side during different periods of the year 2014*


*Figure 18. The location of breakages on each side during different periods of the year 2015*

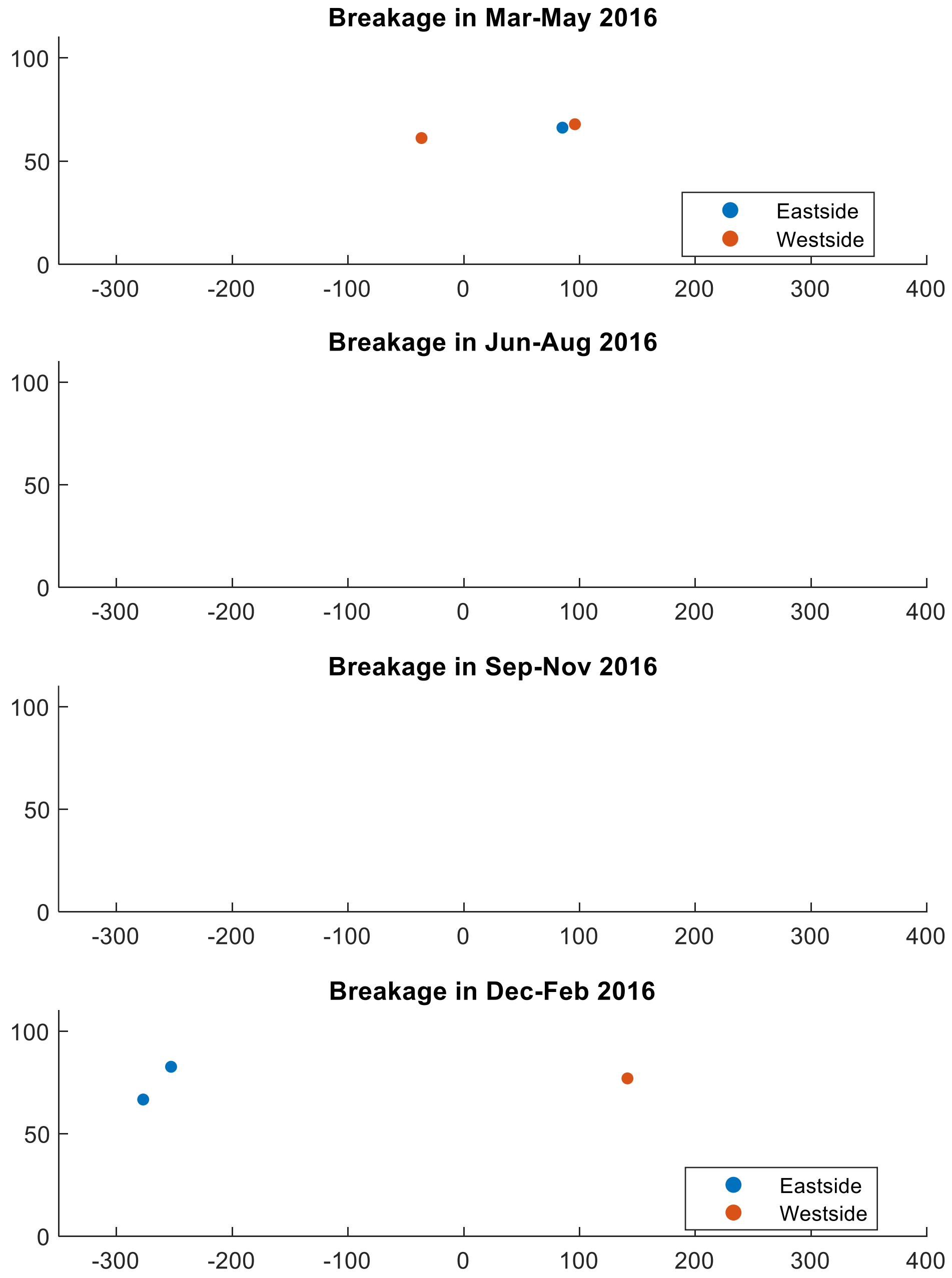


*Figure 19. The location of breakages on each side during different periods of the year 2016*

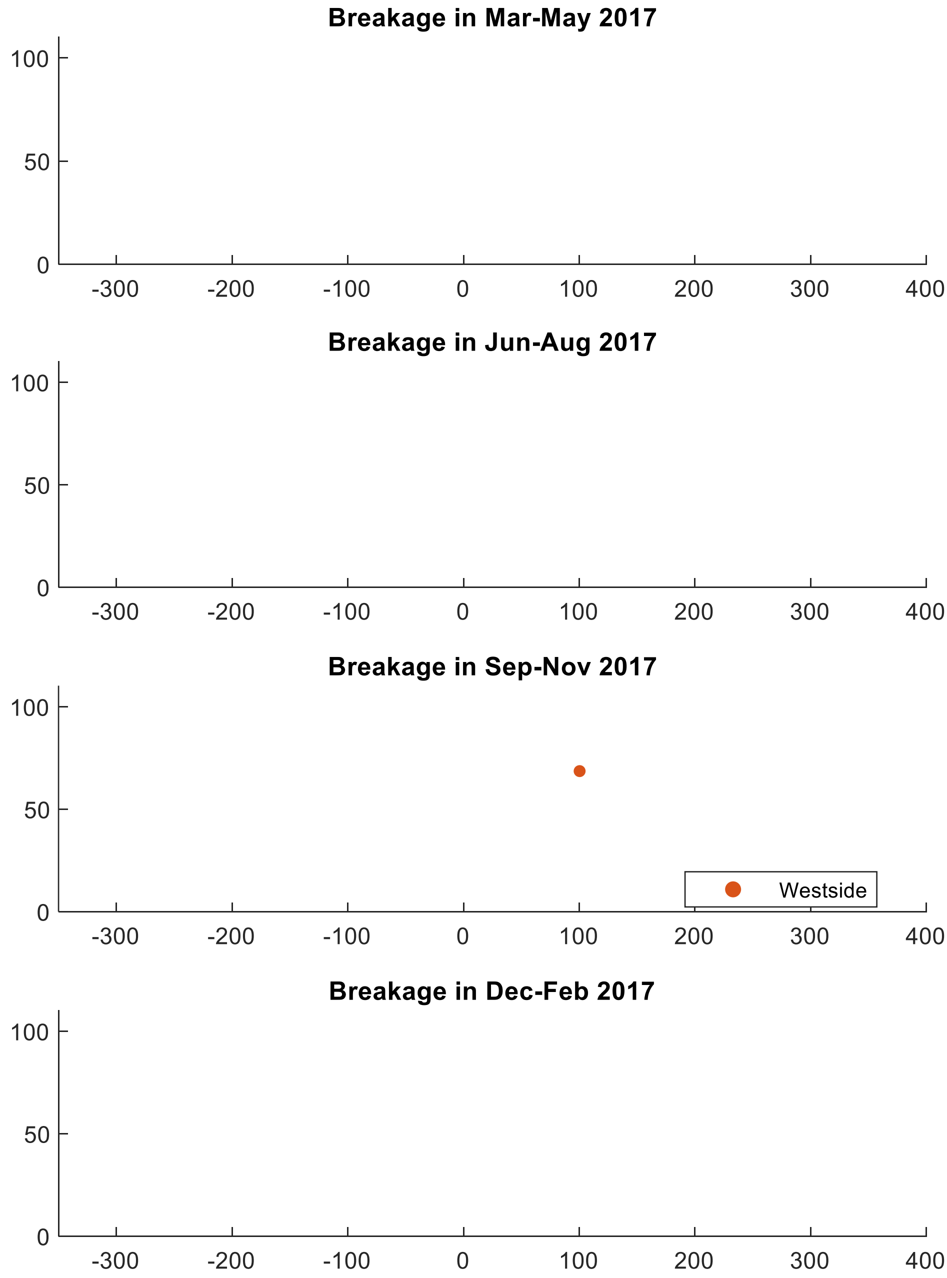


*Figure 20. The location of breakages on each side during different periods of the year 2017*

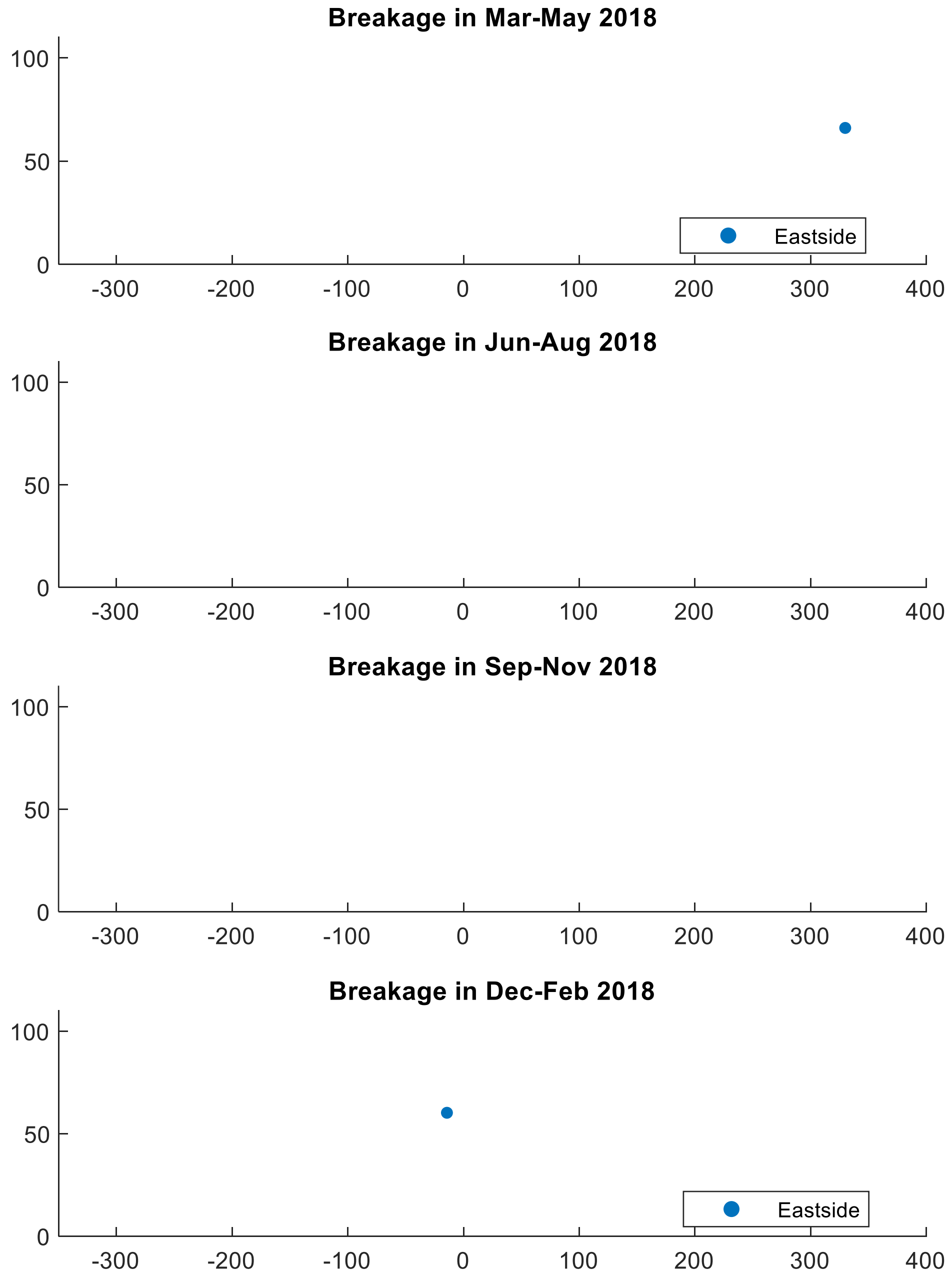


*Figure 21. The location of breakages on each side during different periods of the year 2018*

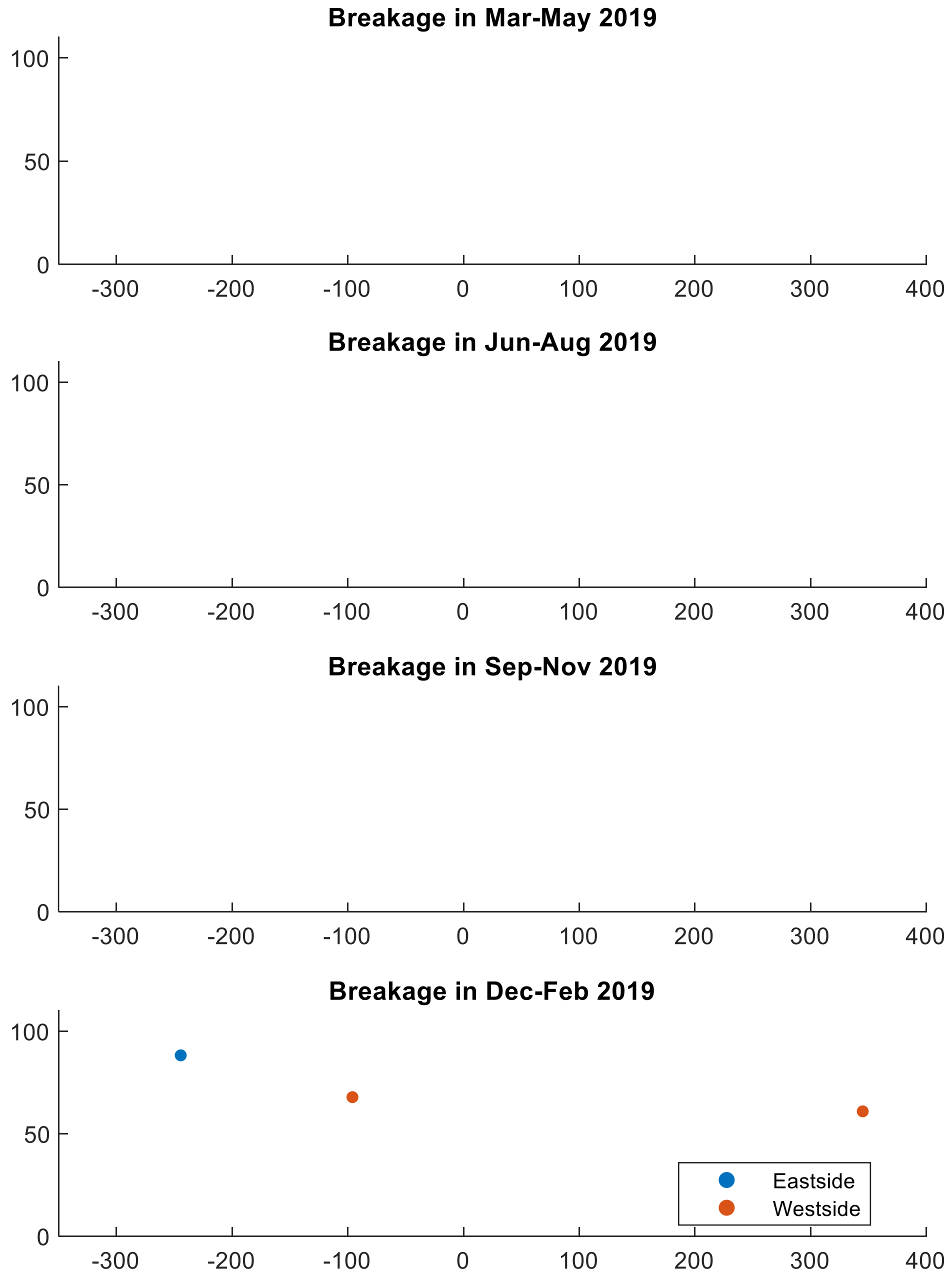


*Figure 22. The location of breakages on each side during different periods of the year 2019*

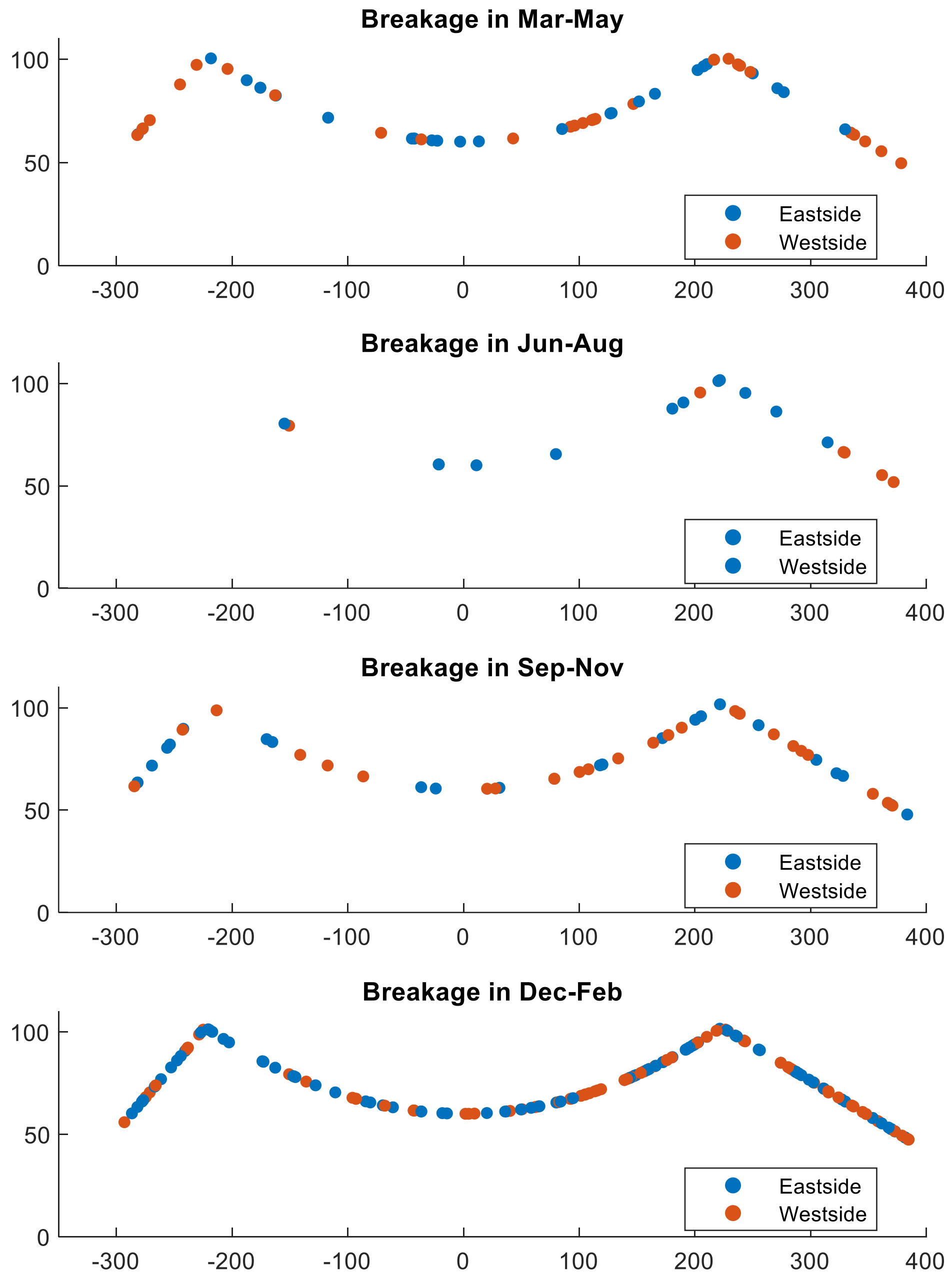


*Figure 23. The location of breakages during different periods of a year*

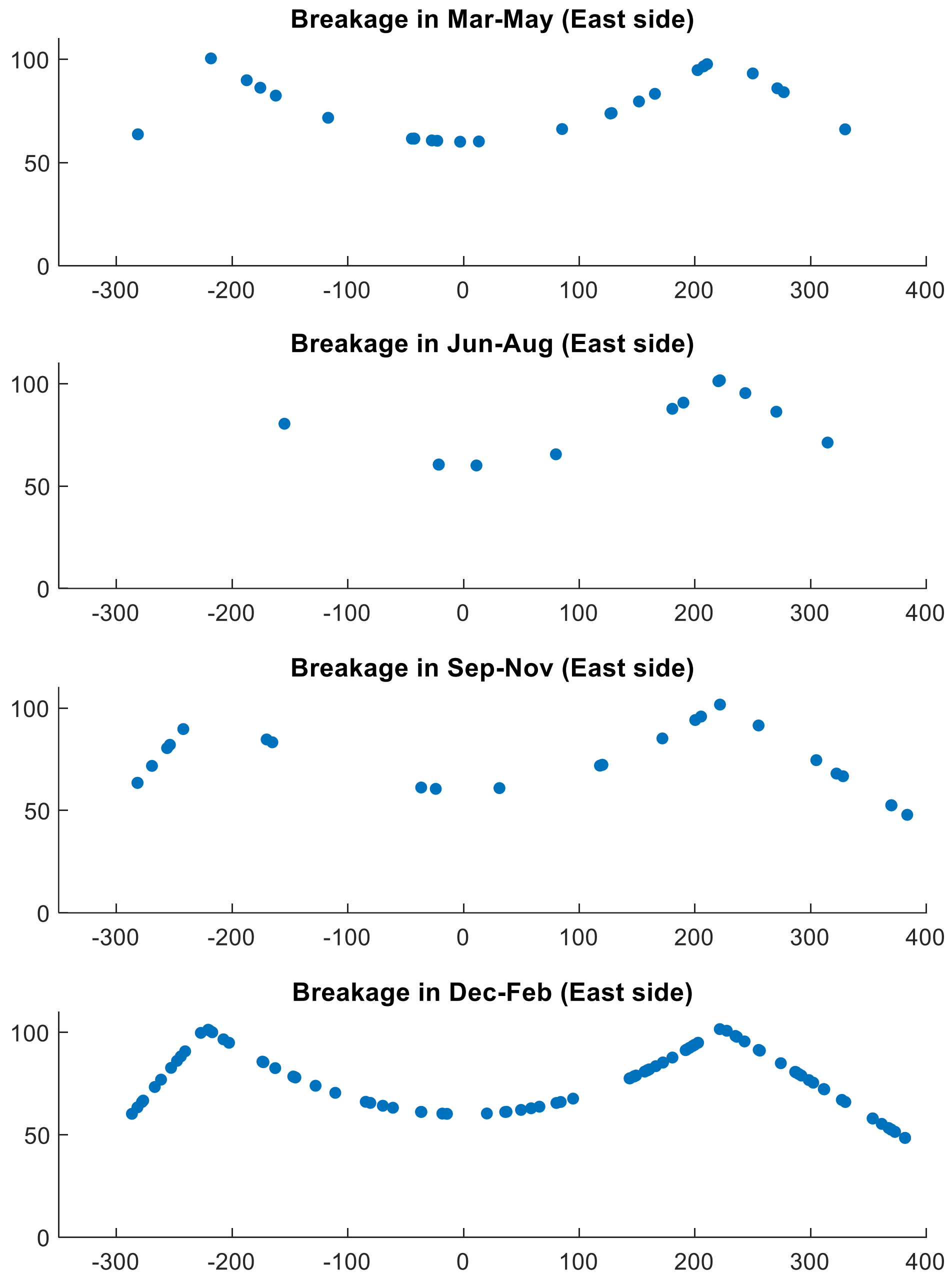


*Figure 24. The location of breakages on the east side during different periods of a year*

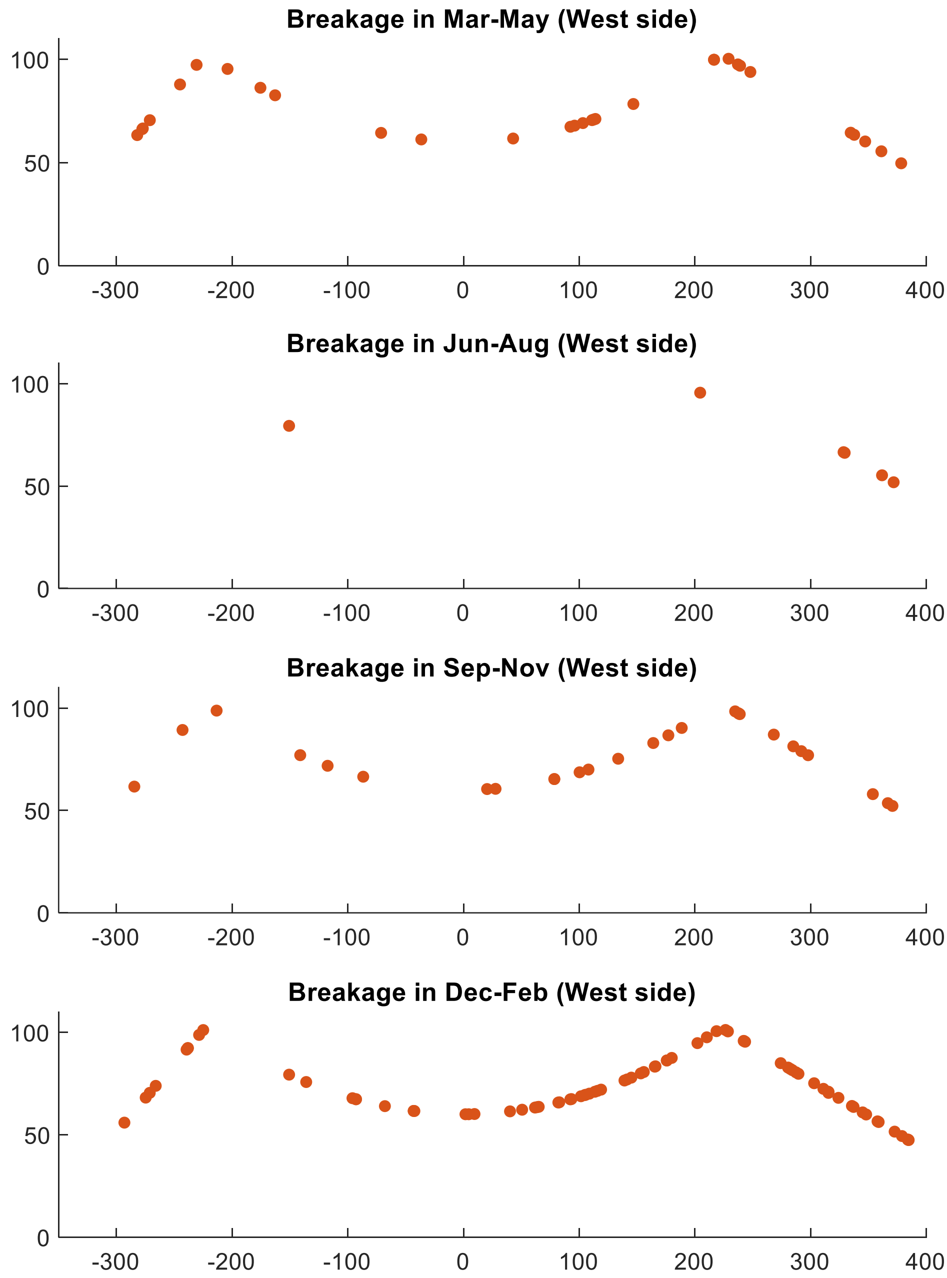


*Figure 25. The location of breakages on the west side during different periods of a year*

## 3.2 Discussion

According to the graphs above, it is more obvious that there were breakages to the south of the bridge in the months of December through May, but it is declining each year so that it is no longer significant after 2014. An investigation into the reason for this should be conducted, since it may have been caused by an error in the monitoring system, inaccurate data analysis, or redistributing forces on the bridge. Following is a summary of the different types of breakages that have occurred.

*Table 2.Visual Wire registered and automatic recording between October [4]*

| Months after bridge opens for traffic | Number of wire breaks recorded after visual inspection |
|---|---|
| 141 (2009, October) | 0 |
| 148 (2010, April) | 67 |
| 254 (2010, October) | 75 |
| 173 (2012, May) | 152 |
| 200 (2014, August) | 281 |
| 220 (2016, April) | 287 |
| 233 (2017, May) | 291 |
| 246 (2018, June) | 294 |

# 4 Field measurement data

In order to collect and analyze environmental data, several stations' temperatures and wind speeds were obtained from the Norwegian climate service center [27] and then compared according to their distance from the bridge and the likelihood of getting comprehensive information.

List of stations:

- Sola
- Stavanger
- Liarvatn
- Lysebotn
- Fv316 Tengesdal
- Fv45 Dirdal
- Rv13 Jørpeland

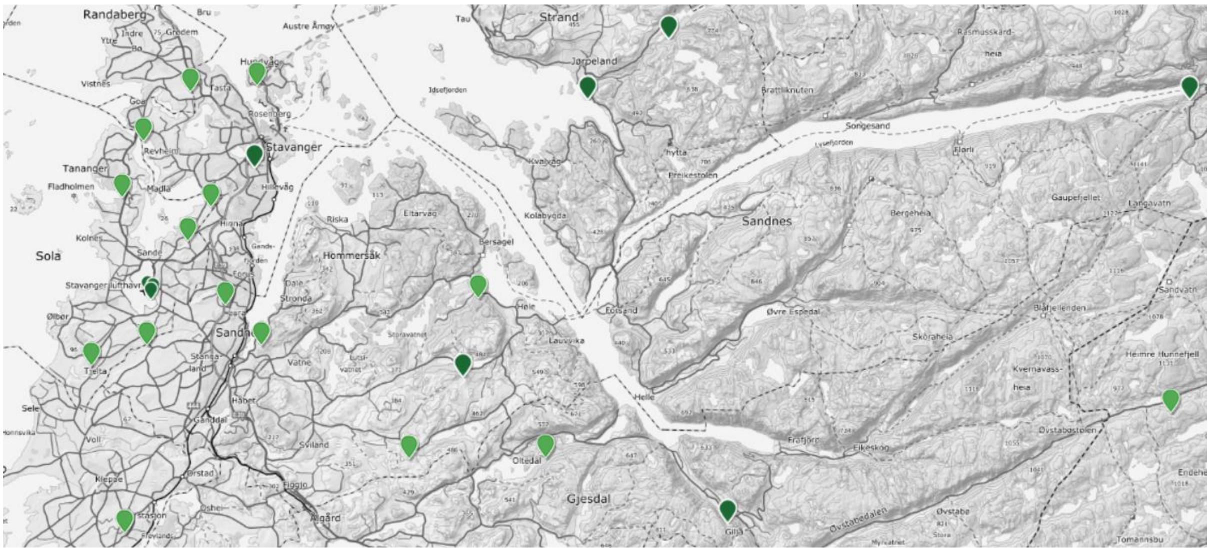


*Figure 26. Location of stations*

Compared to the figures in Appendix C, all stations' data follow the same pattern as Sola station, with the exception of Liarvatn, where a temperature gradient differs, and only wind speed data from Sola and Liarvatn are available. As a result of these observations, the further steps are based on the data from these two stations.

*Table 3. Sola and Liarvatn stations' specification*

| Station | Code | Masl (m): |
|---|---|---|
| Sola | SN44560 | 7 |
| Liarvatn | SN45530 | 300 |

## 4.1 Enviromental data regarding to breakages

An analysis of the environmental conditions at the events is conducted by extracting and comparing the temperature and wind speed at the Sola and Liarvatn stations from the Norwegian climate service center [27]. Additionally, the environmental conditions are compared to the whole period trends using MATLAB and probability density functions. Below is an explanation of the probability density functions used in this study.

### 4.1.1 Generalized Extreme Value Distribution:

When a large set of independent, identically distributed random values representing measurements or observations are combined, the generalized extreme value distribution can be used to predict the smallest or largest values between them. As a result of the combination of three simpler distributions, the generalized extreme value is able to represent all three distributions individually and in a continuous range of possible shapes including all three distributions within the range of possible shapes. It is possible to model a particular dataset of block maxima using any one of those distributions that you are familiar with. You can "let the data decide" which distribution is appropriate when you use the generalized extreme value distribution. Types I, II, and III are commonly referred to as the three cases covered by the generalized extreme value distribution. Different classes of underlying distributions correspond to different types of limiting distributions. A distribution with exponential tails, such as the normal, leads to a Type I distribution. A distribution with polynomial tails, such as Student's t, leads to a Type II distribution. A distribution with finite tails, such as the beta, leads to a Type III distribution. The Types I, II, and III are also known as Gumbel, Frechet, and Weibull types, although this terminology is somewhat confusing. As a result, a Type II (Frechet) case represents the reciprocal of a standard Weibull distribution [28].

With location parameter , scale parameter $\mu$, and shape parameter $k \neq 0$, the probability density function for the generalized extreme value distribution is [28] :

For

$$1+k\frac{(x-\mu)}{\sigma}>0$$

$$y=f(x|\,k,\mu,\sigma)=\left(\frac{1}{\sigma}\right)\exp\left(-\left(1+k\frac{(x-\mu)}{\sigma}\right)^{-\frac{1}{k}}\right)\left(1+k\frac{(x-\mu)}{\sigma}\right)^{-1-\frac{1}{k}}$$

Type II corresponds to k > 0, while Type III corresponds to k < 0. In the Type I case, k = 0, the density equals:

$$y=f(x|\,0,\mu,\sigma)=\left(\frac{1}{\sigma}\right)\exp\left(-\exp\left(-\frac{(x-\mu)}{\sigma}\right)-\frac{(x-\mu)}{\sigma}\right)$$

### 4.1.2 Normal Distribution

A normal distribution is a family of curves with two parameters, sometimes known as the Gaussian distribution. The Central Limit Theorem is usually used to justify the use of the normal distribution in modeling. This theorem states that as sample sizes grow, the mean and variance of any distribution converge to the normal distribution [29].

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left( -\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2 \right)$$

Parameter $\mu$ represents the mean or expectation of the distribution, while parameter $\sigma$ represents its standard deviation.

### 4.1.3 Weibull Distribution

Weibull distributions are two-parameter curve families. In his work on material breaking strength modeling, Waloddi Weibull offered this distribution as an appropriate analytical tool. Reliability and lifetime modeling are also included in the current use. Due to the constant hazard function of the exponential distribution, the Weibull distribution is more flexible [30].

The probably density function of Weibull is:

$$y = f(x| \text{a}, b) = \begin{cases} \frac{b}{a}\left(\frac{x}{a}\right)^{b-1} e^{-(x/a)^b} & if \;\; x \geq 0 \\ 0 & f \;\; x < 0 \end{cases}$$

Parameter a represents the scale, while parameter b the shape of ditribution.

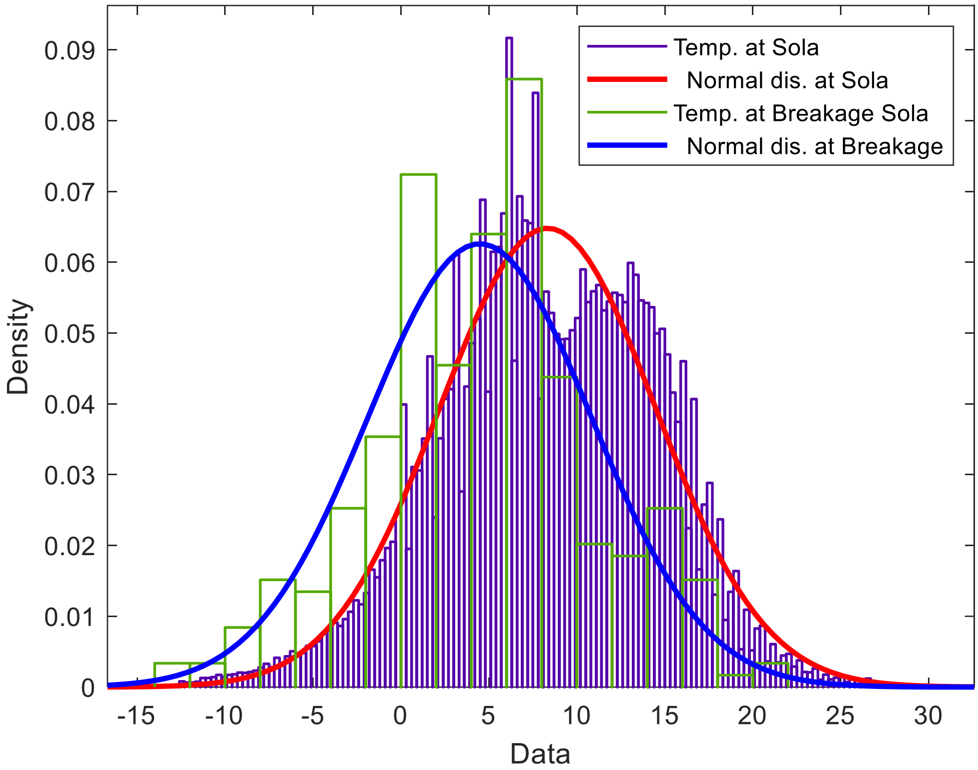


*Figure 27. Normal distribution of temperatures at events vs normal distribution of temperatures at Sola*

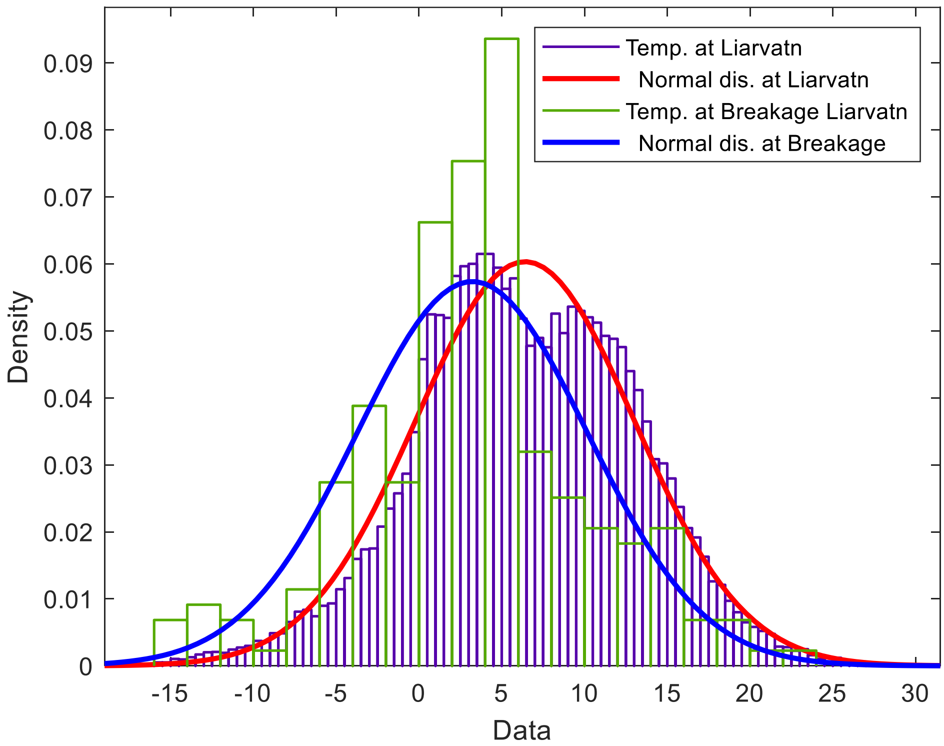


*Figure 28. Normal distribution of temperatures at events vs normal distribution of temperatures at Liarvatn*

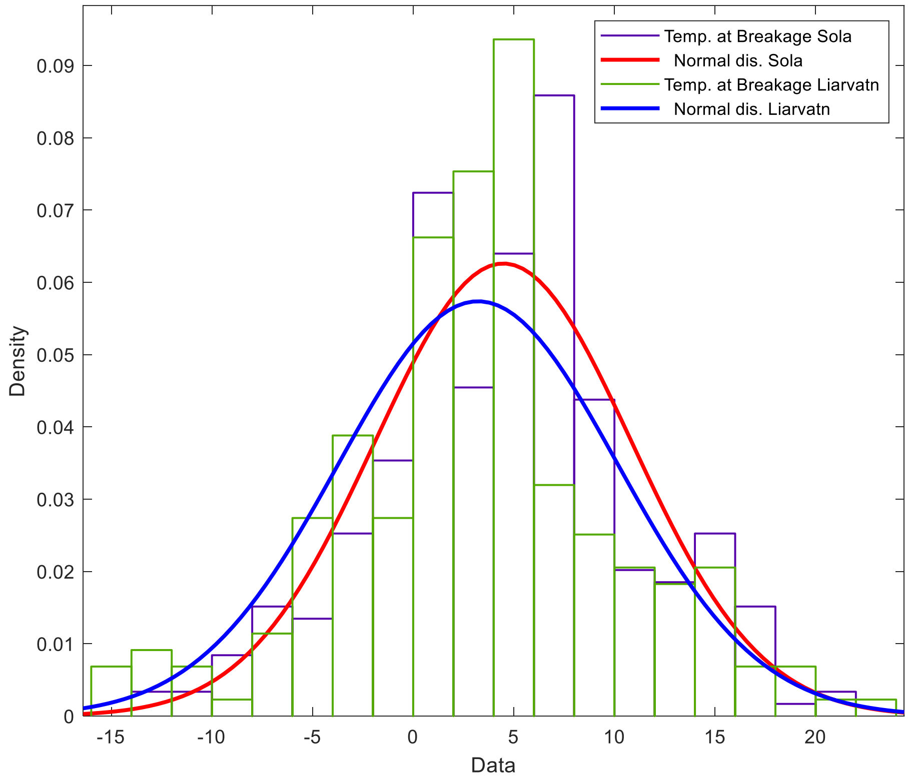


*Figure 29. Normal distribution of temperatures at events at Sola and Liarvatn*

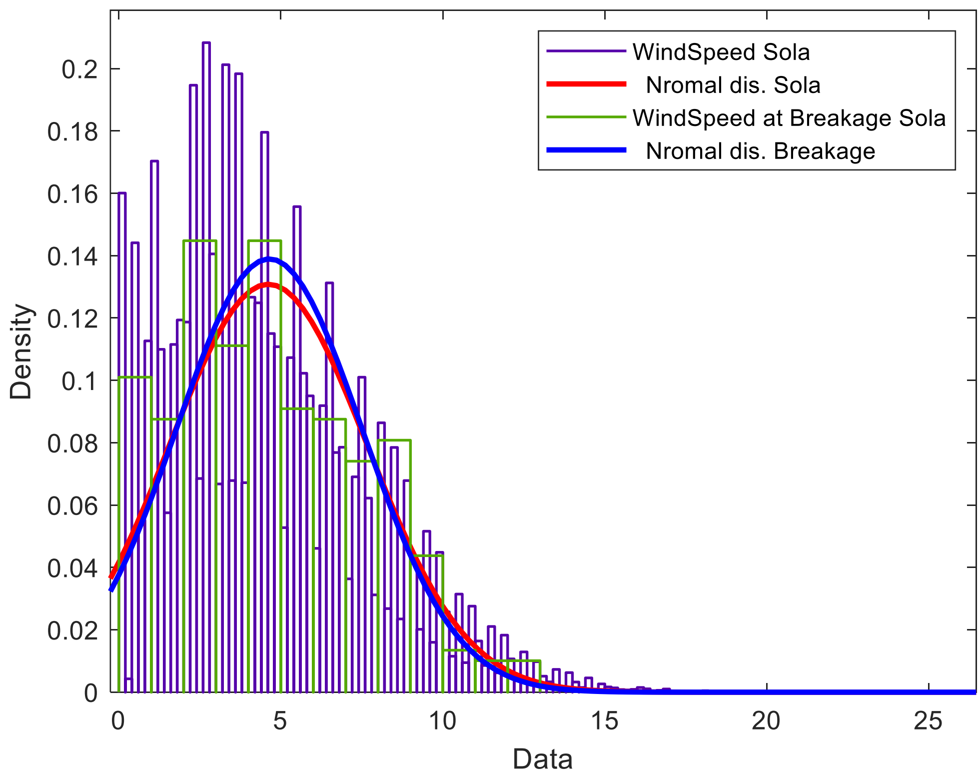


*Figure 30. Normal distribution of wind speeds at events vs normal distribution of wind speeds at Sola*

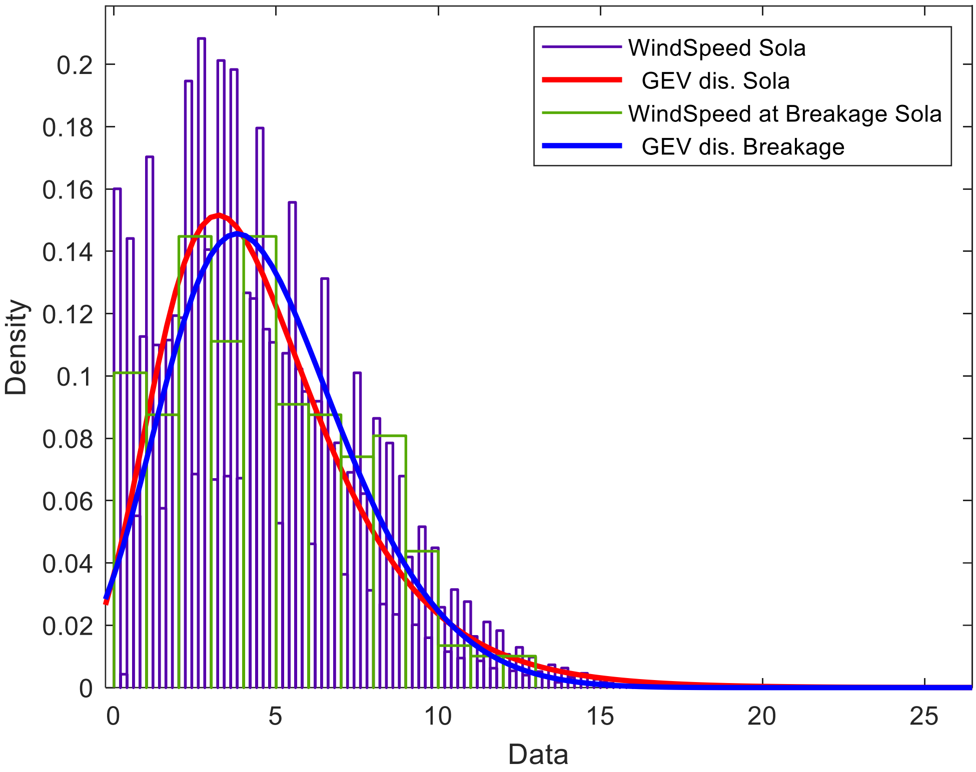


*Figure 31. GEV distribution of wind speeds at events vs GEV distribution of wind speeds at Sola*

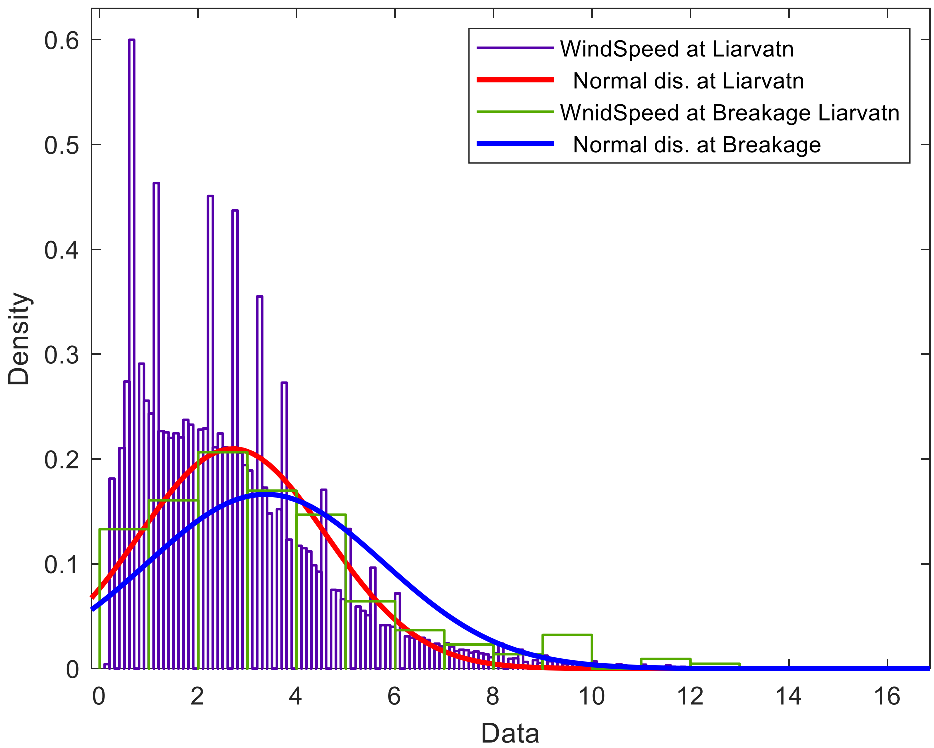


*Figure 32. Normal distribution of wind speeds at events vs normal distribution of wind speeds at Liarvatn*

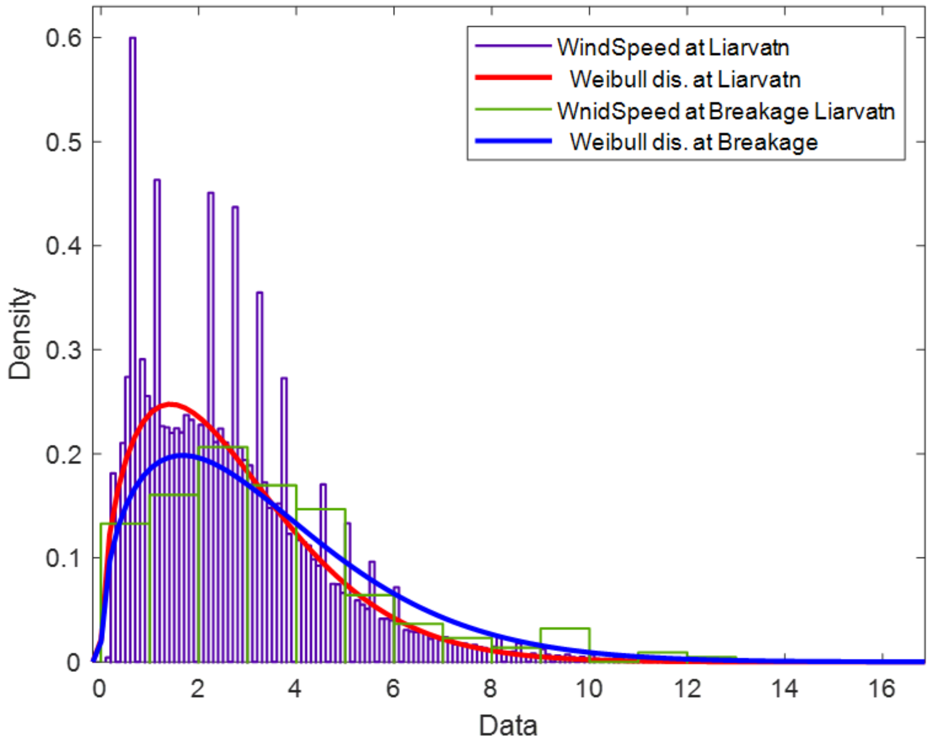


*Figure 33. Weibull distribution of wind speeds at events vs weibull distribution of wind speeds at Liarvatn*

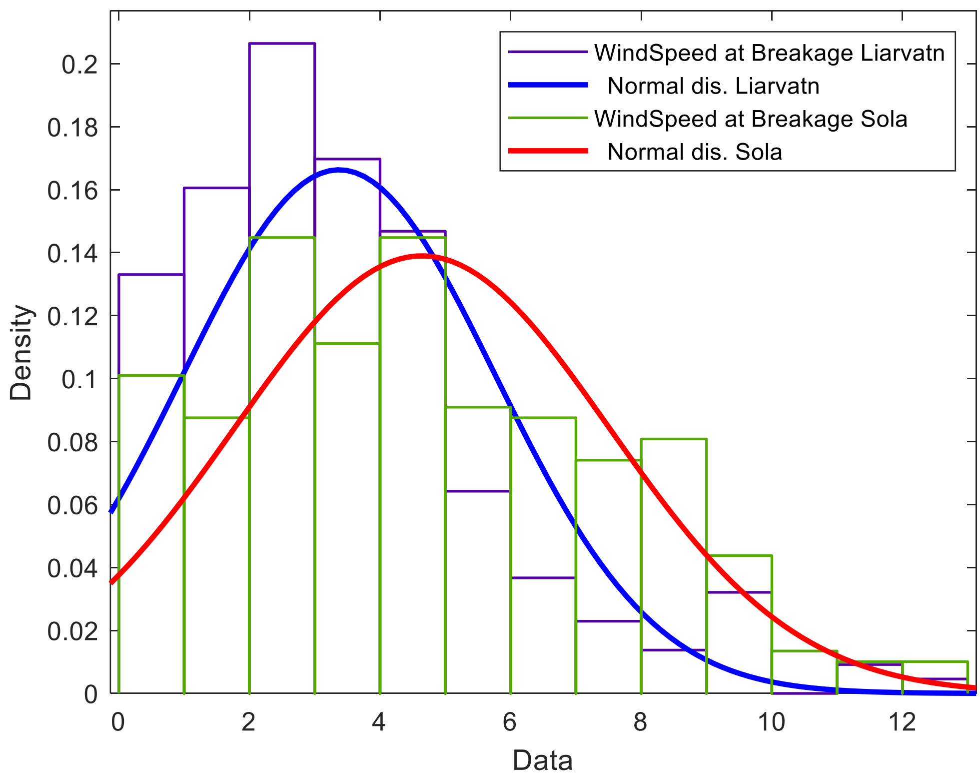


*Figure 34. Normal distribution of wind speed at events at Sola and Liarvatn*

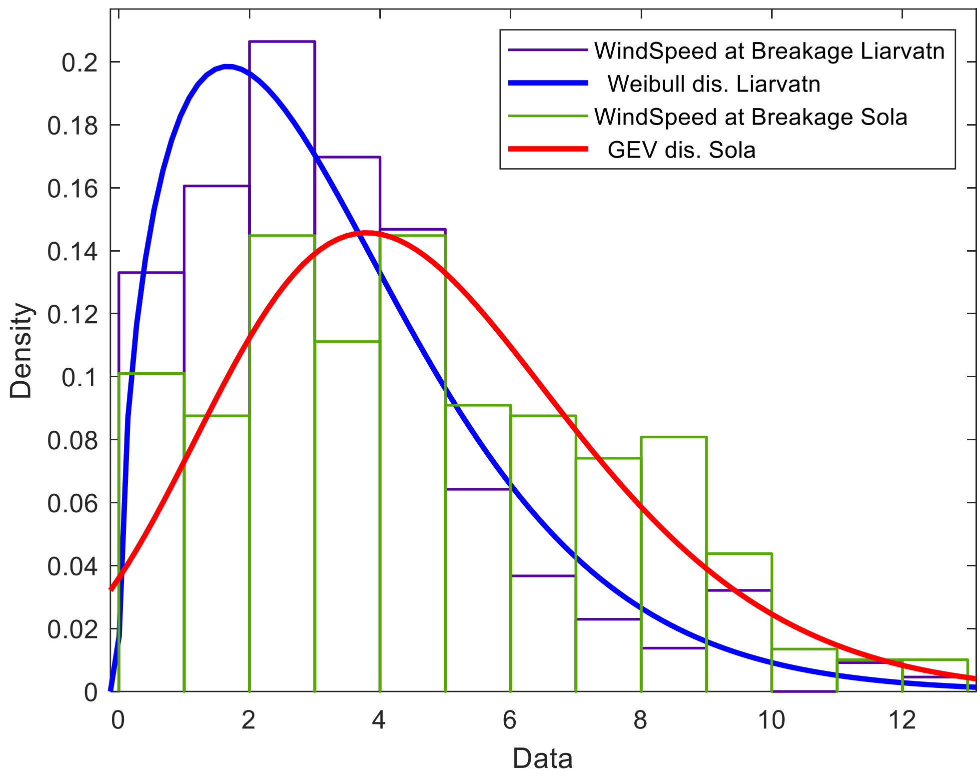


*Figure 35. Weibull distribution of wind speeds at events at Liarvatn vs GEV distribution of wind speeds at events at Sola*

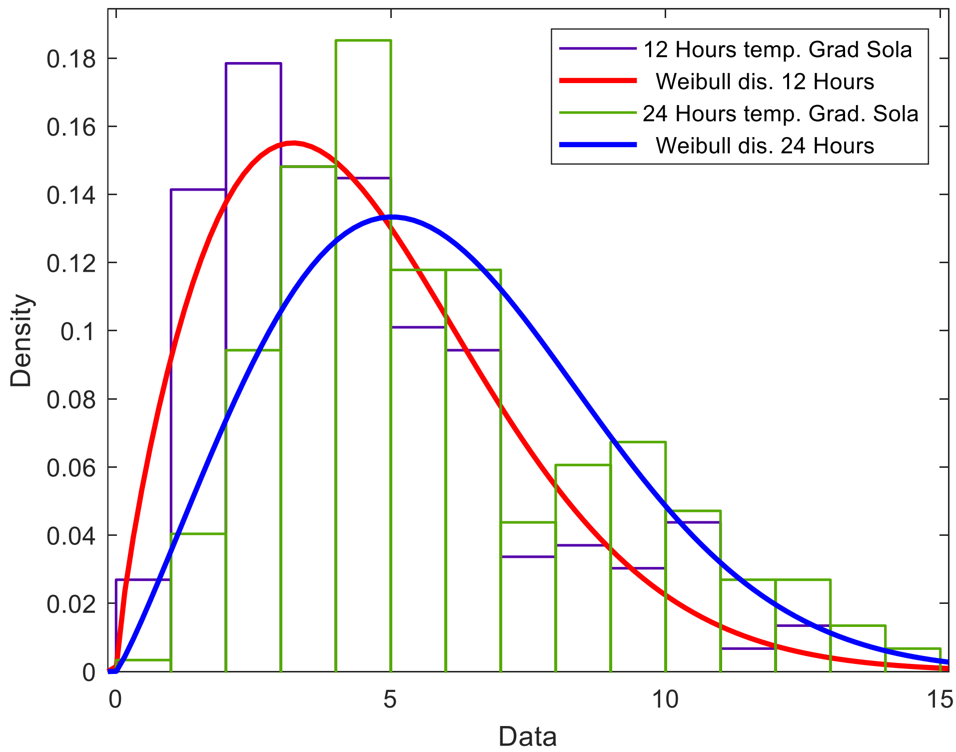


*Figure 36. Weibull distribution of 12 hours temperature gradient at events vs 24 hours at Sola*

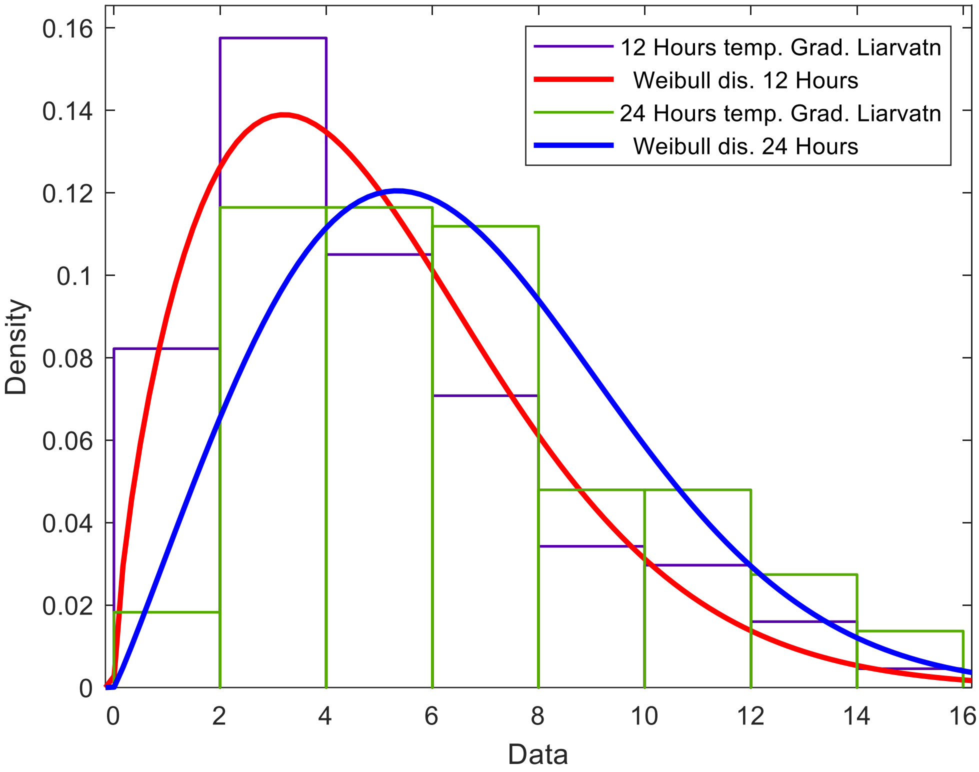


*Figure 37. Weibull distribution of 12 hours temperature gradient at events vs 24 hours at Liarvatn*

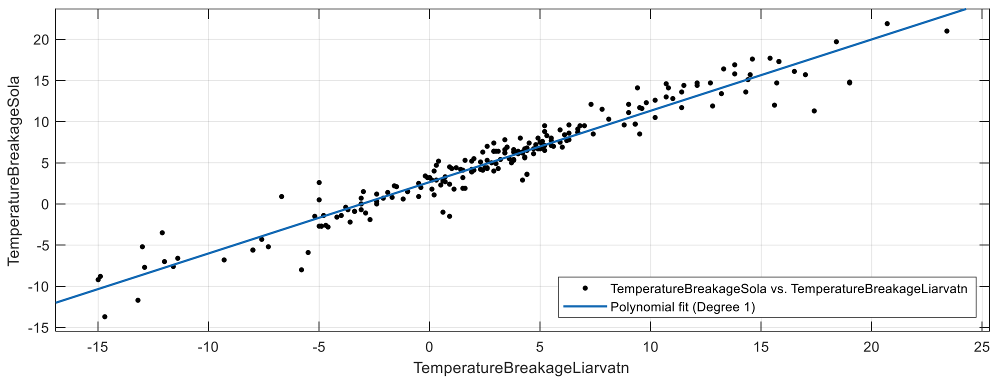


*Figure 38. Distribution of events temperature at Sola vs Liarvatn*

Linear model Poly1:

f(x) = p1*x + p2

Coefficients (with 95% confidence bounds):

p1 = 0.8663 (0.8359, 0.8968)

p2 = 2.658 (2.425, 2.89)

Goodness of fit:

SSE: 544.4

R-square: 0.9356

Adjusted R-square: 0.9353

RMSE: 1.584

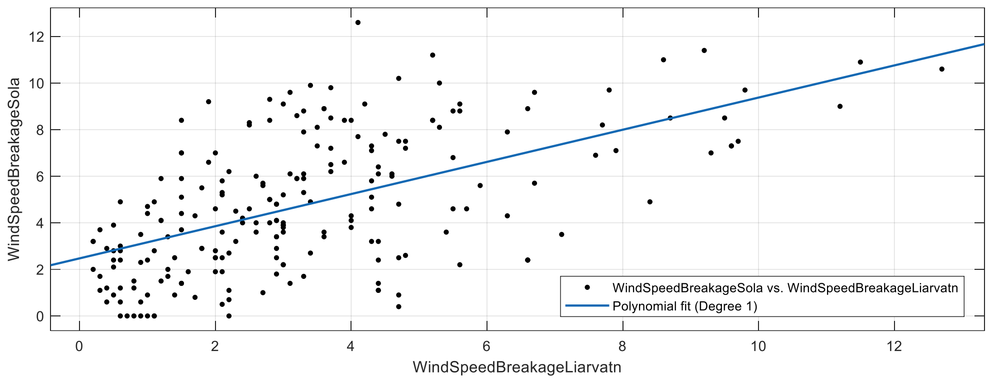


*Figure 39. Distribution of events wind speed at Sola vs Liarvatn*

Linear model Poly1:

f(x) = p1*x + p2

Coefficients (with 95% confidence bounds):

p1 = 0.6903 (0.5559, 0.8248)

p2 = 2.473 (1.917, 3.029)

Goodness of fit:

SSE: 1255

R-square: 0.3216

Adjusted R-square: 0.3184

RMSE: 2.411

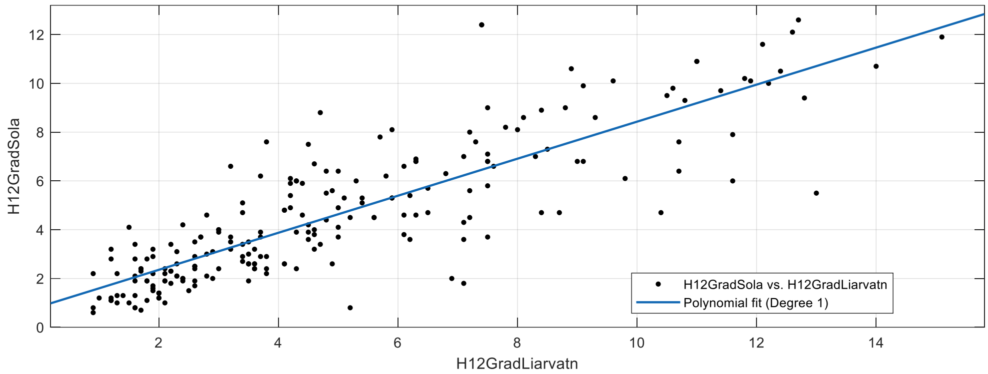


*Figure 40. Distribution of events 12 hours gradient at Sola vs Liarvatn*

Linear model Poly1:

f(x) = p1*x + p2

Coefficients (with 95% confidence bounds):

p1 = 0.7591 (0.6943, 0.8239)

p2 = 0.8386 (0.458, 1.219)

Goodness of fit:

SSE: 515.8

R-square: 0.7107

Adjusted R-square: 0.7094

RMSE: 1.542

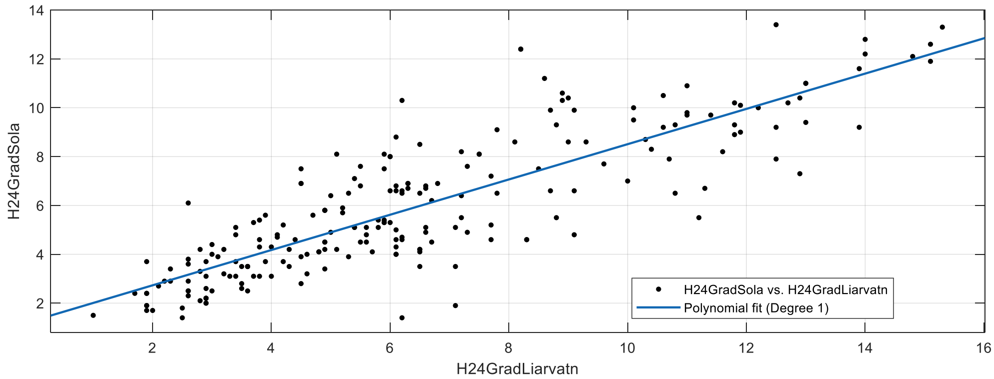


*Figure 41. Distribution of events 24 hours gradient at Sola vs Liarvatn*

Linear model Poly1:

f(x) = p1*x + p2

Coefficients (with 95% confidence bounds):

p1 =     0.7223  (0.6605, 0.7842)

p2 =      1.285  (0.837, 1.734)

Goodness of fit:

SSE: 513.9

R-square: 0.7094

Adjusted R-square: 0.7081

RMSE: 1.539

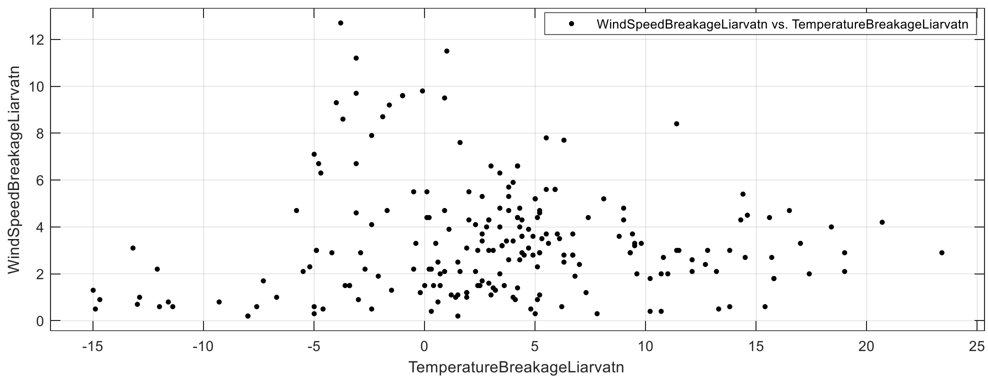


*Figure 42. Distribution of enviromental data at the time of events in Liarvatn*

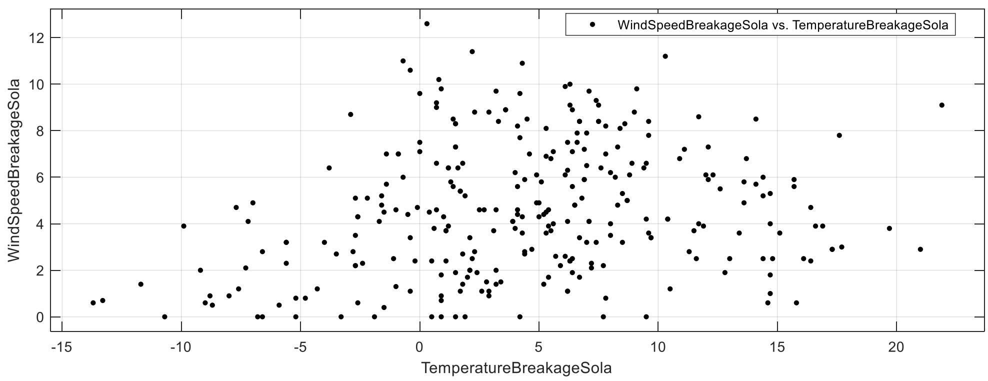


*Figure 43. Distribution of enviromental data at the time of events in Sola*

## 4.2 Discussion

At each station at the time of the breakage, the normal distribution has a close variance (Table 4) to the whole period's normal distribution (Figure 27 & Figure 28), except for the fact that the normal distribution occurs at the time of the breakage at a relatively lower temperature (lower mean value). The explanation for this phenomenon can be found in the months when the most breakages occurred. As a result of the fact that Liarvatn station is located at a higher level above sea level than Sola station, its normal distribution is lower than that of Sola station Figure 29.

*Table 4. Distribution parameters of Figure 27 and Figure 28*

| Figure 27 | | Figure 28 | |
|---|---|---|---|
| Normal dis. at Sola | | Normal dis. at Liarvatn | |
| Mean: | Variance: | Mean: | Variance: |
| 8.33658 | 37.9007 | 6.40284 | 43.7148 |
| Normal dis. at Breakage | | Normal dis. at Breakage | |
| Mean: | Variance: | Mean: | Variance: |
| 4.47609 | 40.6066 | 3.221 | 48.3455 |

As with temperature distribution, wind distribution at the time of breakage follows the same law (Figure 30 to Figure 35).

At the time of breakage, the temperature gradient is examined for 12 and 24 hours. These gradients are distributed between 3 and 6 degrees Celsius at both stations, following a trend (Figure 36 & Figure 37).

A first-order linear distribution is fitted to each of the variables at the stations in Figure 38 to Figure 41 to obtain its degree, and the results of this are presented at the bottom of the figures.

As a final note, Figure 42 and Figure 43 depict the distribution of environmental data (temperature and velocity) at each station at the time of breakage. Given the wide spread of this data, it can be concluded that other factors such as traffic load can play a decisive role and should be considered for a better and clearer conclusion.

# 5 Finite element model of the Bridge

In this chapter, an ABAQUS model is introduced for the Lysefjord Bridge based on the previous models and tries to use different elements to compare the results (Appendix E). Wind, traffic, and temperature loads will be evaluated using the ABAQUS model, along with the bridge's eigenfrequencies. User manuals and help functions found in ABAQUS CAE explain the commands used in ABAQUS. The interactive user interface can be used to determine how ABAQUS expects the command structure.

## 5.1 Introduction

It is well known that the finite element method (FE) is an excellent tool for the design and analysis of structural systems in civil engineering. This method can also be used in predicting dynamic and static structural behaviour in service, in addition to its usefulness for predicting static and dynamic structural behaviour in service. Models developed with finite element analysis can also provide new information upon experimental validation, which can then be compared with data from long term monitoring systems for the purposes of detecting structural damage and predicting future performance [15]. In FE models, overly idealized engineering designs and constructions are often used as the basis for the models that illustrate actual structures. However, often, these highly idealized designs and constructions do not represent fully the actual structure's physical characteristics. As a result, there may be a significant difference between the predictions made by the FE model and the measured values of the actual structure. There are a lot of reasons that this issue may arise, but one of the main reasons is because of the reliance on simplified assumptions in models. However, uncertainties in materials and geometric properties can also lead to erronous parameter estimations. It is often used to adjust the FE model using the measured modal data of the actual structure in order to minimize the discrepancy between the FE model and the actual structure, and to maximize the correlation of the FE model and the actual structure [31].

There has been considerable research on the use of vibration measurements in updating FE models over the last few decades [32, 33]. Model updating methods can be divided into two major categories: direct methods and iterative methods. The direct method is a two-step procedure that directs the stiffness and mass matrices to be updated using one step. [34, 35]. In this method, it is possible to reproduce measured vibration modal data, but it is not guaranteed that the actual structure's physical characteristics will be accurately reflected in the analytical model. Additionally, iterative parameter updating methods use sensitivity to update the analytical model, taking into account whether a parameter has been adapted to the given example [36-38]. These methods are based on the assumption that the errors between analytic and measured data will form an objective function, and then a given set of physical parameters that represent the analytical model will be adapted in order to minimise this objective function. This sensitivity-based approach and the dynamic perturbation method, which are methods used in these iterative approaches, are more popular than direct methods because they can be implemented more easily in existing FE codes [39, 40]. There is a physical explanation for each structural updating parameter as well, which is normally described in relation to the stiffness and mass of the elements in the analytical model [31].

With a wide variety of applications, sensitivity-based methods are usually the optimum way to deal with model updating problems. According to Brownjohn and Xia (2000), sensitivity-based updating factors in all parameters that need to be updated, objective functions, constraints, and optimization techniques that will determine its performance [41]. It can be interpreted that the objective function is defined as the difference between the modal data measured and the associated predictions, such as differences in modes and heights, based on the measured data and associated FE models. It is essential to have extensive physical insight into the tested structure to be able to select the structural parameters that should be updated to correctly characterize the properties of the structural elements at local level, such as at connection points between structural elements [42]. In order to reduce the uncertainty associated with structural parameters and vibration measurements, Bayesian updating can also be used in conjunction with FE models [43]. As a result of these two techniques, along with sensitivity analyses, an advanced global optimization can be achieved. In order to avoid local optimal solutions, structural updating parameters are commonly obtained using these techniques. It should be noted that, despite the fact that the sensitivity-based updating procedure is computationally demanding, the optimisation and sensitivity analysis procedures may not guarantee optimal results. The problem occurs particularly when there is a large discrepancy between the initial numerical model and the actual structure during the testing process, and the expansion of many parameters within the structure is required as well [31].

By using measured incomplete modal data, dynamic perturbation methods can directly evaluate selected structural updating parameters regardless of the data type [44, 45]. This method requires perturbing structural parameters and calculating the modal data. The modal data will be measured for the structural model. Thus, it is not necessary to perform a sensitivity analysis or construct an objective function from the sensitivity analysis. An iterative procedure using least squares is then used to estimate the choice of the structural updating parameters, which does not require any optimisation on the part of the user. This method has been successfully used to update FE models of the supertall building Canton Tower [39, 46].

## 5.2 Structural behavior and components of suspension Bridges

A suspension bridge can be described as a structure that takes loads from the girder to the curve cables, which will be under tension, via the hangers. Normally, the loads are transferred to the twoers, which carry them to the anchorages, and to the ground and back stayed cables, which carry them to the foundations (Figure 44).

The main structural components of Lysefjord Bridge:

- Concrete Towers
- Main cables
- Anchor bolts
- Hanger cables
- Steel stiffening box girder

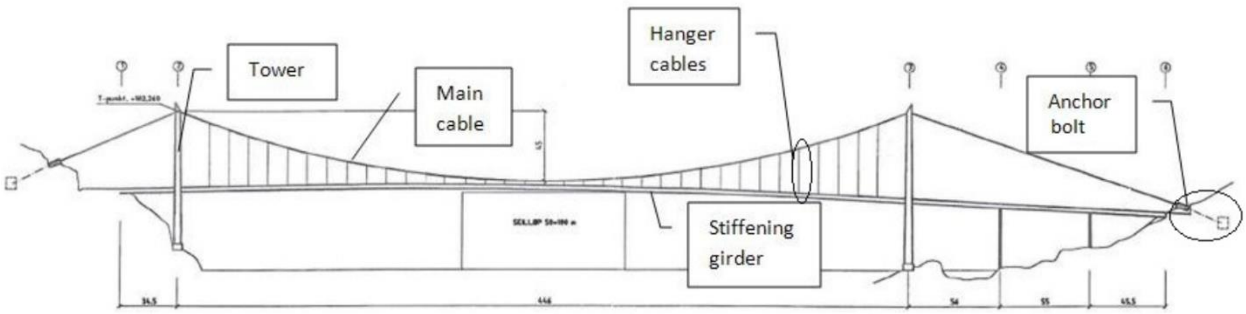


*Figure 44. The main components of the Lysefjord Bridge [1, 2]*

### 5.2.1 Stiffening girder

The stiffening girders of suspension bridges are the main components that are exposed to the effects of external loads such as traffic, wind, snow, and dead loads. After a series of events, the design and shape of the bridge was developed, improved, and modified in order to meet the aerodynamic requirements, withstand twisting and fatigue, and withstand different forces and events. As shown in Figure 45 , the Lysefjord Bridge has a narrow bridge girder with two types of stiffeners in a trapezoidal shape.

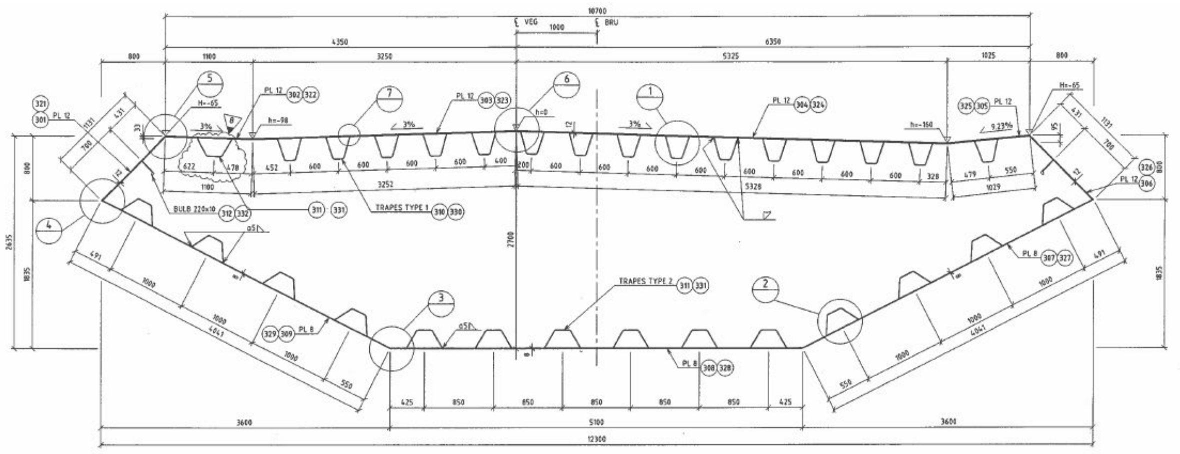


*Figure 45. The details of the Stiffening girder cross-section[1]*

### 5.2.1.1 The geometry of the girder

The geometry of the girder is obtained by studying the attached drawing (Appendix F), locating three known points, and by using a parabolic line to connect them, the geometry is obtained as follows:

A negative deflection of 1.5 m is taken into account before the dead load is applied. This value should be revised and if necessary modified after modeling and analyzing it [2].

- Elevation of the northern tower: 53.465 m
- Elevation of middle: 54.472+1.5=55.972m
- Elevation of the southern tower: 46 m

$$y = ax^2 + bx + c$$

*Table 5. Coordinates of three known points of the girder*

| Point | Start | middle | End |
|---|---|---|---|
| X | -223 | 0 | 223 |
| y | 53.465 | 56.979 | 46 |

$$\Rightarrow y = -0.00012542x^2 - 0.016735x + 55.97$$

#### 5.2.1.2 Modeling in ABAQUS

In order to model bridge girders, beam elements B31 are used as shown in Figure 46 and Figure 47. It is imperative to model a beam element between each hanger and at the neutral axes in order to put the hangers vertically, and a dummy element between the midpoint and the side points is also modeled based on the distance between the hangers(Figure 48).

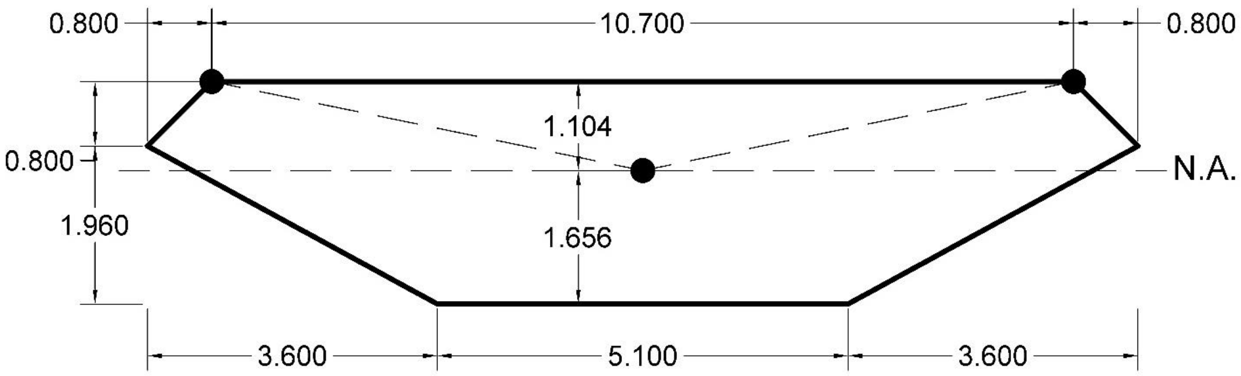


Figure 46. Neutral axes and dimensions of the girder

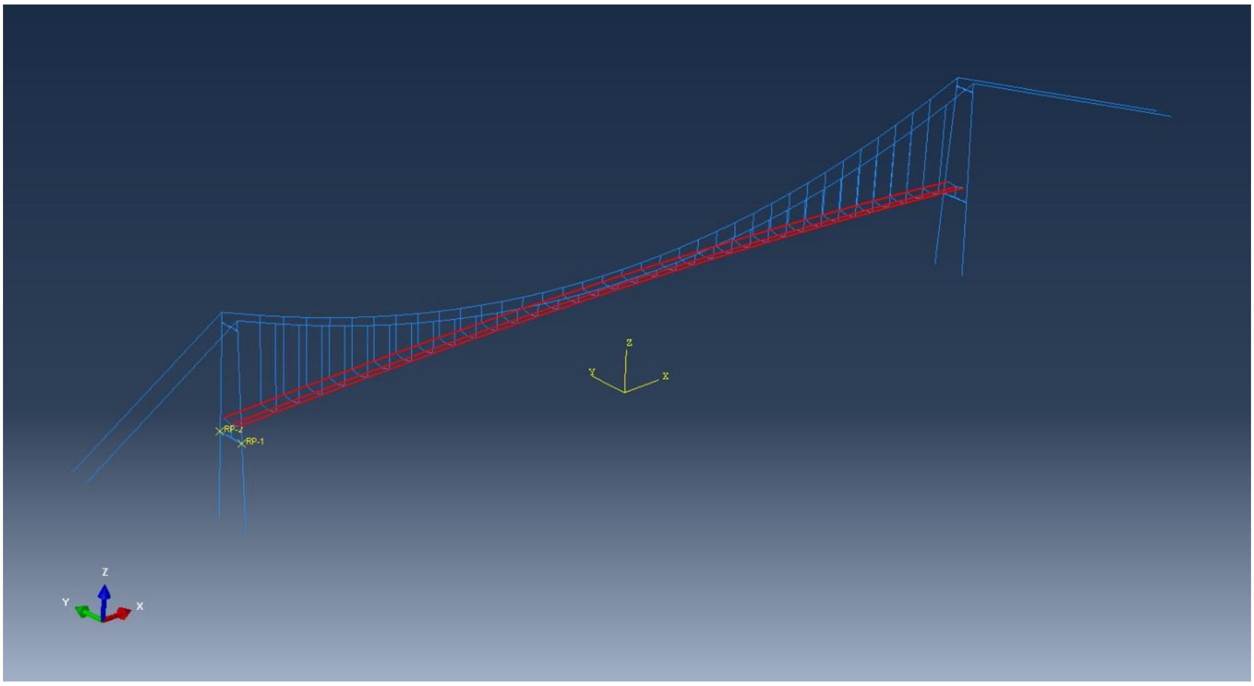

Figure 47. Modeling of the girders

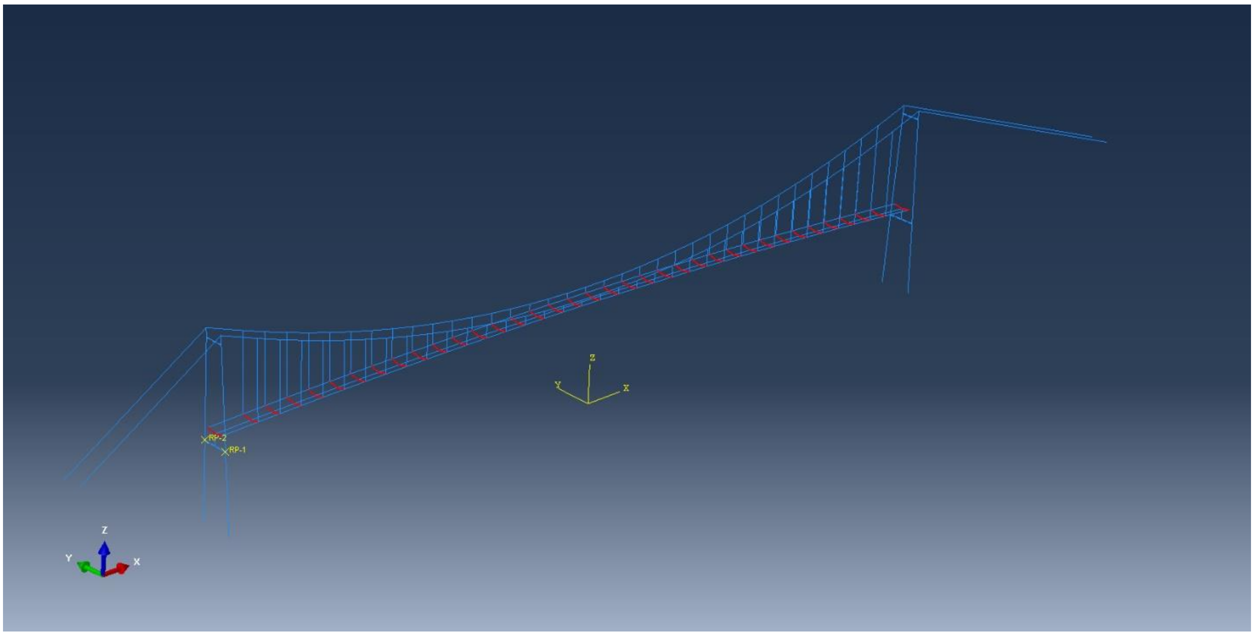

*Figure 48. Modeling of the dummy elements*

### 5.2.2 Main Cables

On each side of a bridge, six separate cables are installed - each with a high-strength wire. Before the dead load, the wires were 713 meters long and were made up of 225 wires and 54 Z-wires in the outer layer [47]. There have been fractures in the wires since the bridge was built, and this has continued.

#### *5.2.2.1 The geometry of the main cables*

Following the attached drawing (Appendix F), there are three points that are known, and the geometry of the main cables can be derived by establishing a parabolic line between these three points and finding their elevations:

A negative deflection of 2.8 m is taken into account before the dead load is applied. In case this value needs to be revised after analyzing and modeling the situation, the revised value should be disclosed [1].

- Elevation of the northern tower: 102.26 m
- Elevation of middle: 102.26-45+2.8=60.06 m
- Elevation of the southern tower: 102.26 m

A parabolic line will be established between these three points in order to determine the geometry of the main cable.

$$y = ax^2 + bx + c$$

*Table 6. Coordinates of three known points of the main cable*

| Point | Start | middle | End |
|---|---|---|---|

| | | | |
|---|---|---|---|
| X | 223 | 0 | -223 |
| y | 102.26 | 60.06 | 102.26 |

$$\Rightarrow y = 0.0008486x^2 + 60.06$$

The coordinates of the modeling which is shown in Figure 49 are obtained using MATLAB software as well as the two formulas obtained in the previous part for the girder and main cables. Using these points, the geometry of the bridge was first modeled in Autocad (Figure 50) The exported iges file was then imported into ABAQUS and the geometry of the bridge was eventually modeled.

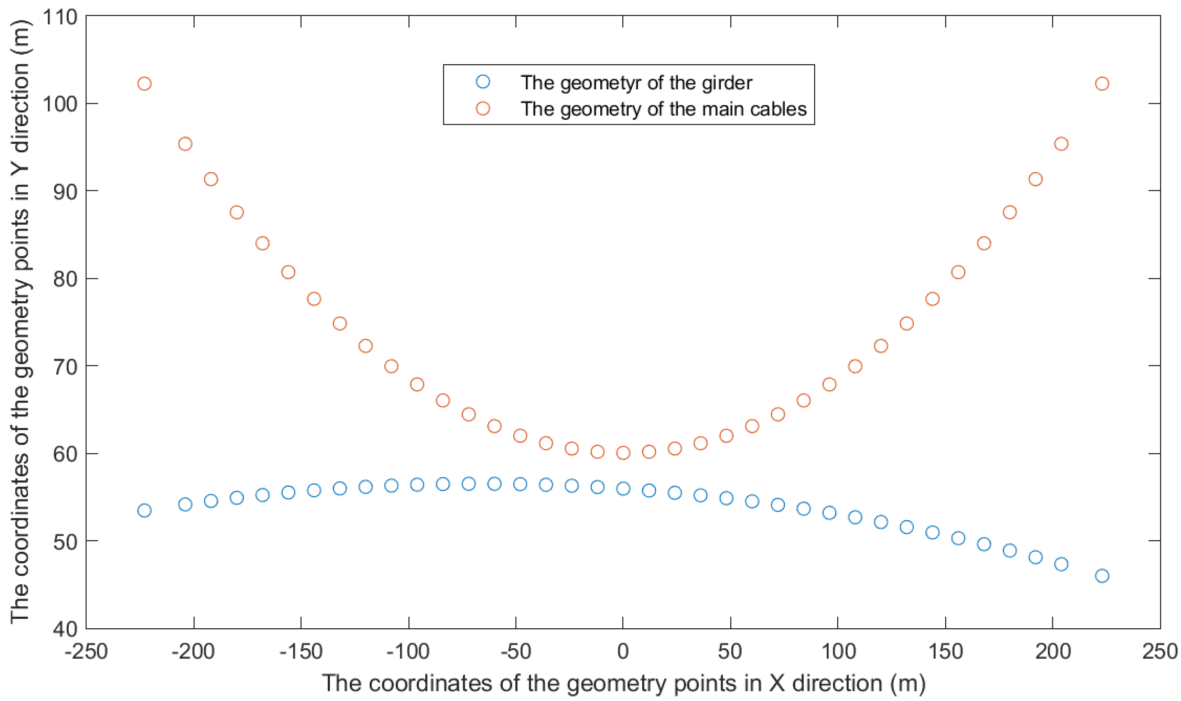


*Figure 49. The coordinates of the points for drawing the geometry*

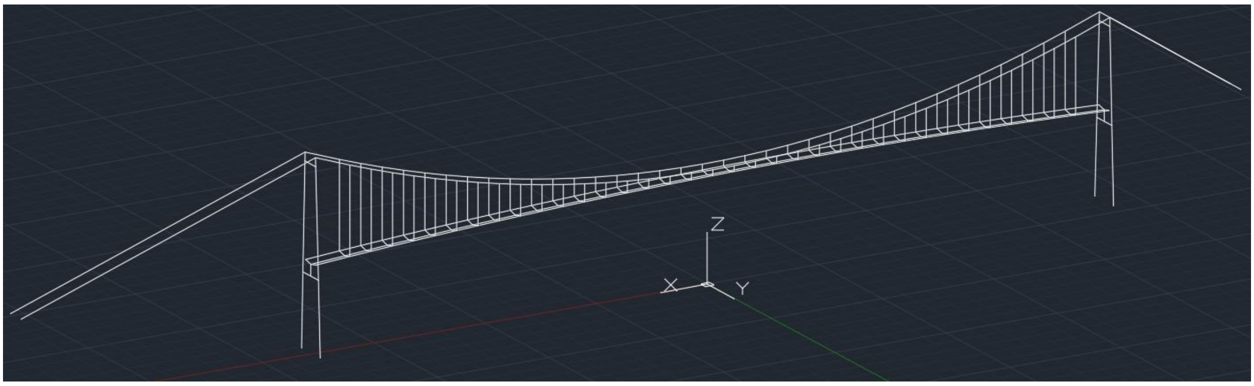


*Figure 50. The geometry model of the bridge in AutoCAD*

#### *5.2.2.2 Modeling in ABAQUS*

It is assumed that the main cables at both ends are single coaxial cables with beam element type B31. During simulation, the bending stiffness of the cables is set near zero (1 percent of the circle's cross-section) so as to achieve the real behavior of the cables. In addition to that, each hanger is connected to a beam element.

### 5.2.3 Hanger cables

In order to transfer loads from the girder to the main cables, hanger cables are installed at a specific distance. The beam element B31 is used in ABAQUS for modeling. One element is assigned to each hanger. Approximately one percent of the circular cross-section of the cable is set as the bending stiffness for the cable to replicate the real behavior of the cable. One beam element is placed between each hanger (Figure 51).

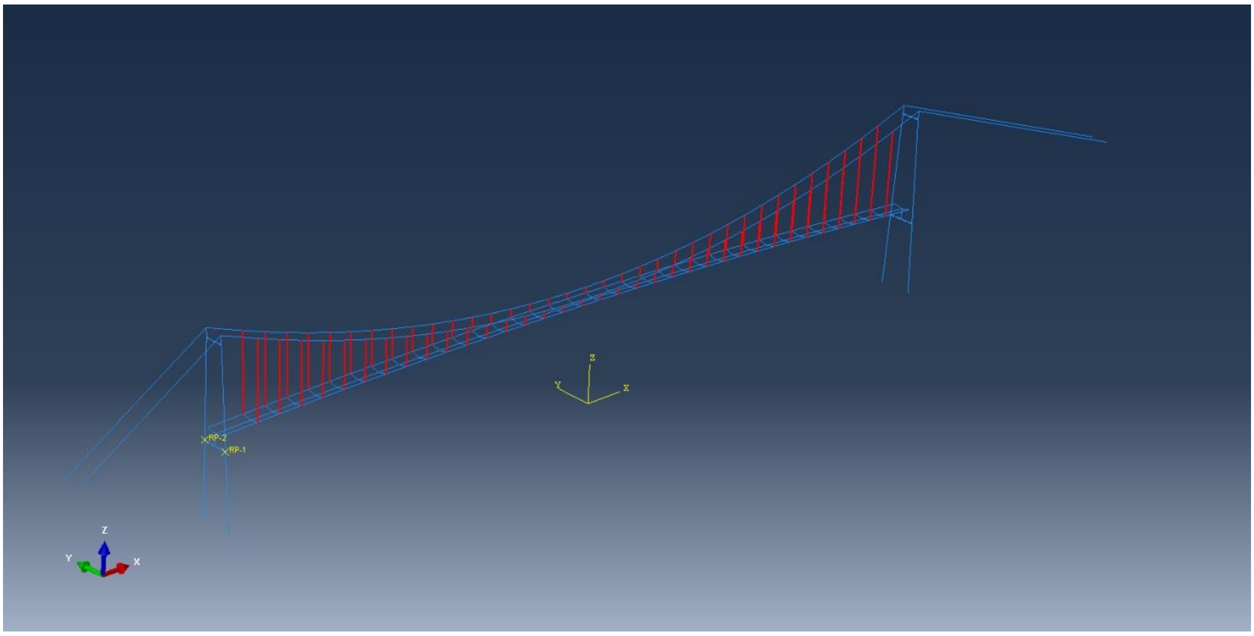

*Figure 51. Modeling of the hangers*

### 5.2.4 Towers

The Lysefjord Bridge has two towers at both ends of the bridge that transfer loads from the main cables to the foundation. Due to its superior performance under high compression pressure and buckling in comparison with steel, steel-reinforced concrete was the material of choice for this tower. From the bottom to the top, the cross-section of the twoers varies in size. In the attached drawing, the cross-section and the thickness remain the same during the length, while the size decreases. The reason for this can be explained by the type of tower support that is used.

#### *5.2.4.1 Modeling in ABAQUS*

The main tower is modeled as a series of tapered beam elements. One beam element is located between the foundation and the crossbeam, one beam element is positioned between the crossbeam and the main cable, and two beam elements are located between the crossbeam and the main cable.

## 5.3 Boundary conditions

The legs of the tower are fixed to the ground thus all degrees of freedom with the exception of UR3 are closed. The backstayed cables were connected to the rock with fixed degrees of freedom of displacement, and rotational degrees of freedom were released. In order to connect the ends of the cross beams, MPC connectors are used (Figure 52). In the absence of information about the details of the stiffness properties of the sections, the stiffness properties are based on previous work [2].

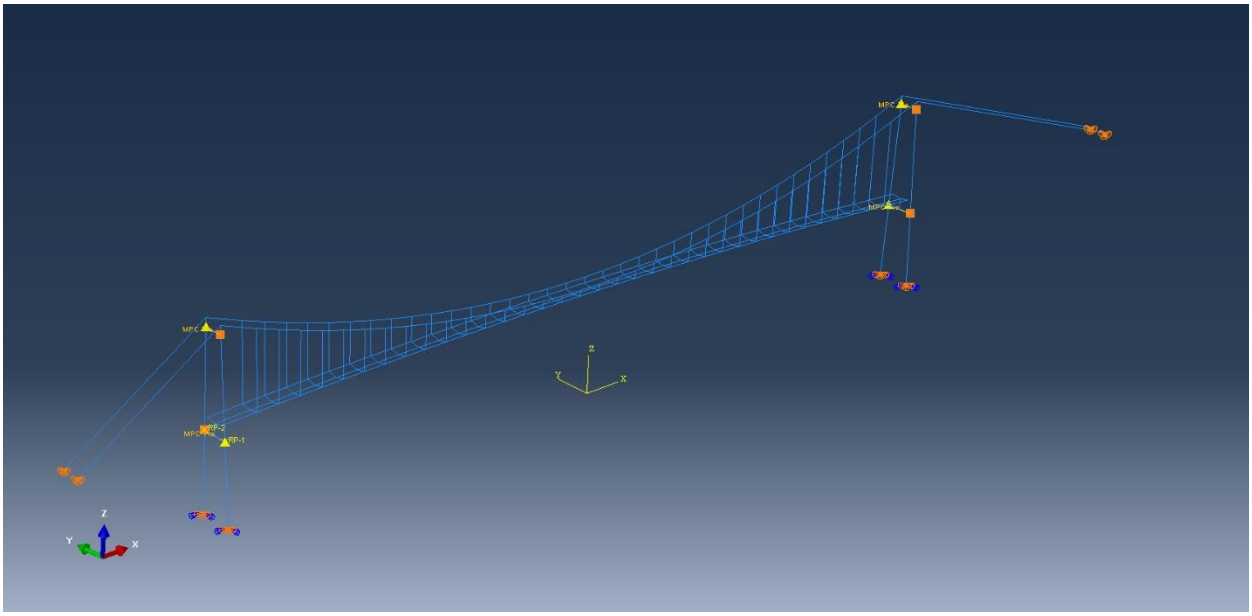

*Figure 52. Boundary conditions*

*Table 7. Properties of the sections*

| | |
|---|---|
| **Bridge girder** | |
| $A$ | $0.343\ m^2$ |
| $I_1$ | $0.429\ m^4$ |
| $I_2$ | $4.952\ m^4$ |
| $I_T$ | $0.929\ m^4$ |
| $C_w$ | $4.762\ m^4$ |
| $E$ | $210\ N/mm^2$ |
| $G$ | $80.7\ N/mm^2$ |
| **Hangers** | |
| $A$ | $0.0018\ m^2$ |
| $I$ | 1 % of a circle with an outer diameter of 48 mm |
| $E$ | $180\ N/mm^2$ |
| **Main cable** | |
| $A$ | $0.044\ m^2$ |
| $I$ | 1 % of a circle with an outer diameter of 97 mm |
| $E$ | $180\ N/mm^2$ |
| **Twoers** | |
| $E_c$ | $40\ N/mm^2$ |

*Table 8. Material properties*

| | |
|---|---|
| **Temperature coefficient** | $0.00001\ 1/{}^0C$ |
| **Gravity of acceleration** | $9.81\ m/s^2$ |

## 5.4 Applying load in ABAQUS

### 5.4.1 Mass

The total mass of the girder including trapes, stiffeners, railings, asphalt, lower hanger links, and half of the hanger links according to the previous modeling comprises the following amount [2]:

$$W_{total} = 5350 \frac{kg}{m}$$
$$W = 5350 \times 12 = 64200 kg$$

In this project for simplifying the modeling 50% of the mass is given to the middle node and the remains are given to the side nodes and the location of the mass center is considered in the neutral axes, but for the more accurate model, the mass center and their contribution percentage should be calculated:

$$W_{middle} = 32100 \frac{kg}{m}$$

$$W_{side} = 16050 \frac{kg}{m}$$

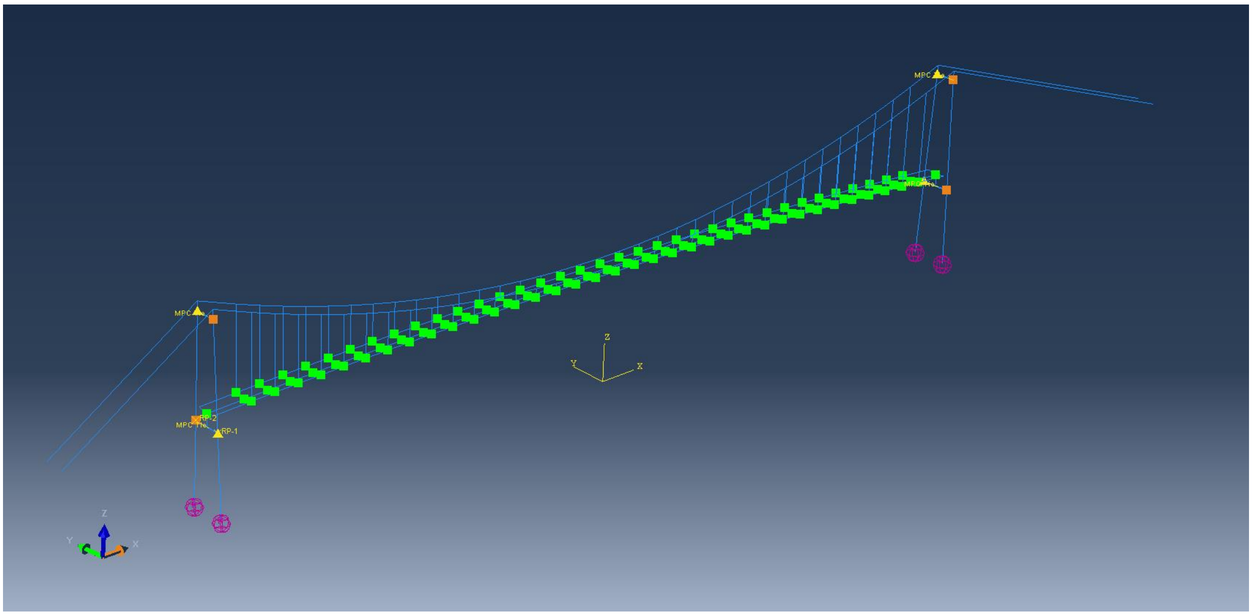


*Figure 53. Modeling of mass inertia [2]*

### 5.4.2 Wind load

As of this point and for this project, only static wind loads are applied to the structure; the dynamic wind load and its profile should be studied in the next steps. The Norwegian Standard NS-EN 1991-1-4:2005+NA2009 is used for calculating wind loads. [48].

Drag force per length:

$$D = \frac{1}{2} \rho U^2 H C_D$$

Lift force per length:

$$L = \frac{1}{2} \rho U^2 B C_L$$

Overturning moment, the moment per length:

$$M = \frac{1}{2} \rho U^2 B C_M$$

The value of Coefficients is investigated in the previous works, so for this project, we just use the result. By considering zero angles of attack:

| Drag coefficient | Lift coefficient | Moment coefficient |
|---|---|---|
| $C_D = 1$ | $C_L = 0.1$ | $C_M = 0.1$ |

Calculating mean wind speed:

$$v_{ref} = 26\frac{m}{s}$$

$$c_{ret} = 1$$

$$c_{ars} = 1$$

$$c_{hoh} = 1$$

$$c_{san} = 1$$

$$v_b = 26\frac{m}{s}$$

$$\rho = 1.25\frac{kg}{m^3}$$

$$q_b = \frac{\rho}{2}v_b^2 = 422.5\frac{N}{m^2}$$

$$z = 50m$$

$$k_T = 0.17$$

$$z_0 = 0.01m$$

$$z_{\min} = 2m$$

$$c_r = k_T \ln\left(\frac{z}{z_0}\right) = 1.448$$

$$c_t = 1$$

$$v_s = c_r.c_t.v_b$$

$$v_s = 37.6\frac{m}{s}$$

$$q_s = \frac{\rho}{2}v_s^2 = 885.763\frac{N}{m^2}$$

*Table 9. Wind loads*

| Drag force per length | Lift force per length | Moment force per length |
|---|---|---|
| $D = 2445\ (N/m)$ | $L = 1178\ (N/m)$ | $M = 1178\ (N/m)$ |
| Applied on the bridge girder, and the dummies on the side of the bridge girder | Applied on the bridge girder, and the dummies on the side of the bridge girder | Applied as a vertical force couple on the dummies on the side of the bridge girder |

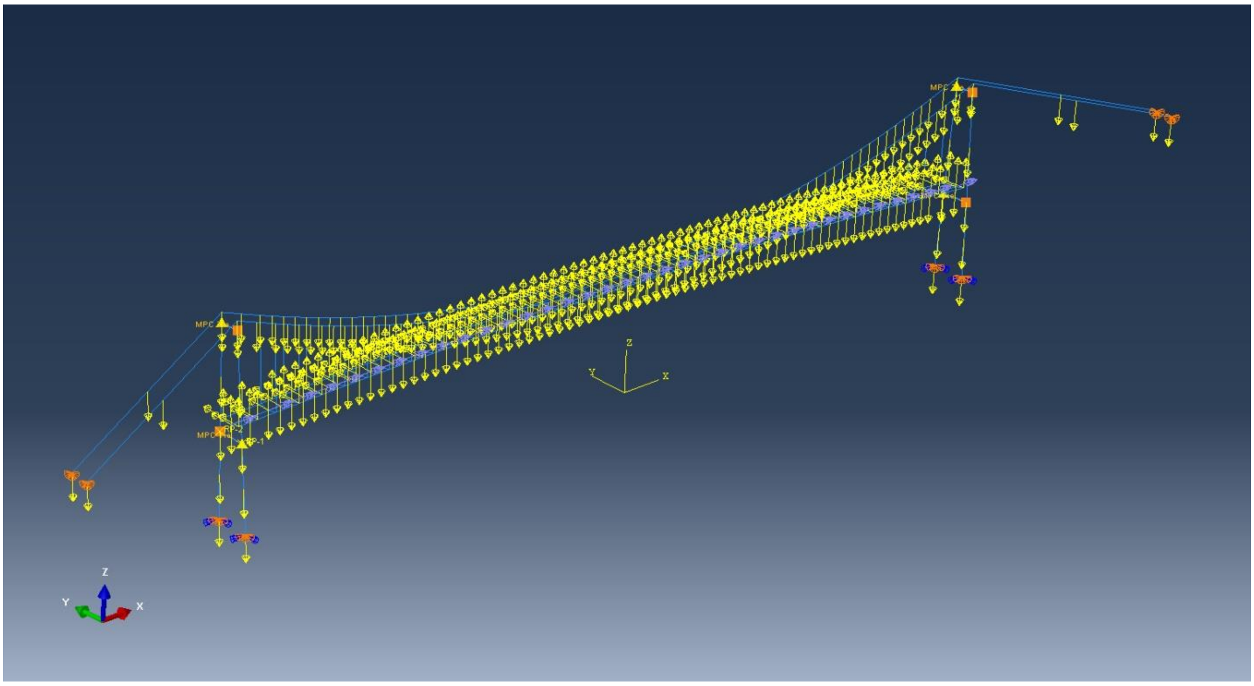

*Figure 54. Applying loads on the model*

## 5.5 Results

The first 100 frequencies of the bridge are chosen as output. Below the shape and values of the first 10 eigen-modes are shown.

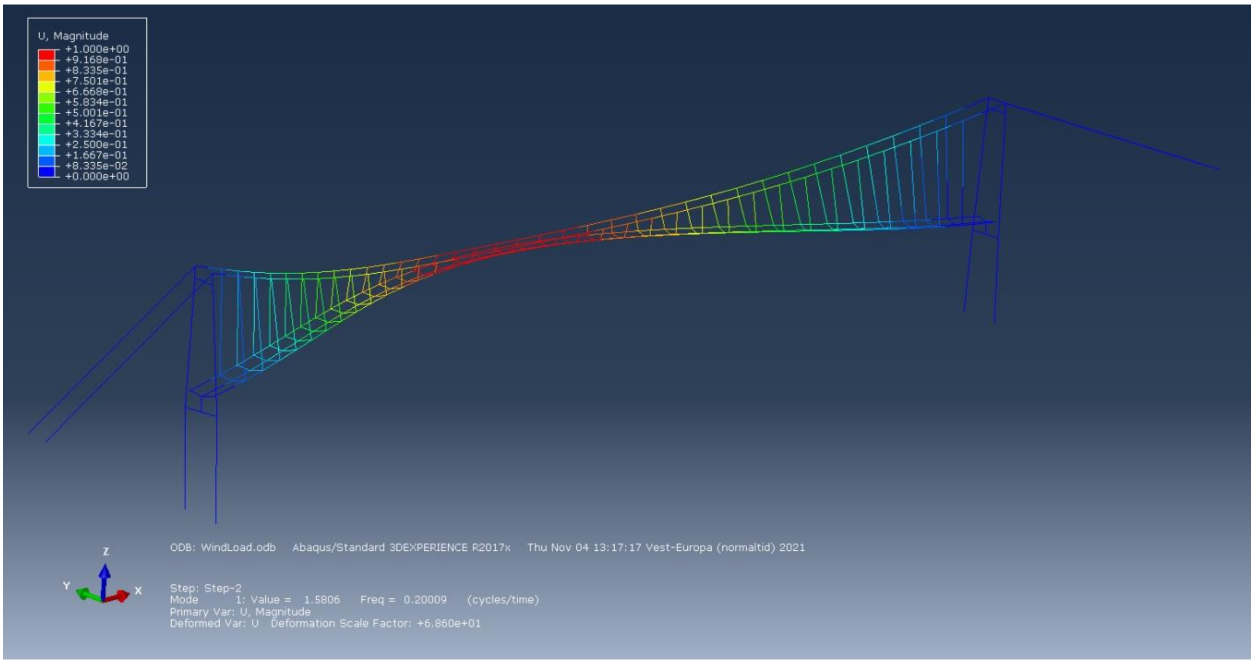


*Figure 55. Mode 1*

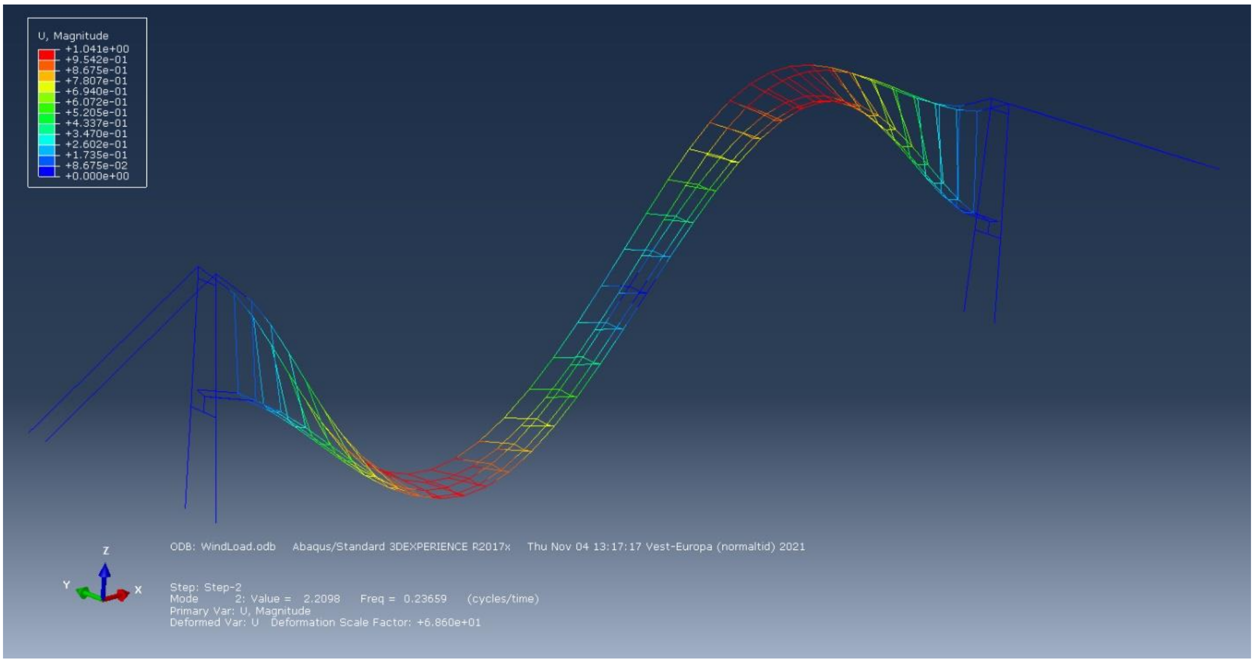


*Figure 56. Mode 2*

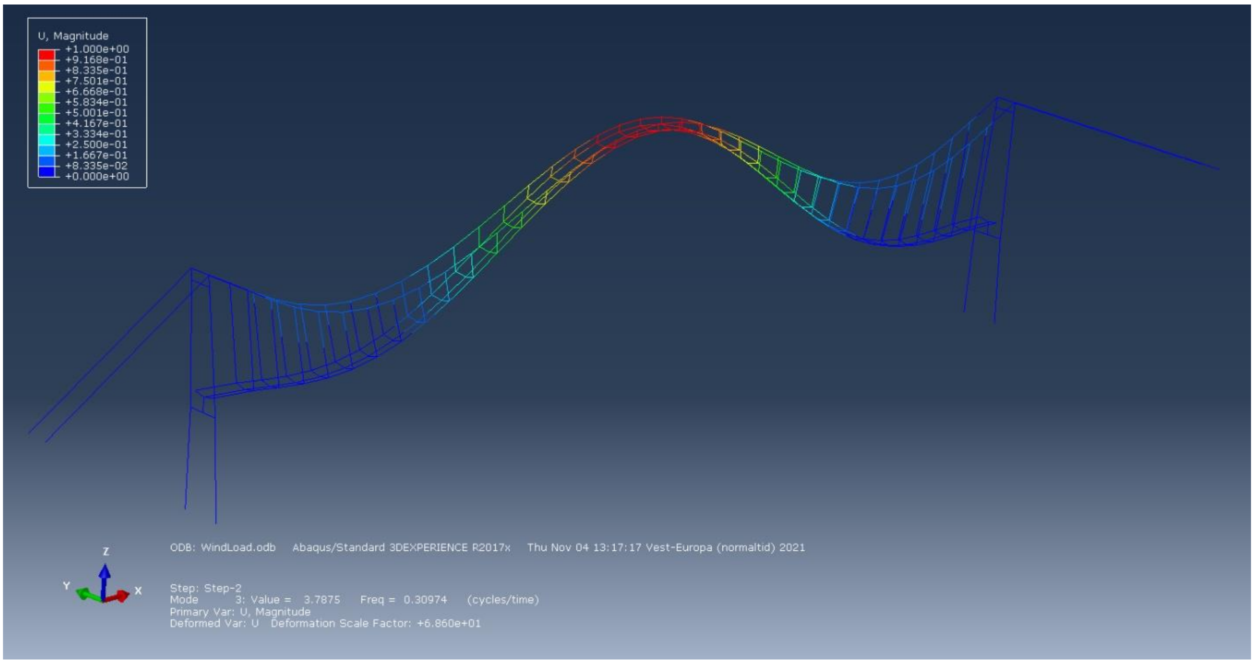


*Figure 57. Mode 3*

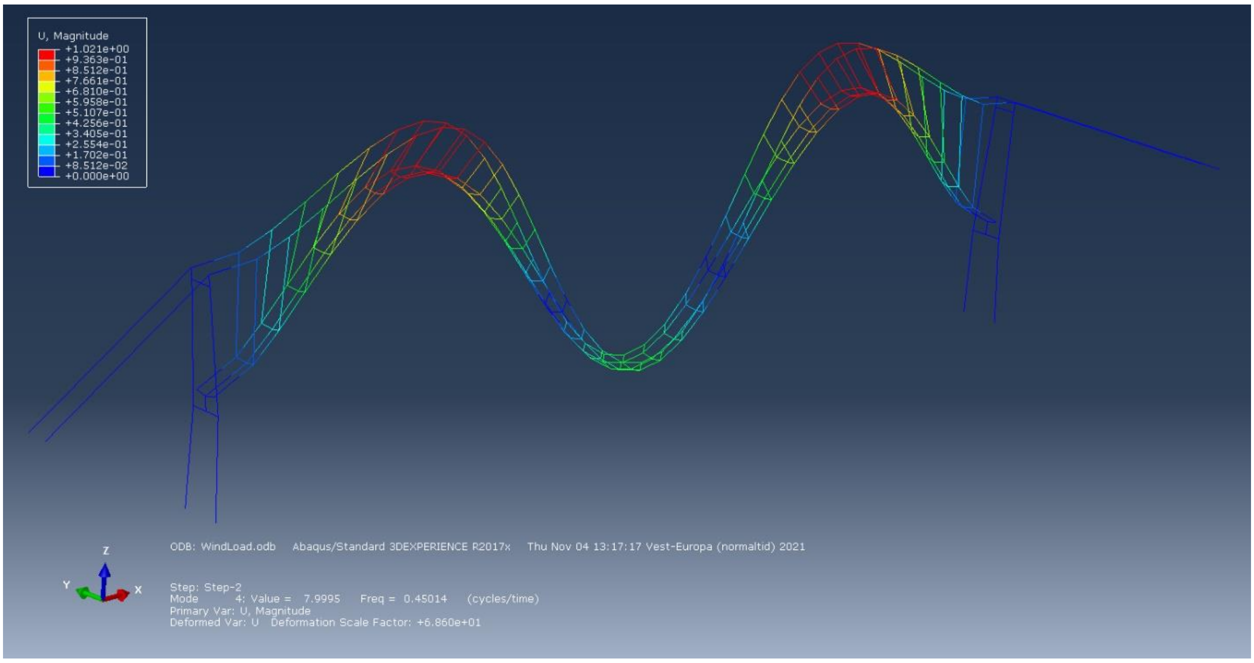


*Figure 58. Mode 4*

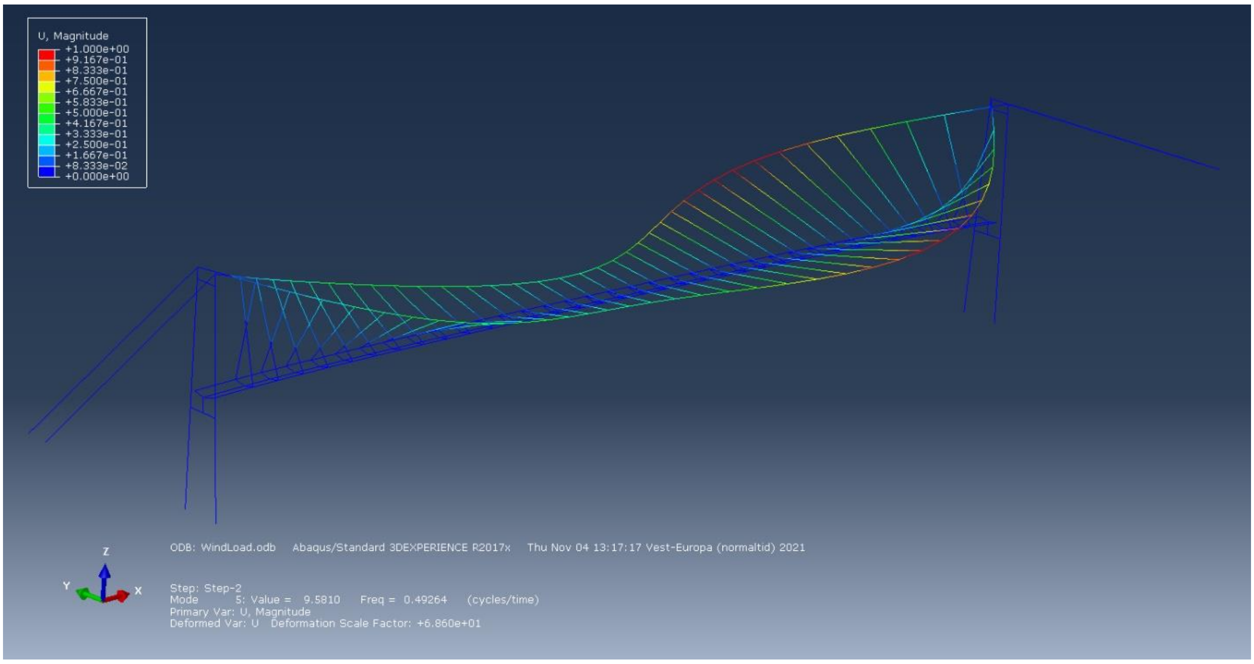


*Figure 59. Mode 5*

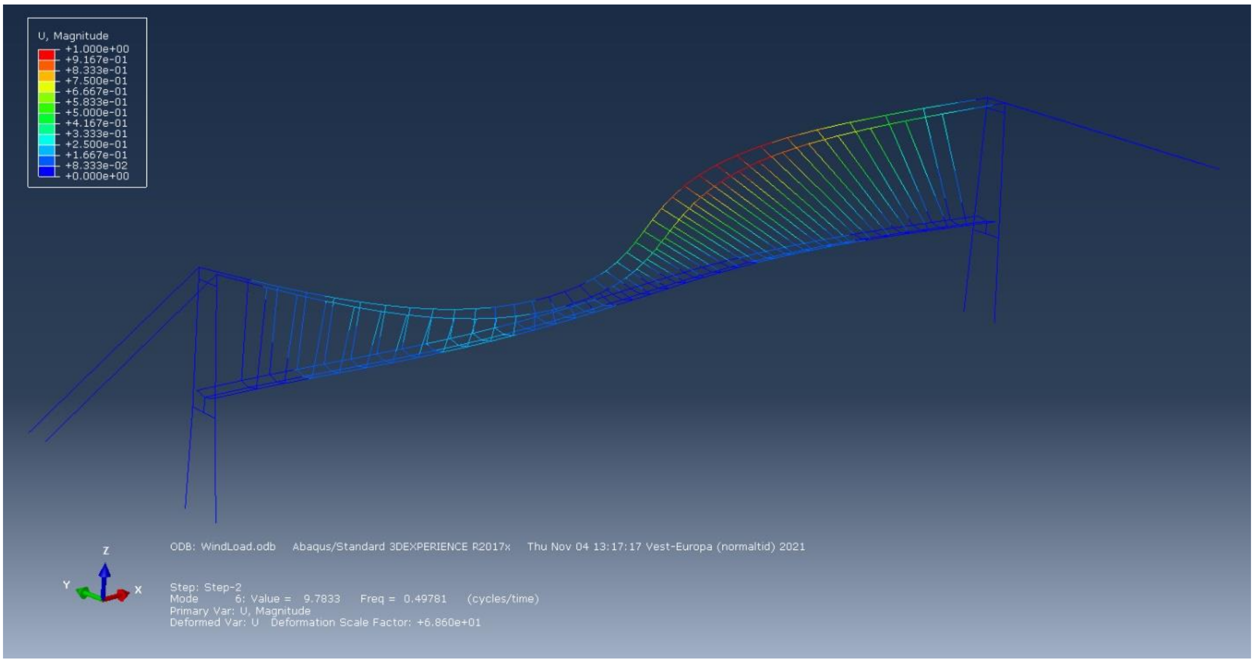


*Figure 60. Mode 6*

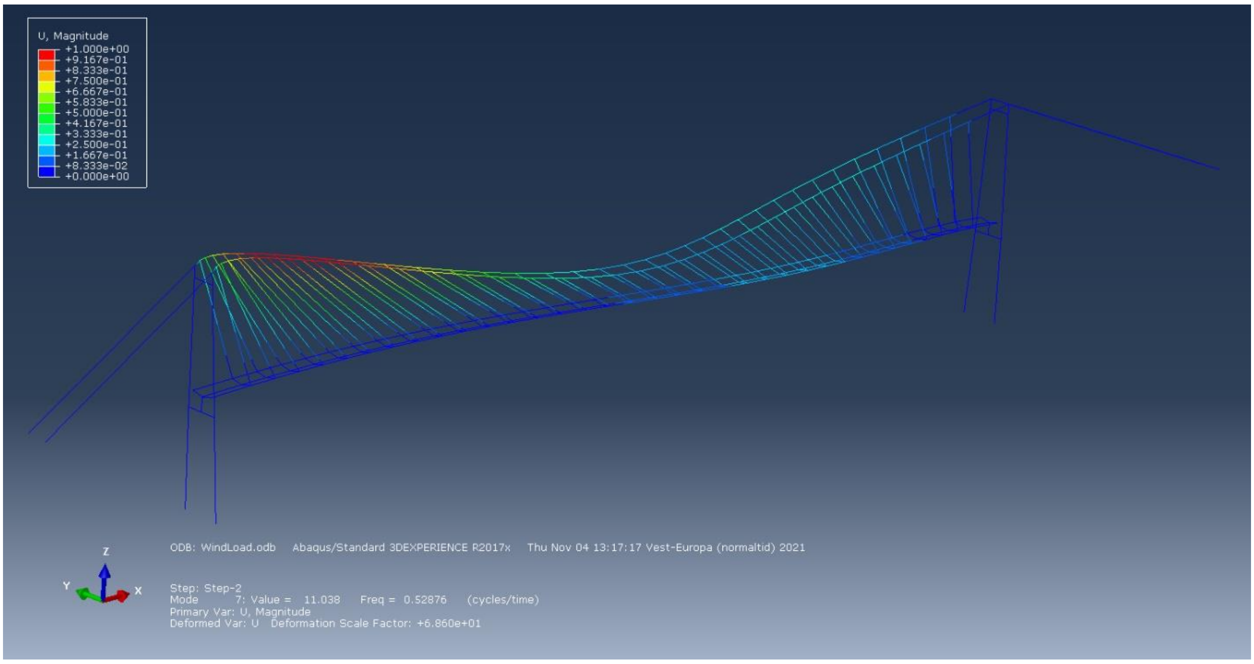


*Figure 61. Mode 7*

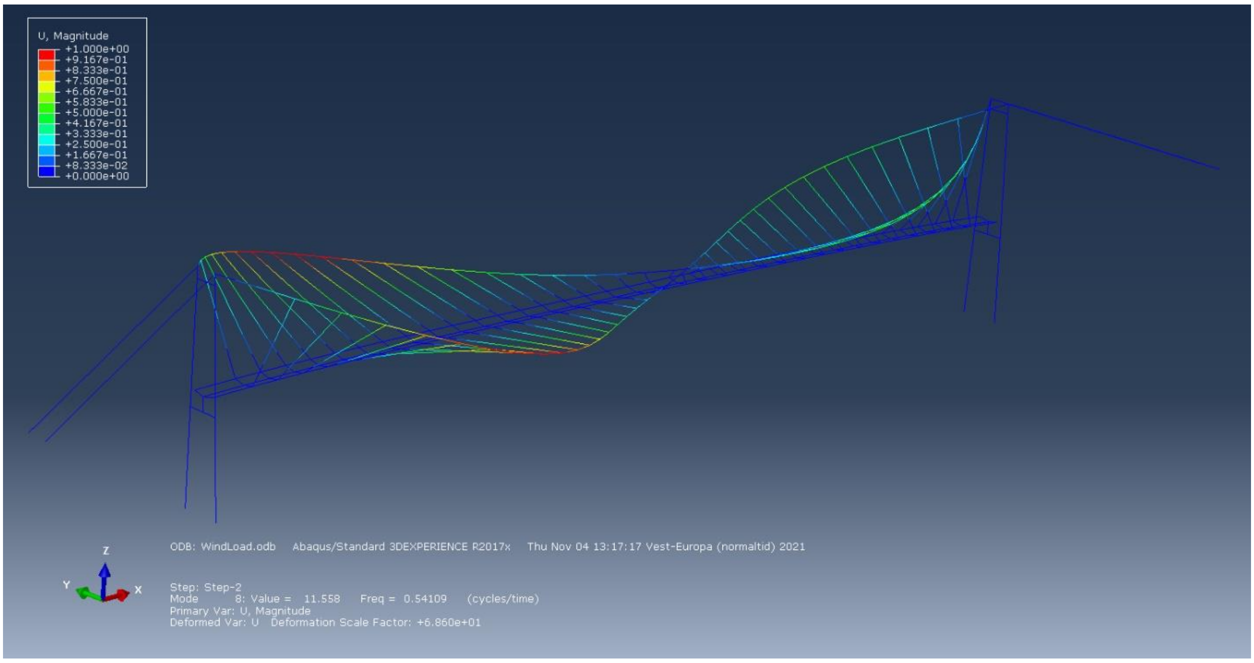


*Figure 62. Mode 8*

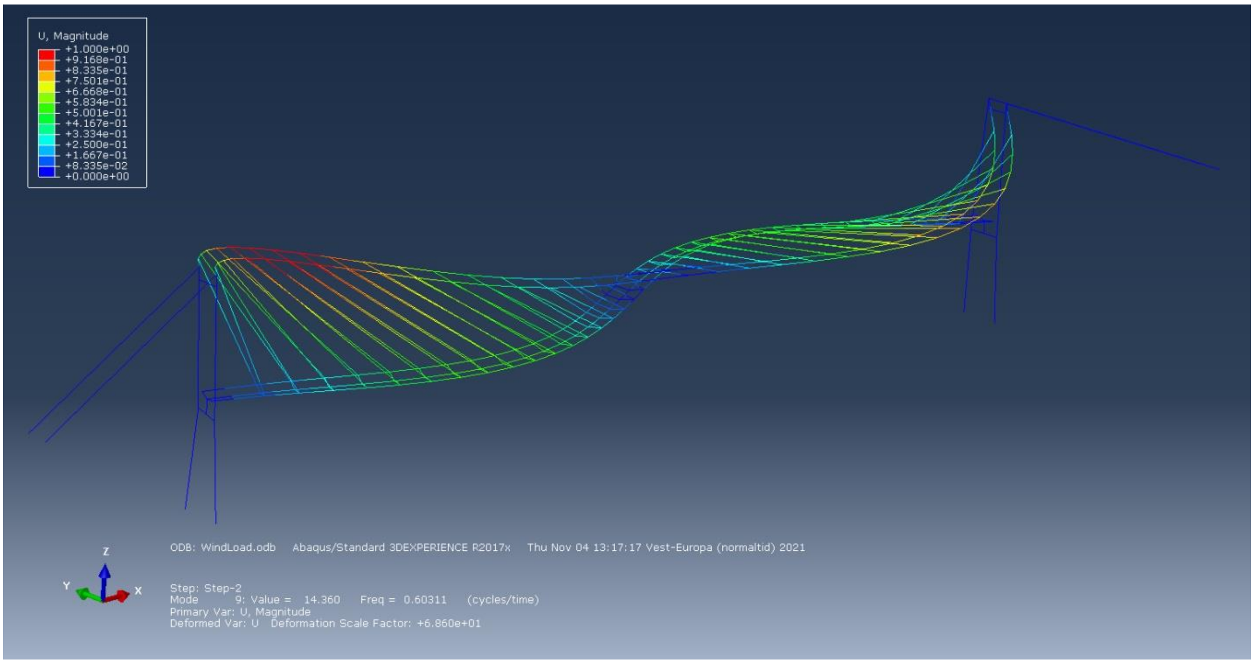


*Figure 63. Mode 9*

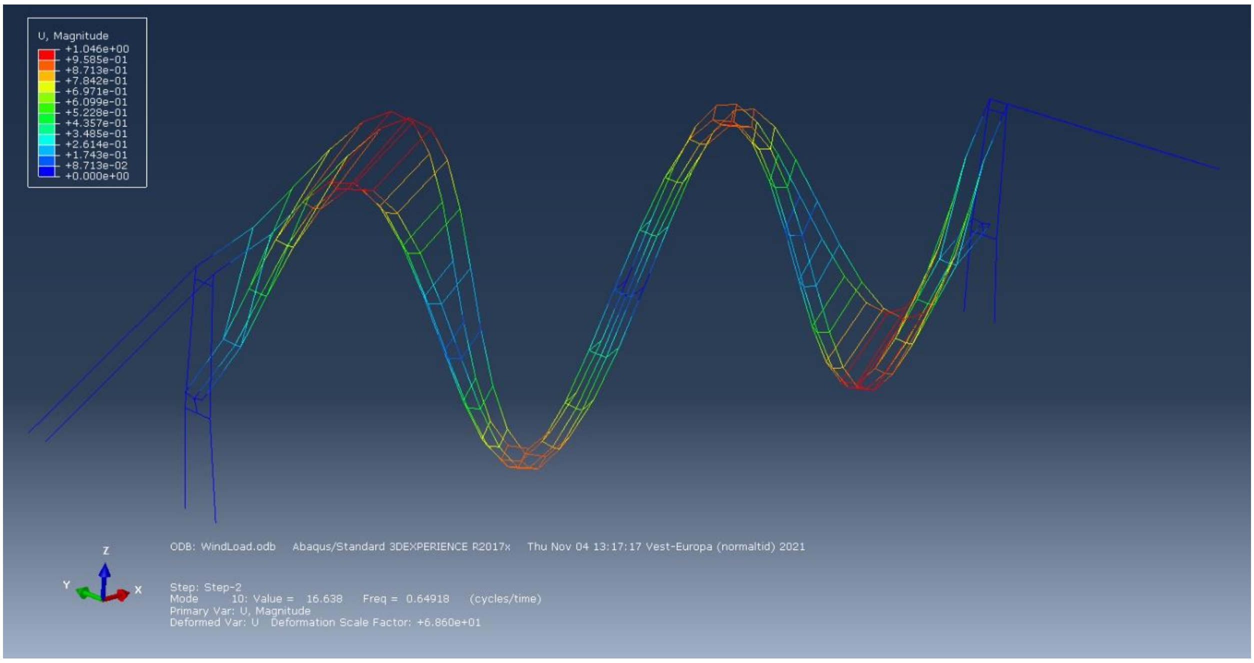


*Figure 64. Mode 10*

# 6 Discussion

For modeling the tower leg the geometry of the towers before dead load and after that should be considered. Another type of element that can be used in modeling towers and the taperd cross-section is FRAME3D and comparing it with the B31 element. For simulating the wind load with different angles of attack, a python code could be developed and check the result. The result of this model should be checked, compared, and validated with the hand calculation, previous works, and sensor data. In relation to cable wire fracture, traffic loads play a significant role between environmental loads. The relationship between stress in wire and applied loads can be studied in detail by combining traffic load and other loads. The stiffness of the model could also be updated by defining a framework [49].

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# Appendix A. List of probable Wire Breaks since 2009

The data below is accordance with reference [4]

| N° | Event time | East/West ? | Span ? | North /South ? | Location | | | Section | Reference sensor | Location from reference sensor |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 04/11/2009 07:30 | East Side | Back span | South | Cable 9 | Clamp 9 | Clamp 8 | A15-A13 | A13 | 81.7 |
| 2 | 04/11/2009 11:37 | East Side | Main span | - | Hanger 2 | Pylon | - | A12-A13 | A12 | 51.6 |
| 3 | 05/11/2009 06:30 | East Side | Back span | North | Cable 11 | Clamp 3 | Pylon | A03-A06 | A03 | 61.1 |
| 4 | 07/11/2009 21:48 | East Side | Back span | South | Cable 10 | Clamp 3 | Clamp 2 | A17-A13 | A13 | 150.3 |
| 5 | 07/11/2009 21:48 | East Side | Back span | South | Cable 10 | Clamp 3 | Clamp 2 | A17-A13 | A13 | 150.1 |
| 6 | 12/11/2009 08:08 | East Side | Back span | North | Cable 9 | Clamp 4 | Clamp 3 | A02-A06 | A02 | 44.3 |
| 7 | 18/11/2009 00:58 | East Side | Main span | - | Hanger 14 | Hanger 13 | - | A10-A11 | A10 | 138.3 |
| 8 | 26/11/2009 12:49 | East Side | Back span | South | Cable 9 | Clamp 7 | Clamp 6 | A15-A13 | A13 | 106.1 |
| 9 | 05/12/2009 16:02 | East Side | Main span | - | Hanger 2 | Pylon | - | A12-A13 | A12 | 68.8 |
| 10 | 08/12/2009 10:22 | East Side | Main span | - | Hanger 7 | Hanger 6 | - | A11-A12 | A11 | 52.4 |
| 11 | 09/12/2009 21:14 | East Side | Main span | - | Hanger 34 | Hanger 33 | - | A06-A07 | A06 | 53.4 |
| 12 | 21/12/2009 10:03 | East Side | Back span | South | Cable 10 | Clamp 7 | Clamp 6 | A13-A17 | A13 | 105.0 |
| 13 | 23/12/2009 00:09 | East Side | Back span | South | Cable 11 | Clamp 7 | Clamp 6 | A14-A13 | A13 | 108.2 |
| 14 | 23/12/2009 07:06 | East Side | Back span | South | Cable 7 | Clamp 11 | Clamp 10 | A13-A16 | A13 | 63.3 |
| 15 | 23/12/2009 10:49 | East Side | Main span | - | Hanger 3 | Hanger 2 | - | A12-A13 | A12 | 45.8 |
| 16 | 24/12/2009 08:05 | East Side | Main span | - | Hanger 6 | Hanger 5 | - | A12-A13 | A12 | 0.6 |
| 17 | 24/12/2009 23:24 | East Side | Main span | - | Hanger 7 | Hanger 6 | - | A11-A12 | A11 | 54.3 |
| 18 | 25/12/2009 05:51 | East Side | Main span | - | Hanger 3 | Hanger 2 | - | A12-A13 | A12 | 48.9 |
| 19 | 25/12/2009 15:46 | East Side | Main span | - | Hanger 5 | Hanger 4 | - | A12-A13 | A12 | 25.2 |
| 20 | 25/12/2009 20:54 | East Side | Back span | South | Cable 9 | Clamp 14 | Clamp 12 | A15-A13 | A13 | 33.6 |
| 21 | 26/12/2009 17:54 | East Side | Back span | South | Cable 7 | Clamp 4 | Clamp 3 | A13-A16 | A13 | 137.8 |
| 22 | 26/12/2009 21:19 | East Side | Back span | South | Cable 9 | Clamp 10 | Clamp 9 | A15-A13 | A13 | 62.4 |
| 23 | 27/12/2009 13:00 | East Side | Main span | - | Hanger 7 | Hanger 6 | - | A11-A12 | A11 | 52.6 |
| 24 | 28/12/2009 05:24 | East Side | Back span | North | Cable 9 | Clamp 4 | Clamp 3 | A02-A06 | A02 | 38.0 |
| 25 | 29/12/2009 03:23 | East Side | Main span | - | Pylon | Hanger 36 | - | A06-A07 | A06 | 21.9 |
| 26 | 29/12/2009 15:53 | East Side | Main span | - | Hanger 27 | Hanger 26 | - | A08-A09 | A08 | 11.6 |
| 27 | 30/12/2009 09:40 | East Side | Back span | South | Cable 7 | Clamp 10 | Clamp 9 | A13-A16 | A13 | 68.1 |
| 28 | 30/12/2009 15:34 | East Side | Back span | North | Cable 10 | Clamp 3 | Pylon | A05-A06 | A05 | 54.6 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 29 | 01/01/2010 14:20 | East Side | Back span | South | Cable 9 | Clamp 14 | Clamp 13 | A13-A15 | A13 | 30.2 |
| 30 | 09/01/2010 22:33 | East Side | Back span | South | Cable 11 | Clamp 10 | Clamp 11 | A14-A13 | A13 | 49.3 |
| 31 | 14/01/2010 11:33 | East Side | Main span | - | Hanger 3 | Hanger 2 | - | A12-A13 | A12 | 43.8 |
| 32 | 14/01/2010 17:47 | East Side | Main span | - | Hanger 21 | Hanger 20 | - | A09-A10 | A09 | 17.7 |
| 33 | 18/01/2010 07:13 | East Side | Main span | - | Hanger 34 | Hanger 33 | - | A06-A07 | A06 | 52.2 |
| 34 | 27/01/2010 14:33 | East Side | Back span | South | Cable 12 | Clamp 10 | Clamp 9 | A13-A19 | A13 | 74.9 |
| 35 | 01/02/2010 08:28 | East Side | Main span | - | Hanger 25 | Hanger 24 | - | A08-A09 | A08 | 26.5 |
| 36 | 22/02/2010 05:22 | East Side | Back span | South | Cable 9 | Clamp 9 | Clamp 8 | A13-A15 | A13 | 89.0 |
| 37 | 24/02/2010 20:50 | East Side | Main span | - | Hanger 12 | Hanger 11 | - | A10-A11 | A10 | 126.5 |
| 38 | 14/03/2010 23:08 | East Side | Back span | South | Cable 10 | Clamp 14 | Clamp 13 | A13-A17 | A13 | 23.7 |
| 39 | 24/04/2010 12:21 | East Side | Main span | - | Hanger 9 | Hanger 8 | - | A12-A11 | A11 | 32.6 |
| 40 | 03/05/2010 07:24 | East Side | Main span | - | Hanger 21 | Hanger 20 | - | A09-A10 | A09 | 13.3 |
| 41 | 17/05/2010 18:56 | East Side | Back span | South | Cable 10 | Clamp 12 | Clamp 11 | A13-A17 | A13 | 46.1 |
| 42 | 03/08/2010 13:00 | East Side | Back span | South | Cable 12 | Clamp 8 | Clamp 7 | A19-A13 | A13 | 92.0 |
| 43 | 22/08/2010 01:27 | East Side | Main span | - | Hanger 2 | Pylon | - | A13-A12 | A12 | 67.5 |
| 44 | 20/09/2010 01:43 | East Side | Back span | South | Cable 9 | Clamp 7 | Clamp 6 | A13-A15 | A13 | 104.7 |
| 45 | 05/11/2010 01:36 | East Side | Main span | - | Hanger 17 | Hanger 16 | - | A09-A10 | A09 | 67.1 |
| 46 | 22/11/2010 12:53 | East Side | Main span | - | Hanger 34 | Hanger 33 | - | A06-A07 | A06 | 56.0 |
| 47 | 09/12/2010 09:14 | East Side | Back span | South | Cable 12 | Clamp 15 | Clamp 14 | A19-A13 | A13 | 16.2 |
| 48 | 22/12/2010 08:47 | East Side | Main span | - | Hanger 23 | Hanger 22 | - | A08-A09 | A08 | 59.6 |
| 49 | 27/12/2010 07:04 | East Side | Main span | - | Hanger 16 | Hanger 15 | - | A10-A11 | A10 | 1.2 |
| 50 | 11/01/2011 13:52 | East Side | Main span | - | Hanger 32 | Hanger 31 | - | A07-A08 | A07 | 9.9 |
| 51 | 25/02/2011 08:01 | East Side | Back span | South | Cable 12 | Clamp 3 | Clamp 2 | A19-A13 | A13 | 153.5 |
| 52 | 25/02/2011 08:01 | East Side | Back span | South | Cable 12 | Clamp 3 | Clamp 2 | A19-A13 | A13 | 153.4 |
| 53 | 04/03/2011 10:59 | East Side | Main span | - | Hanger 35 | Hanger 34 | - | A06-A07 | A06 | 42.5 |
| 54 | 05/03/2011 14:46 | East Side | Main span | - | Hanger 20 | Hanger 19 | - | A09-A10 | A09 | 33.1 |
| 55 | 16/03/2011 12:38 | East Side | Main span | - | Hanger 18 | Hanger 17 | - | A09-A10 | A09 | 49.3 |
| 56 | 17/03/2011 23:34 | East Side | Main span | - | Hanger 23 | Hanger 22 | - | A08-A09 | A08 | 51.8 |
| 57 | 11/04/2011 11:19 | East Side | Main span | - | Pylon | Hanger 36 | - | A06-A07 | A06 | 68.7 |
| 58 | 22/04/2011 15:59 | East Side | Main span | - | Hanger 9 | Hanger 8 | - | A11-A12 | A11 | 31.4 |
| 59 | 28/04/2011 12:17 | East Side | Main span | - | Hanger 6 | Hanger 5 | - | A12-A13 | A12 | 9.8 |
| 60 | 05/05/2011 14:25 | East Side | Main span | - | Hanger 29 | Hanger 28 | - | A07-A08 | A07 | 40.0 |
| 61 | 08/05/2011 22:31 | East Side | Back span | North | Cable 8 | Clamp 3 | Clamp 4 | A00-A06 | A06 | 65.3 |
| 62 | 18/05/2011 17:36 | East Side | Back span | South | Cable 11 | Clamp 12 | Clamp 11 | A13-A14 | A13 | 52.0 |
| 63 | 01/06/2011 | East Side | Main span | - | Hanger 2 | Pylon | - | A12-A13 | A12 | 33.5 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 08:46 | | | | | | | | | |
| 64 | 21/06/2011 08:21 | East Side | Main span | - | Hanger 2 | Pylon | - | A12-A13 | A12 | 25.5 |
| 65 | 27/06/2011 15:58 | East Side | Back span | South | Cable 10 | Clamp 15 | Clamp 14 | A13-A17 | A13 | 16.9 |
| 66 | 29/06/2011 02:30 | East Side | Back span | South | Cable 9 | Clamp 15 | Clamp 14 | A13-A15 | A13 | 45.2 |
| 67 | 02/09/2011 10:48 | East Side | Back span | South | Cable 9 | Clamp 2 | Anchorage | A13-A15 | A13 | 164.7 |
| 68 | 04/09/2011 14:18 | East Side | Back span | North | Cable 11 | Clamp 4 | Clamp 3 | A03-A06 | A03 | 47.2 |
| 69 | 07/09/2011 17:20 | East Side | Back span | South | Cable 9 | Clamp 11 | Clamp 10 | A13-A15 | A13 | 29.0 |
| 70 | 18/09/2011 09:01 | East Side | Main span | - | Hanger 23 | Hanger 22 | - | A08-A09 | A08 | 59.8 |
| 71 | 28/09/2011 09:00 | East Side | Main span | - | Hanger 3 | Hanger 2 | - | A12-A13 | A12 | 46.3 |
| 72 | 12/10/2011 04:17 | East Side | Main span | - | Hanger 10 | Hanger 9 | - | A11-A12 | A11 | 24.4 |
| 73 | 11/11/2011 18:58 | East Side | Back span | North | Cable 11 | Clamp 7 | Clamp 6 | A03-A06 | A03 | 13.6 |
| 74 | 11/11/2011 18:58 | East Side | Back span | North | Cable 11 | Clamp 7 | Clamp 6 | A03-A06 | A03 | 13.8 |
| 75 | 13/12/2011 17:21 | East Side | Main span | - | Hanger 25 | Hanger 24 | - | A08-A09 | A08 | 35.3 |
| 76 | 25/01/2012 04:38 | East Side | Main span | - | Hanger 13 | Hanger 12 | - | A10-A11 | A10 | 44.5 |
| 77 | 03/02/2012 19:02 | East Side | Main span | - | Hanger 5 | Hanger 4 | - | A12-A13 | A12 | 16.6 |
| 78 | 03/02/2012 19:10 | East Side | Main span | - | Hanger 5 | Hanger 4 | - | A12-A13 | A12 | 17.0 |
| 79 | 13/02/2012 12:01 | East Side | Back span | South | Cable 7 | Clamp 9 | Clamp 8 | A13-A16 | A13 | 78.9 |
| 80 | 19/02/2012 23:52 | East Side | Back span | South | Cable 8 | Pylon | Clamp 15 | A13-A18 | A13 | 0.2 |
| 81 | 17/04/2012 12:00 | East Side | Main span | - | Pylon | Hanger 36 | - | A06-A07 | A06 | 9.8 |
| 82 | 17/06/2012 16:07 | East Side | Main span | - | Hanger 32 | Hanger 33 | - | A07-A08 | A07 | 1.2 |
| 83 | 12/08/2012 19:51 | East Side | Main span | - | Pylon | Hanger 2 | - | A12-A13 | A12 | 68.9 |
| 84 | 24/08/2012 14:53 | East Side | Main span | - | Hanger 21 | Hanger 20 | - | A09-A10 | A09 | 14.6 |
| 85 | 24/08/2012 14:53 | East Side | Main span | - | Hanger 21 | Hanger 20 | - | A09-A10 | A09 | 14.3 |
| 86 | 17/10/2012 12:28 | East Side | Back span | North | Cable 9 | Clamp 6 | Clamp 5 | A02-A06 | A02 | 28.6 |
| 87 | 05/11/2012 03:44 | East Side | Main span | - | Hanger 9 | Hanger 8 | - | A11-A12 | A11 | 24.6 |
| 88 | 08/11/2012 14:54 | East Side | Main span | - | Hanger 10 | Hanger 9 | - | A11-A12 | A11 | 22.3 |
| 89 | 09/11/2012 19:17 | East Side | Main span | - | Hanger 2 | Pylon | - | A12-A13 | A12 | 69.0 |
| 90 | 10/12/2012 08:58 | East Side | Back span | South | Cable 12 | Clamp 11 | Clamp 10 | A13-A19 | A13 | 63.4 |
| 91 | 14/12:2012 13:03 | East Side | Main span | - | Hanger 2 | Hanger 3 | - | A12-A13 | A12 | 38.2 |
| 92 | 16/12/2012 09:33 | East Side | Back span | South | Cable 11 | Clamp 4 | Clamp 3 | A13-A14 | A13 | 141.4 |
| 93 | 17/12/2012 07:20 | East Side | Main span | - | Hanger 6 | Hanger 5 | - | A12-A13 | A12 | 3.2 |
| 94 | 17/12/2012 09:17 | East Side | Back span | South | Cable 9 | Clamp 3 | Clamp 2 | A13-A15 | A13 | 150.0 |
| 95 | 17/12/2012 09:29 | East Side | Back span | South | Cable 9 | Clamp 3 | Clamp 2 | A13-A15 | A13 | 149.2 |
| 96 | 17/12/2012 14:48 | East Side | Main span | - | Hanger 26 | Hanger 25 | - | A08-A09 | A08 | 15.6 |
| 97 | 17/12/2012 15:02 | East Side | Main span | - | Hanger 4 | Hanger 3 | - | A12-A13 | A12 | 37.3 |

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| 98 | 18/12/2012 00:30 | East Side | Main span | - | Hanger 6 | Hanger 5 | - | A12-A13 | A12 | 10.6 |
| 99 | 26/12/2012 02:08 | East Side | Main span | - | Hanger 16 | Hanger 15 | - | A10-A11 | A10 | 0.6 |
| 100 | 26/12/2012 22:52 | East Side | Back span | South | Cable 10 | Clamp 5 | Clamp 4 | A13-A17 | A13 | 133.1 |
| 101 | 27/12/2012 09:54 | East Side | Main span | - | Hanger 32 | Hanger 31 | - | A07-A08 | A07 | 9.1 |
| 102 | 30/12/2012 01:49 | East Side | Back span | North | Cable 9 | Clamp 7 | Clamp 6 | A02-A06 | A02 | 13.5 |
| 103 | 31/12/2012 22:57 | East Side | Back span | South | Cable 10 | Clamp 2 | Anchorage | A13 -A17 | A13 | 162.7 |
| 104 | 31/12/2012 23:07 | East Side | Back span | South | Cable 10 | Clamp 2 | Anchorage | A13 -A17 | A13 | 162.2 |
| 105 | 04/01/2013 00:00 | East Side | Back span | South | Cable 9 | Clamp 4 | Clamp 3 | A13-A15 | A13 | 147.7 |
| 106 | 14/01/2013 07:09 | East Side | Back span | South | Cable 9 | Clamp 11 | Clamp 10 | A13-A15 | A13 | 62.9 |
| 107 | 14/01/2013 07:09 | East Side | Back span | South | Cable 9 | Clamp 11 | Clamp 10 | A13-A15 | A13 | 62.9 |
| 108 | 15/01/2013 10:17 | East Side | Back span | North | Cable 11 | Clamp 3 | Pylon | A03-A06 | A03 | 63.0 |
| 109 | 18/01/2013 06:39 | East Side | Main span | - | Hanger 18 | Hanger 17 | - | A09-A10 | A09 | 56.2 |
| 110 | 21/01/2013 02:50 | East Side | Main span | - | Hanger 29 | Hanger 28 | - | A07-A08 | A07 | 46.3 |
| 111 | 29/01/2013 04:59 | East Side | Main span | - | Hanger 30 | Hanger 29 | - | A07-A08 | A07 | 28.9 |
| 112 | 07/02/2013 14:39 | East Side | Back span | South | Cable 10 | Clamp 10 | Clamp 11 | A13-A17 | A13 | 65.7 |
| 113 | 08/02/2013 13:38 | East Side | Back span | South | Cable 10 | Clamp 15 | Clamp 14 | A13-A17 | A13 | 9.2 |
| 114 | 10/02/2013 09:26 | East Side | Back span | South | Cable 9 | Clamp 15 | Pylon | A15-A13 | A13 | 7.9 |
| 115 | 24/03/2013 04:27 | East Side | Main span | - | Hanger 23 | Hanger 22 | - | A08-A09 | A08 | 53.8 |
| 116 | 24/03/2013 05:37 | East Side | Main span | - | Hanger 23 | Hanger 22 | - | A08-A09 | A08 | 53.7 |
| 117 | 01/04/2013 08:04 | East Side | Main span | - | Hanger 7 | Hanger 6 | - | A11-A12 | A11 | 56.9 |
| 118 | 05/04/2013 10:19 | East Side | Main span | - | Hanger 22 | Hanger 21 | - | A09-A10 | A09 | 8.6 |
| 119 | 26/05/2013 10:23 | East Side | Main span | - | Hanger 34 | Hanger 33 | - | A06-A07 | A06 | 54.8 |
| 120 | 31/05/2013 17:38 | East Side | Main span | - | Hanger 2 | Pylon | - | A12-A13 | A12 | 56.8 |
| 121 | 10/06/2013 04:01 | East Side | Main span | - | Hanger 19 | Hanger 18 | - | A09-A10 | A09 | 47.2 |
| 122 | 10/06/2013 21:01 | East Side | Main span | - | Hanger 13 | Hanger 12 | - | A10-A11 | A10 | 44.1 |
| 123 | 18/10/2013 09:05 | East Side | Main span | - | Hanger 33 | Hanger 32 | - | A06-A07 | A06 | 65.6 |
| 124 | 11/12/2013 21:27 | East Side | Main span | - | Hanger 34 | Hanger 33 | - | A06-A07 | A06 | 63.7 |
| 125 | 13/12/2013 18:57 | East Side | Back span | South | Cable 12 | Clamp 8 | Clamp 7 | A13-A19 | A13 | 88.5 |
| 126 | 15/12/2013 13:52 | East Side | Back span | North | Cable 11 | Clamp 5 | Clamp 4 | A03-A06 | A03 | 31.5 |
| 127 | 24/12/2013 04:43 | East Side | Main span | - | Hanger 3 | Hanger 2 | - | A12-A13 | A12 | 41.0 |
| 128 | 25/12/2014 04:51 | East Side | Back span | North | Cable 10 | Anchorage | Clamp 7 | A05-A06 | A06 | 0.0 |
| 129 | 11/01/2014 21:17 | East Side | Main span | - | Hanger 34 | Hanger 33 | - | A06-A07 | A06 | 57.2 |
| 130 | 16/01/2014 16:02 | East Side | Main span | - | Pylon | Hanger 36 | - | A06-A07 | A06 | 8.5 |
| 131 | 16/01/2014 21:33 | East Side | Main span | - | Pylon | Hanger 36 | - | A06-A07 | A06 | 7.6 |
| 13 | 21/01/2014 | East Side | Main span | - | Hanger 32 | Hanger 31 | - | A07-A08 | A07 | 11.0 |

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| 2 | 10:57 | | | | | | | | | |
| 133 | 22/01/2014 13:46 | East Side | Main span | - | Pylon | Hanger 36 | - | A06-A07 | A06 | 11.0 |
| 134 | 22/01/2014 22:45 | East Side | Main span | - | Hanger 15 | Hanger 14 | - | A10-A11 | A10 | 13.7 |
| 135 | 23/01/2014 22:46 | East Side | Main span | - | Hanger 7 | Hanger 6 | - | A11-A12 | A11 | 49.5 |
| 136 | 25/01/2014 23:38 | East Side | Main span | - | Hanger 12 | Hanger 11 | - | A10-A11 | A10 | 59.1 |
| 137 | 30/01/2014 07:45 | East Side | Main span | - | Pylon | Hanger 36 | - | A06-A07 | A06 | 21.3 |
| 138 | 31/01/2014 13:48 | East Side | Main span | - | Hanger 14 | Hanger 13 | - | A10-A11 | A10 | 29.7 |
| 139 | 01/02/2014 06:06 | East Side | Main span | - | Hanger 8 | Hanger 7 | - | A11-A12 | A11 | 48.5 |
| 140 | 02/02/2014 18:15 | East Side | Back span | North | Cable 10 | Clamp 6 | Clamp 5 | A05-A06 | A05 | 18.2 |
| 141 | 03/02/2014 14:39 | East Side | Back span | North | Cable 7 | Clamp 7 | Clamp 6 | A04-A06 | A04 | 7.8 |
| 142 | 11/02/2014 09:43 | East Side | Main span | - | Hanger 15 | Hanger 14 | - | A10-A11 | A10 | 22.5 |
| 143 | 17/02/2014 01:21 | East Side | Main span | - | Hanger 6 | Hanger 5 | - | A12-A13 | A12 | 2.8 |
| 144 | 16/03/2014 05:43 | East Side | Main span | - | Hanger 2 | Pylon | - | A12-A13 | A12 | 65.9 |
| 145 | 16/05/2014 18:20 | East Side | Main span | - | Hanger 4 | Hanger 3 | - | A12-A13 | A12 | 35.9 |
| 146 | 16/12/2014 21:32 | East Side | Main span | - | Hanger 12 | Hanger 11 | - | A10-A11 | A10 | 48.9 |
| 147 | 19/12/2014 23:25 | East Side | Main span | - | Hanger 23 | Hanger 22 | - | A08-A09 | A08 | 60.0 |
| 148 | 13/09/2015 18:13 | East Side | Main span | - | Hanger 22 | Hanger 21 | - | A09-A10 | A09 | 12.8 |
| 149 | 23/02/2016 05:59 | East Side | Back span | North | Cable 12 | Clamp 4 | Clamp 3 | A01-A06 | A01 | 48.4 |
| 150 | 29/05/2016 13:26 | East Side | Main span | - | Hanger 15 | Hanger 14 | - | A11-A10 | A11 | 10.9 |
| 151 | 29/12/2016 11:38 | East Side | Back span | North | Cable 10 | Clamp 6 | Clamp 5 | A05-A06 | A05 | 19.5 |
| 152 | 25/01/2018 10:03 | East Side | Main span | - | Hanger 20 | Hanger 21 | - | A09-A10 | A09 | 21.7 |
| 153 | 07/03/2018 02:41 | East Side | Back span | South | Cable 7 | Clamp 7 | Clamp 8 | A13-A16 | A13 | 108.0 |
| 154 | 13/02/2019 03:20 | East Side | Back span | North | Cable 7 | Clamp 3 | Clamp 2 | A04-A06 | A04 | 58.5 |
| 1 | 02/10/2009 05:49 | West Cable | Back span | South | Cable 1 | Clamp 14 | Clamp 13 | A24-A26 | A26 | 7.6 |
| 2 | 17/11/2009 20:22 | West Cable | Back span | South | Cable 4 | Clamp 13 | Clamp 11 | A26-A21 | A26 | 42.9 |
| 3 | 01/12/2009 17:21 | West Cable | Back span | North | Cable 1 | Anchorage | Clamp 7 | A37-A33 | A37 | 1.8 |
| 4 | 23/12/2009 04:02 | West Cable | Back span | South | Cable 6 | Clamp 11 | Clamp 10 | A26-A20 | A26 | 63.1 |
| 5 | 23/12/2009 07:25 | West Cable | Back span | South | Cable 3 | Clamp 11 | Clamp 10 | A26-A22 | A26 | 59.9 |
| 6 | 23/12/2009 15:09 | West Cable | Main span | - | Hanger 32 | Hanger 31 | - | A32-A31 | A32 | 5.4 |
| 7 | 25/12/2009 02:52 | West Cable | Main span | - | Hanger 5 | Hanger 4 | - | A27-A26 | A27 | 24.7 |
| 8 | 25/12/2009 20:45 | West Cable | Back span | South | Cable 3 | Pylon | Clamp 15 | A22-A26 | A26 | 1 |
| 9 | 26/12/2009 00:41 | West Cable | Main span | - | Hanger 11 | Hanger 10 | - | A28-A27 | A28 | 8.9 |
| 10 | 26/12/2009 00:42 | West Cable | Main span | - | Hanger 11 | Hanger 10 | - | A28-A27 | A28 | 9.9 |
| 11 | 26/12/2009 14:40 | West Cable | Back span | South | Cable 4 | Clamp 2 | Anchorage | A21-A26 | A21 | 167.2 |
| 12 | 26/12/2009 14:44 | West Cable | Back span | South | Cable 1 | Clamp 15 | Clamp 14 | A24-A26 | A26 | 15.7 |

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| 13 | 26/12/2009 18:45 | West Cable | Back span | South | Cable 4 | Clamp 11 | Clamp 12 | A21-A26 | A26 | 65.4 |
| 14 | 26/12/2009 21:26 | West Cable | Main span | - | Hanger 19 | Hanger 18 | - | A30-A29 | A30 | 40.5 |
| 15 | 27/12/2009 16:35 | West Cable | Back span | South | Cable 5 | Clamp 4 | Clamp 3 | A26-A25 | A26 | 137.6 |
| 16 | 04/01/2010 10:53 | West Cable | Main span | - | Hanger 4 | Hanger 5 | - | A27-A26 | A27 | 20.5 |
| 17 | 04/01/2010 12:45 | West Cable | Main span | - | Hanger 23 | Hanger 22 | - | A31-A30 | A31 | 53.9 |
| 18 | 07/01/2010 16:02 | West Cable | Back span | South | Cable 1 | Clamp 7 | Clamp 6 | A26-A24 | A26 | 101.9 |
| 19 | 07/01/2010 17:13 | West Cable | Main span | - | Hanger 15 | Hanger 14 | - | A29-A28 | A29 | 14.7 |
| 20 | 09/01/2010 01:48 | West Cable | Main span | - | Hanger 31 | Hanger 30 | - | A32-A31 | A32 | 20.6 |
| 21 | 16/01/2010 10:21 | West Cable | Main span | - | Hanger 14 | Hanger 13 | - | A29-A28 | A29 | 27.6 |
| 22 | 21/01/2010 15:31 | West Cable | Main span | - | Hanger 10 | Hanger 9 | - | A28-A27 | A28 | 17.8 |
| 23 | 22/01/2010 22:52 | West Cable | Back span | South | Cable 1 | Clamp 8 | Clamp 7 | A26-A24 | A26 | 92.9 |
| 24 | 25/01/2010 08:21 | West Cable | Main span | - | Hanger 19 | Hanger 18 | - | A30-A29 | A30 | 37.7 |
| 25 | 25/01/2010 09:34 | West Cable | Main span | - | Hanger 6 | Hanger 5 | - | A27-A26 | A27 | 9.7 |
| 26 | 29/01/2010 04:41 | West Cable | Main span | - | Hanger 16 | Hanger 15 | - | A29-A28 | A29 | 4.2 |
| 27 | 31/01/2010 02:10 | West Cable | Main span | - | Hanger 3 | Hanger 2 | - | A27-A26 | A27 | 48.3 |
| 28 | 31/01/2010 02:51 | West Cable | Main span | - | Hanger 2 | Pylon | - | A27-A26 | A27 | 56.9 |
| 29 | 04/02/2010 21:33 | West Cable | Back span | South | Cable 6 | Clamp 10 | Clamp 9 | A20-A26 | A26 | 58 |
| 30 | 23/04/2010 21:22 | West Cable | Main span | - | Hanger 12 | Hanger 11 | - | A28-A29 | A29 | 56.8 |
| 31 | 01/05/2010 23:27 | West Cable | Main span | - | Hanger 11 | Hanger 10 | - | A28-A27 | A28 | 7.3 |
| 32 | 04/10/2010 14:17 | West Cable | Main span | - | Hanger 5 | Hanger 4 | - | A27-A26 | A27 | 21.9 |
| 33 | 12/10/2010 20:37 | West Cable | Back span | South | Cable 1 | Clamp 4 | Clamp 3 | A26-A24 | A26 | 140.7 |
| 34 | 30/10/2010 12:46 | West Cable | Main span | - | Hanger 13 | Hanger 12 | - | A29-A28 | A29 | 42.7 |
| 35 | 06/11/2010 09:53 | West Cable | Main span | - | Hanger 4 | Hanger 3 | - | A27-A26 | A27 | 34 |
| 36 | 08/11/2010 11:34 | West Cable | Back span | South | Cable 2 | Clamp 4 | Clamp 3 | A26-A23 | A26 | 147 |
| 37 | 11/11/2010 15:28 | West Cable | Back span | South | Cable 4 | Clamp 10 | Clamp 9 | A26-A21 | A26 | 74.2 |
| 38 | 21/12/2010 13:30 | West Cable | Back span | South | Cable 4 | Clamp 8 | Clamp 7 | A26-A21 | A26 | 88.2 |
| 39 | 25/12/2010 13:27 | West Cable | Back span | South | Cable 1 | Clamp 6 | Clamp 5 | A26-A24 | A26 | 114.2 |
| 40 | 26/12/2010 15:44 | West Cable | Back span | South | Cable 3 | Clamp 2 | Anchorage | A26-A22 | A26 | 165.2 |
| 41 | 16/01/2011 06:52 | West Cable | Back span | South | Cable 1 | Clamp 15 | Clamp 14 | A26-A24 | A26 | 16.7 |
| 42 | 24/01/2011 05:04 | West Cable | Main span | - | Hanger 13 | Hanger 12 | - | A28-A29 | A29 | 46.2 |
| 43 | 10/02/2011 20:44 | West Cable | Back span | South | Cable 1 | Clamp 9 | Clamp 8 | A26-A24 | A26 | 79.7 |
| 44 | 16/02/2011 10:55 | West Cable | Back span | South | Cable 3 | Clamp 4 | Clamp 3 | A26-A22 | A26 | 138.6 |
| 45 | 19/02/2011 01:13 | West Cable | Main span | - | Hanger 10 | Hanger 9 | - | A28-A27 | A28 | 23.3 |
| 46 | 19/02/2011 01:56 | West Cable | Main span | - | Hanger 12 | Hanger 11 | - | A28-A29 | A29 | 56.7 |
| 47 | 02/03/2011 | West | Back span | North | Cable 4 | Clamp 2 | Pylon | A36-A33 | A36 | 60.7 |

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| | 20:58 | Cable | | | | | | | | |
| 48 | 05/03/2011 16:32 | West Cable | Back span | South | Cable 1 | Clamp 4 | Clamp 3 | A26-A24 | A24 | 144.5 |
| 49 | 11/03/2011 23:44 | West Cable | Back span | North | Cable 4 | Clamp 7 | Clamp 6 | A36-A33 | A36 | 13.3 |
| 50 | 13/03/2011 10:40 | West Cable | Back span | North | Cable 6 | Clamp 6 | Clamp 5 | A33-A34 | A34 | 19.1 |
| 51 | 16/03/2011 08:22 | West Cable | Main span | - | Hanger 10 | Hanger 9 | - | A28-A27 | A28 | 16.6 |
| 52 | 16/03/2011 17:09 | West Cable | Main span | - | Hanger 10 | Hanger 9 | - | A28-A27 | A28 | 15.3 |
| 53 | 31/03/2011 07:36 | West Cable | Back span | South | Cable 4 | Clamp 3 | Clamp 2 | A26-A21 | A26 | 159.2 |
| 54 | 07/05/2011 02:29 | West Cable | Main span | - | Hanger 25 | Hanger 24 | - | A31-A30 | A31 | 25 |
| 55 | 30/05/2011 10:00 | West Cable | Main span | - | Hanger 34 | Hanger 33 | - | A33-A32 | A33 | 50.4 |
| 56 | 02/06/2011 12:42 | West Cable | Main span | - | Hanger 32 | Hanger 31 | - | A33-A32 | A33 | 76.1 |
| 57 | 09/06/2011 09:50 | West Cable | Back span | South | Cable 2 | Clamp 4 | Clamp 3 | A26-A23 | A26 | 141.7 |
| 58 | 19/06/2011 10:35 | West Cable | Main span | - | Hanger 2 | Pylon | - | A27-A26 | A27 | 50.8 |
| 59 | 06/07/2011 07:28 | West Cable | Back span | South | Cable 2 | Clamp 3 | Clamp 2 | A26-A23 | A26 | 152.3 |
| 60 | 28/09/2011 13:59 | West Cable | Main span | - | Hanger 31 | Hanger 30 | - | A32-A31 | A32 | 15.3 |
| 61 | 13/10/2011 12:24 | West Cable | Main span | - | Pylon | Hanger 36 | - | A33-A32 | A33 | 15 |
| 62 | 29/10/2011 13:15 | West Cable | Back span | South | Cable 4 | Clamp 11 | Clamp 10 | A26-A21 | A26 | 60.7 |
| 63 | 02/11/2011 09:12 | West Cable | Main span | - | Hanger 18 | Hanger 17 | - | A30-A29 | A30 | 56.4 |
| 64 | 13/11/2011 03:08 | West Cable | Main span | - | Hanger 8 | Hanger 7 | - | A28-A27 | A28 | 38.4 |
| 65 | 25/11/2011 12:56 | West Cable | Main span | - | Hanger 6 | Hanger 5 | - | A27-A26 | A27 | 8.3 |
| 66 | 01/12/2011 21:54 | West Cable | Main span | - | Hanger 6 | Hanger 5 | - | A27-A26 | A27 | 10.3 |
| 67 | 03/12/2011 19:15 | West Cable | Back span | South | Cable 5 | Clamp 6 | Clamp 5 | A26-A25 | A26 | 115.7 |
| 68 | 12/12/2011 04:52 | West Cable | Back span | North | Cable 1 | Clamp 2 | Pylon | A37-A33 | A37 | 65.9 |
| 69 | 05/01/2012 10:54 | West Cable | Main span | - | Hanger 5 | Hanger 4 | - | A27-A26 | A27 | 20.5 |
| 70 | 13/03/2012 21:26 | West Cable | Back span | South | Cable 4 | Clamp 15 | Clamp 14 | A26-A21 | A26 | 12.1 |
| 71 | 15/04/2012 06:36 | West Cable | Main span | - | Hanger 10 | Hanger 9 | - | A28-A27 | A28 | 18.2 |
| 72 | 10/05/2012 10:31 | West Cable | Back span | South | Cable 3 | Clamp 15 | Clamp 14 | A26-A22 | A26 | 10.1 |
| 73 | 19/05/2012 23:47 | West Cable | Back span | South | Cable 1 | Clamp 6 | Clamp 5 | A26-A24 | A26 | 113.1 |
| 74 | 21/05/2012 07:36 | West Cable | Main span | - | Hanger 7 | Hanger 6 | - | A28-A27 | A28 | 51.9 |
| 75 | 26/05/2012 10:07 | West Cable | Back span | South | Cable 2 | Clamp 4 | Clamp 3 | A26-A23 | A26 | 141.1 |
| 76 | 17/07/2012 19:48 | West Cable | Back span | South | Cable 4 | Clamp 7 | Clamp 6 | A26-A21 | A21 | 106.6 |
| 77 | 14/10/2012 09:55 | West Cable | Back span | South | Cable 2 | Clamp 15 | Clamp 14 | A26-A23 | A26 | 11.8 |
| 78 | 22/10/2012 11:09 | West Cable | Back span | North | Cable 4 | Clamp 7 | Clamp 6 | A36-A33 | A36 | 10.3 |
| 79 | 01/11/2012 02:24 | West Cable | Main span | - | Hanger 29 | Hanger 28 | - | A32-A31 | A32 | 39.5 |
| 80 | 05/11/2012 21:40 | West Cable | Main span | - | Hanger 27 | Hanger 26 | - | A31-A30 | A31 | 9.4 |
| 81 | 11/11/2012 14:59 | West Cable | Back span | North | Cable 3 | Clamp 2 | A33 | A35-A33 | A35 | 60.3 |

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| 82 | 11/11/2012 22:28 | West Cable | Back span | South | Cable 1 | Clamp 5 | Clamp 4 | A26-A24 | A26 | 133.3 |
| 83 | 18/11/2012 15:09 | West Cable | Main span | - | Hanger 17 | Hanger 16 | - | A30-A29 | A30 | 63.7 |
| 84 | 09/12/2012 01:52 | West Cable | Main span | - | Pylon | Hanger 36 | - | A33-A32 | A33 | 2.5 |
| 85 | 09/12/2012 09:52 | West Cable | Main span | - | Hanger 8 | Hanger 7 | - | A28-A27 | A28 | 44 |
| 86 | 16/12/2012 13:42 | West Cable | Back span | North | Cable 1 | Clamp 2 | A33 | A37-A33 | A37 | 65.7 |
| 87 | 16/12/2012 17:45 | West Cable | Back span | North | Cable 1 | Clamp 2 | A33 | A37-A33 | A37 | 65.7 |
| 88 | 17/12/2012 14:58 | West Cable | Back span | South | Cable 4 | Clamp 15 | Clamp 14 | A26-A21 | A26 | 15.4 |
| 89 | 19/12/2012 09:34 | West Cable | Main span | - | Hanger 11 | Hanger 10 | - | A28-A27 | A28 | 5.6 |
| 90 | 19/12/2012 14:21 | West Cable | Back span | South | Cable 2 | Clamp 2 | Anchorage | A26-A23 | A26 | 165.7 |
| 91 | 22/12/2012 15:07 | West Cable | Main span | - | Hanger 27 | Hanger 26 | - | A31-A30 | A31 | 3.1 |
| 92 | 24/12/2012 01:20 | West Cable | Main span | - | Hanger 14 | Hanger 13 | - | A29-A28 | A29 | 25.9 |
| 93 | 26/12/2012 05:38 | West Cable | Main span | - | Hanger 2 | Pylon | - | A27-A26 | A27 | 65.8 |
| 94 | 26/12/2012 07:05 | West Cable | Back span | South | Cable 4 | Clamp 3 | Clamp 2 | A26-A21 | A26 | 153.2 |
| 95 | 26/12/2012 09:19 | West Cable | Main span | - | Hanger 7 | Hanger 6 | - | A28-A27 | A28 | 61.2 |
| 96 | 27/12/2012 23:18 | West Cable | Main span | - | Hanger 25 | Hanger 24 | - | A31-A30 | A31 | 28.3 |
| 97 | 29/12/2012 01:33 | West Cable | Back span | South | Cable 2 | Clamp 13 | Clamp 12 | A26-A23 | A21 | 38.8 |
| 98 | 30/12/2012 16:12 | West Cable | Back span | North | Cable 4 | Clamp 6 | Clamp 5 | A36-A33 | A36 | 26.3 |
| 99 | 30/12/2012 22:39 | West Cable | Main span | - | Hanger 14 | Hanger 13 | - | A29-A28 | A29 | 29.1 |
| 100 | 31/12/2012 14:00 | West Cable | Main span | - | Hanger 10 | Hanger 9 | - | A28-A27 | A28 | 20.2 |
| 101 | 01/01/2013 17:49 | West Cable | Main span | - | Hanger 10 | Hanger 9 | - | A28-A27 | A28 | 13 |
| 102 | 02/01/2013 11:31 | West Cable | Main span | - | Hanger 13 | Hanger 12 | - | A29-A28 | A29 | 47 |
| 103 | 04/01/2013 00:10 | West Cable | Main span | - | Hanger 19 | Hanger 18 | - | A30-A29 | A30 | 45.5 |
| 104 | 15/01/2013 07:17 | West Cable | Back span | South | Cable 3 | Clamp 2 | Anchorage | A26-A22 | A26 | 159.9 |
| 105 | 17/01/2013 09:25 | West Cable | Back span | South | Cable 4 | Clamp 2 | Anchorage | A26-A21 | A26 | 165.5 |
| 106 | 17/01/2013 09:25 | West Cable | Back span | South | Cable 4 | Clamp 2 | Anchorage | A26-A21 | A26 | 166.2 |
| 107 | 21/01/2013 03:48 | West Cable | Main span | - | Hanger 12 | Hanger 11 | - | A29-A28 | A29 | 57.6 |
| 108 | 21/01/2013 08:58 | West Cable | Main span | - | Hanger 7 | Hanger 6 | - | A28-A27 | A28 | 50.1 |
| 109 | 24/01/2013 17:24 | West Cable | Back span | North | Cable 3 | Anchorage | Clamp 7 | A35-A33 | A35 | 0.1 |
| 110 | 14/02/2013 18:00 | West Cable | Back span | South | Cable 4 | Clamp 10 | Clamp 11 | A26-A21 | A26 | 55.9 |
| 111 | 17/02/2013 13:03 | West Cable | Main span | - | Hanger 23 | Hanger 22 | - | A31-A30 | A31 | 53.3 |
| 112 | 17/02/2013 13:03 | West Cable | Main span | - | Hanger 23 | Hanger 22 | - | A31-A30 | A31 | 53.5 |
| 113 | 06/03/2013 13:03 | West Cable | Back span | South | Cable 4 | Clamp 5 | Clamp 4 | A26-A21 | A26 | 126.3 |
| 114 | 15/03/2013 21:07 | West Cable | Back span | South | Cable 3 | Pylon | Clamp 15 | A26-A22 | A26 | 1.6 |
| 115 | 05/04/2013 01:47 | West Cable | Back span | South | Cable 1 | Clamp 6 | Clamp 5 | A26-A24 | A26 | 116.3 |
| 11 | 09/04/2013 | West | Main span | - | Hanger 16 | Hanger 15 | - | A29-A28 | A29 | 6.9 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 14:01 | Cable | | | | | | | | |
| 117 | 10/04/2013 23:24 | West Cable | Main span | - | Hanger 36 | Hanger 35 | - | A33-A32 | A33 | 26 |
| 118 | 16/04/2013 20:02 | West Cable | Back span | North | Cable 3 | Clamp 6 | Clamp 7 | A35-A33 | A35 | 57.7 |
| 119 | 11/05/2013 16:36 | West Cable | Back span | North | Cable 1 | Pylon | Clamp 2 | A37-A33 | A33 | 4.4 |
| 120 | 13/05/2013 11:39 | West Cable | Back span | North | Cable 2 | Clamp 2 | Clamp 3 | A38-A33 | A33 | 52.9 |
| 121 | 27/07/2013 04:55 | West Cable | Back span | South | Cable 3 | Clamp 6 | Clamp 7 | A26-A22 | A26 | 107.6 |
| 122 | 02/09/2013 09:53 | West Cable | Back span | South | Cable 3 | Clamp 10 | Clamp 9 | A26-A22 | A26 | 68 |
| 123 | 11/09/2013 03:00 | West Cable | Back span | South | Cable 3 | Clamp 3 | Clamp 2 | A26-A22 | A26 | 151.2 |
| 124 | 17/09/2013 06:30 | West Cable | Back span | South | Cable 3 | Clamp 15 | Clamp 14 | A26-A22 | A26 | 10.7 |
| 125 | 17/09/2013 06:31 | West Cable | Back span | South | Cable 3 | Clamp 15 | Clamp 14 | A26-A22 | A26 | 10.6 |
| 126 | 27/11/2013 08:32 | West Cable | Main span | - | Hanger 11 | Hanger 10 | - | A28-A27 | A28 | 12.5 |
| 127 | 08/12/2013 20:19 | West Cable | Back span | North | Cable 1 | Clamp 2 | Pylon | A37-A33 | A37 | 64.5 |
| 128 | 16/01/2014 08:06 | West Cable | Back span | North | Cable 1 | Clamp 6 | Clamp 5 | A37-A33 | A37 | 22.1 |
| 129 | 19/01/2014 22:11 | West Cable | Back span | South | Cable 4 | Clamp 8 | Clamp 7 | A26-A21 | A26 | 92.8 |
| 130 | 19/01/2014 22:25 | West Cable | Back span | South | Cable 4 | Clamp 8 | Clamp 7 | A26-A21 | A26 | 92.5 |
| 131 | 26/01/2014 22:45 | West Cable | Back span | North | Cable 4 | Clamp 5 | Clamp 4 | A36-A33 | A36 | 32.5 |
| 132 | 05/02/2014 00:10 | West Cable | Main span | - | Hanger 27 | Hanger 26 | - | A31-A30 | A31 | 3.1 |
| 133 | 20/02/2014 22:10 | West Cable | Main span | - | Hanger 7 | Hanger 6 | - | A28-A27 | A28 | 58.5 |
| 134 | 19/03/2014 14:48 | West Cable | Main span | - | Hanger 2 | Pylon | - | A27-A26 | A27 | 63.5 |
| 135 | 19/03/2014 14:49 | West Cable | Main span | - | Hanger 2 | Pylon | - | A27-A26 | A27 | 63.4 |
| 136 | 28/03/2014 12:50 | West Cable | Main span | - | Hanger 33 | Hanger 32 | - | A33-A32 | A33 | 68.1 |
| 137 | 27/01/2015 22:32 | West Cable | Back span | South | Cable 6 | Clamp 12 | Clamp 11 | A26-A20 | A26 | 49.2 |
| 138 | 24/02/2016 07:59 | West Cable | Main span | - | Hanger 8 | Hanger 7 | - | A28-A27 | A28 | 46.3 |
| 139 | 04/04/2016 18:53 | West Cable | Main span | - | Hanger 23 | Hanger 22 | - | A31-A30 | A31 | 59.9 |
| 140 | 27/05/2016 08:47 | West Cable | Main span | - | Hanger12 | Hanger 11 | - | A29-A28 | A29 | 60.4 |
| 141 | 30/11/2017 03:05 | West Cable | Main span | | Hanger 10 | Hanger 11 | | A28-A27 | A28 | 4.4 |
| 142 | 07/02/2019 07:37 | West Cable | Back span | South | Cable 5 | Clamp 6 | Clamp 5 | A26-A25 | A26 | 124 |
| 143 | 09/02/2019 01:33 | West Cable | Main span | - | Hanger 28 | Hanger 27 | - | A32-A31 | A32 | 61.4 |

# Appendix B. Matlab code for the analysis of cable breakage data

```
clear all
close all
clc

[NUM,TXT,RAW]=xlsread('CableBeakageData');
X=datetime(RAW(3:end,5),'InputFormat','dd.MM.yyyy HH:mm');
M = month(X);
Y=year(X);
C = hist(M,1:max(M));

A=RAW(3:end,14);
[index,keys]=grp2idx(A);
D = hist(index,1:max(index));

%Breakage in East Side
j=1;
k=1;
n=1;
for i=1:154
    if NUM(i,16)<= -223.3363
        EastN(j,1)=i;
        j=j+1;
    elseif NUM(i,16)>= 223.3363
        EastS(k,1)=i;
        k=k+1;
    else
        EastM(n,:)=NUM(i,:);
        n=n+1;
    end
end
%Breakage in West Side
j=1;
k=1;
n=1;
for i=155:297
    if NUM(i,16)<= -223.3363
        WestN(j,1)=i;
        j=j+1;
    elseif NUM(i,16)>= 223.3363
        WestS(k,1)=i;
        k=k+1;
    else
        WestM(n,:)=NUM(i,:);
        n=n+1;
    end
end
j=1;k=1;l=1;m=1;n=1;o=1;p=1;q=1;r=1;s=1;t=1;w=1;x=1;y=1;z=1;ii=1;jj=1;kk=1;
ll=1;mm=1;nn=1;oo=1;pp=1;qq=1;rr=1;
for i=1:297
    if NUM(i,19)==0
```

```
    A00(j,:)=NUM(i,:);
    j=j+1;
elseif NUM(i,19)==1
    A01(k,:)=NUM(i,:);
    k=k+1;
elseif NUM(i,19)==2
    A02(l,:)=NUM(i,:);
    l=l+1;
elseif NUM(i,19)==3
    A03(m,:)=NUM(i,:);
    m=m+1;
elseif NUM(i,19)==4
    A04(n,:)=NUM(i,:);
    n=n+1;
elseif NUM(i,19)==5
    A05(o,:)=NUM(i,:);
    o=o+1;
elseif NUM(i,19)==14
    A14(p,:)=NUM(i,:);
    p=p+1;
elseif NUM(i,19)==15
    A15(q,:)=NUM(i,:);
    q=q+1;
elseif NUM(i,19)==16
    A16(r,:)=NUM(i,:);
    r=r+1;
elseif NUM(i,19)==17
    A17(s,:)=NUM(i,:);
    s=s+1;
elseif NUM(i,19)==18
    A18(t,:)=NUM(i,:);
    t=t+1;
elseif NUM(i,19)==19
    A19(w,:)=NUM(i,:);
    w=w+1;
elseif NUM(i,19)==20
    A20(x,:)=NUM(i,:);
    x=x+1;
elseif NUM(i,19)==21
    A21(y,:)=NUM(i,:);
    y=y+1;
elseif NUM(i,19)==22
    A22(z,:)=NUM(i,:);
    z=z+1;
elseif NUM(i,19)==23
    A23(ii,:)=NUM(i,:);
    ii=ii+1;
elseif NUM(i,19)==24
    A24(jj,:)=NUM(i,:);
    jj=jj+1;
elseif NUM(i,19)==25
    A25(kk,:)=NUM(i,:);
    kk=kk+1;
elseif NUM(i,19)==34
    A34(ll,:)=NUM(i,:);
    ll=ll+1;
elseif NUM(i,19)==35
    A35(mm,:)=NUM(i,:);
    mm=mm+1;
elseif NUM(i,19)==36
    A36(nn,:)=NUM(i,:);
```

```
        nn=nn+1;
    elseif NUM(i,19)==37
        A37(oo,:)=NUM(i,:);
        oo=oo+1;
    elseif NUM(i,19)==38
        A38(pp,:)=NUM(i,:);
        pp=pp+1;
    elseif NUM(i,19)==39
        A39(qq,:)=NUM(i,:);
        qq=qq+1;
    elseif NUM(i,19)==10
        A10(rr,:)=NUM(i,:);
        rr=rr+1;
    end
end

figure(1)
sensor =
{'A13';'A12';'A03';'A02';'A10';'A11';'A06';'A08';'A05';'A09';'A07';'A04';'A
01';'A26';'A37';'A32';'A27';'A28';'A21';'A30';'A31';'A29';'A36';'A24';'A34'
;'A33';'A35'};
bar(D);
set(gca,'xtick',[1:27],'xticklabel',sensor);
ax = gca;
ax.XTickLabelRotation = 90;
ylabel('Total number of reports')
%title('Number of report per each sensor during 2009-2019')

figure(2)
month =
["Jan","Feb","Mar","Apr","May","Jun","Jul","Aug","Sep","Oct","Nov","Dec"];
bar(C)
xticklabels(month)
ax = gca;
ax.XTickLabelRotation = 90;
ylabel('Total number of breakage')
%title('Number of breakage per each month during 2009-2019')

figure(3)
sz=20;
subplot(211)
scatter(EastM(:,16),EastM(:,18),sz,'filled');
hold on
p0=scatter(A00(:,16),A00(:,18),sz,'r','filled');
hold on
p1=scatter(A01(:,16),A01(:,18),sz,'g','filled');
hold on
p2=scatter(A02(:,16),A02(:,18),sz,'y','filled');
hold on
p3=scatter(A03(:,16),A03(:,18),sz,'k','filled');
hold on
p4=scatter(A04(:,16),A04(:,18),sz,'m','filled');
hold on
p5=scatter(A05(:,16),A05(:,18),sz,'c','filled');
hold on
p14=scatter(A14(:,16),A14(:,18),sz,'r','filled');
hold on
p15=scatter(A15(:,16),A15(:,18),sz,'g','filled');
hold on
p16=scatter(A16(:,16),A16(:,18),sz,'y','filled');
hold on
```

```
p17=scatter(A17(:,16),A17(:,18),sz,'k','filled');
hold on
p18=scatter(A18(:,16),A18(:,18),sz,'m','filled');
hold on
p19=scatter(A19(:,16),A19(:,18),sz,'c','filled');
hold off
legend([p0 p1 p2 p3 p4 p5],{'A00 A14','A01 A15','A02 A16','A03 A17','A04
A18','A05 A19'});
title('Breakage in East Side')
subplot(212)
scatter(EastM(:,16),EastM(:,18),sz,'filled');
hold on
p20=scatter(A20(:,16),A20(:,18),sz,'r','filled');
hold on
p21=scatter(A21(:,16),A21(:,18),sz,'g','filled');
hold on
p22=scatter(A22(:,16),A22(:,18),sz,'y','filled');
hold on
p23=scatter(A23(:,16),A23(:,18),sz,'k','filled');
hold on
p24=scatter(A24(:,16),A24(:,18),sz,'m','filled');
hold on
p25=scatter(A25(:,16),A25(:,18),sz,'c','filled');
hold on
p34=scatter(A34(:,16),A34(:,18),sz,'r','filled');
hold on
p35=scatter(A35(:,16),A35(:,18),sz,'g','filled');
hold on
p36=scatter(A36(:,16),A36(:,18),sz,'y','filled');
hold on
p37=scatter(A37(:,16),A37(:,18),sz,'k','filled');
hold on
p38=scatter(A38(:,16),A38(:,18),sz,'m','filled');
% hold on
% p39=scatter(A39(:,16),A39(:,18),sz,'c','filled');
hold off
legend([p20 p21 p22 p23 p24 p25],{'A20 A34','A21 A35','A22 A36','A23
A37','A24 A38','A25 A39'});
title('Breakage in West Side')

%-------------------------------------------------------------

j=1;k=1;l=1;m=1;n=1;o=1;p=1;q=1;r=1;s=1;t=1;w=1;x=1;y=1;z=1;ii=1;jj=1;kk=1;
ll=1;mm=1;nn=1;oo=1;pp=1;qq=1;rr=1;ss=1;tt=1;ww=1;xx=1;yy=1;zz=1;a=1;b=1;c=
1;d=1;e=1;f=1;g=1;h=1;aa=1;bb=1;cc=1;dd=1;ee=1;
for i=1:154
    if (Y(i)==2009) && ((M(i)==3)|| (M(i)==4)||(M(i)==5))
        B09SpE(j,:)=NUM(i,:);
        j=j+1;
    elseif (Y(i)==2009) && ((M(i)==6)|| (M(i)==7)||(M(i)==8))
        B09SuE(k,:)=NUM(i,:);
        k=k+1;
    elseif (Y(i)==2009) && ((M(i)==9)|| (M(i)==10)||(M(i)==11))
        B09AuE(l,:)=NUM(i,:);
        l=l+1;
    elseif (Y(i)==2009) && ((M(i)==12)|| (M(i)==1)||(M(i)==2))
        B09WiE(m,:)=NUM(i,:);
        m=m+1;
    elseif (Y(i)==2010) && ((M(i)==3)|| (M(i)==4)||(M(i)==5))
        B10SpE(n,:)=NUM(i,:);
        n=n+1;
```

```
elseif (Y(i)==2010) && ((M(i)==6)|| (M(i)==7)||(M(i)==8))
    B10SuE(o,:)=NUM(i,:);
    o=o+1;
elseif (Y(i)==2010) && ((M(i)==9)|| (M(i)==10)||(M(i)==11))
    B10AuE(p,:)=NUM(i,:);
    p=p+1;
elseif (Y(i)==2010) && ((M(i)==12)|| (M(i)==1)||(M(i)==2))
    B10WiE(q,:)=NUM(i,:);
    q=q+1;
elseif (Y(i)==2011) && ((M(i)==3)|| (M(i)==4)||(M(i)==5))
    B11SpE(r,:)=NUM(i,:);
    r=r+1;
elseif (Y(i)==2011) && ((M(i)==6)|| (M(i)==7)||(M(i)==8))
    B11SuE(s,:)=NUM(i,:);
    s=s+1;
elseif (Y(i)==2011) && ((M(i)==9)|| (M(i)==10)||(M(i)==11))
    B11AuE(t,:)=NUM(i,:);
    t=t+1;
elseif (Y(i)==2011) && ((M(i)==12)|| (M(i)==1)||(M(i)==2))
    B11WiE(w,:)=NUM(i,:);
    w=w+1;
elseif (Y(i)==2012) && ((M(i)==3)|| (M(i)==4)||(M(i)==5))
    B12SpE(x,:)=NUM(i,:);
    x=x+1;
elseif (Y(i)==2012) && ((M(i)==6)|| (M(i)==7)||(M(i)==8))
    B12SuE(y,:)=NUM(i,:);
    y=y+1;
elseif (Y(i)==2012) && ((M(i)==9)|| (M(i)==10)||(M(i)==11))
    B12AuE(z,:)=NUM(i,:);
    z=z+1;
elseif (Y(i)==2012) && ((M(i)==12)|| (M(i)==1)||(M(i)==2))
    B12WiE(ii,:)=NUM(i,:);
    ii=ii+1;
elseif (Y(i)==2013) && ((M(i)==3)|| (M(i)==4)||(M(i)==5))
    B13SpE(jj,:)=NUM(i,:);
    jj=jj+1;
elseif (Y(i)==2013) && ((M(i)==6)|| (M(i)==7)||(M(i)==8))
    B13SuE(kk,:)=NUM(i,:);
    kk=kk+1;
elseif (Y(i)==2013) && ((M(i)==9)|| (M(i)==10)||(M(i)==11))
    B13AuE(ll,:)=NUM(i,:);
    ll=ll+1;
elseif (Y(i)==2013) && ((M(i)==12)|| (M(i)==1)||(M(i)==2))
    B13WiE(mm,:)=NUM(i,:);
    mm=mm+1;
elseif (Y(i)==2014) && ((M(i)==3)|| (M(i)==4)||(M(i)==5))
    B14SpE(nn,:)=NUM(i,:);
    nn=nn+1;
elseif (Y(i)==2014) && ((M(i)==6)|| (M(i)==7)||(M(i)==8))
    B14SuE(oo,:)=NUM(i,:);
    oo=oo+1;
elseif (Y(i)==2014) && ((M(i)==9)|| (M(i)==10)||(M(i)==11))
    B14AuE(pp,:)=NUM(i,:);
    pp=pp+1;
elseif (Y(i)==2014) && ((M(i)==12)|| (M(i)==1)||(M(i)==2))
    B14WiE(qq,:)=NUM(i,:);
    qq=qq+1;
elseif (Y(i)==2015) && ((M(i)==3)|| (M(i)==4)||(M(i)==5))
    B15SpE(rr,:)=NUM(i,:);
    rr=rr+1;
elseif (Y(i)==2015) && ((M(i)==6)|| (M(i)==7)||(M(i)==8))
```

```
        B15SuE(ss,:)=NUM(i,:);
        ss=ss+1;
    elseif (Y(i)==2015) && ((M(i)==9)|| (M(i)==10)||(M(i)==11))
        B15AuE(tt,:)=NUM(i,:);
        tt=tt+1;
    elseif (Y(i)==2015) && ((M(i)==12)|| (M(i)==1)||(M(i)==2))
        B15WiE(ww,:)=NUM(i,:);
        ww=ww+1;
    elseif (Y(i)==2016) && ((M(i)==3)|| (M(i)==4)||(M(i)==5))
        B16SpE(xx,:)=NUM(i,:);
        xx=xx+1;
    elseif (Y(i)==2016) && ((M(i)==6)|| (M(i)==7)||(M(i)==8))
        B16SuE(yy,:)=NUM(i,:);
        yy=yy+1;
    elseif (Y(i)==2016) && ((M(i)==9)|| (M(i)==10)||(M(i)==11))
        B16AuE(zz,:)=NUM(i,:);
        zz=zz+1;
    elseif (Y(i)==2016) && ((M(i)==12)|| (M(i)==1)||(M(i)==2))
        B16WiE(a,:)=NUM(i,:);
        a=a+1;
    elseif (Y(i)==2017) && ((M(i)==3)|| (M(i)==4)||(M(i)==5))
        B17SpE(b,:)=NUM(i,:);
        b=b+1;
    elseif (Y(i)==2017) && ((M(i)==6)|| (M(i)==7)||(M(i)==8))
        B17SuE(c,:)=NUM(i,:);
        c=c+1;
    elseif (Y(i)==2017) && ((M(i)==9)|| (M(i)==10)||(M(i)==11))
        B17AuE(d,:)=NUM(i,:);
        d=d+1;
    elseif (Y(i)==2017) && ((M(i)==12)|| (M(i)==1)||(M(i)==2))
        B17WiE(e,:)=NUM(i,:);
        e=e+1;
    elseif (Y(i)==2018) && ((M(i)==3)|| (M(i)==4)||(M(i)==5))
        B18SpE(f,:)=NUM(i,:);
        f=f+1;
    elseif (Y(i)==2018) && ((M(i)==6)|| (M(i)==7)||(M(i)==8))
        B18SuE(g,:)=NUM(i,:);
        g=g+1;
    elseif (Y(i)==2018) && ((M(i)==9)|| (M(i)==10)||(M(i)==11))
        B18AuE(h,:)=NUM(i,:);
        h=h+1;
    elseif (Y(i)==2018) && ((M(i)==12)|| (M(i)==1)||(M(i)==2))
        B18WiE(aa,:)=NUM(i,:);
        aa=aa+1;
    elseif (Y(i)==2019) && ((M(i)==3)|| (M(i)==4)||(M(i)==5))
        B19SpE(bb,:)=NUM(i,:);
        bb=bb+1;
    elseif (Y(i)==2019) && ((M(i)==6)|| (M(i)==7)||(M(i)==8))
        B19SuE(cc,:)=NUM(i,:);
        cc=cc+1;
    elseif (Y(i)==2019) && ((M(i)==9)|| (M(i)==10)||(M(i)==11))
        B19AuE(dd,:)=NUM(i,:);
        dd=dd+1;
    elseif (Y(i)==2019) && ((M(i)==12)|| (M(i)==1)||(M(i)==2))
        B19WiE(ee,:)=NUM(i,:);
        ee=ee+1;
    end
end
```

```
j=1;k=1;l=1;m=1;n=1;o=1;p=1;q=1;r=1;s=1;t=1;w=1;x=1;y=1;z=1;ii=1;jj=1;kk=1;
ll=1;mm=1;nn=1;oo=1;pp=1;qq=1;rr=1;ss=1;tt=1;ww=1;xx=1;yy=1;zz=1;a=1;b=1;c=
1;d=1;e=1;f=1;g=1;h=1;aa=1;bb=1;cc=1;dd=1;ee=1;
for i=155:297
    if (Y(i)==2009) && ((M(i)==3)|| (M(i)==4)||(M(i)==5))
        B09SpW(j,:)=NUM(i,:);
        j=j+1;
    elseif (Y(i)==2009) && ((M(i)==6)|| (M(i)==7)||(M(i)==8))
        B09SuW(k,:)=NUM(i,:);
        k=k+1;
    elseif (Y(i)==2009) && ((M(i)==9)|| (M(i)==10)||(M(i)==11))
        B09AuW(l,:)=NUM(i,:);
        l=l+1;
    elseif (Y(i)==2009) && ((M(i)==12)|| (M(i)==1)||(M(i)==2))
        B09WiW(m,:)=NUM(i,:);
        m=m+1;
    elseif (Y(i)==2010) && ((M(i)==3)|| (M(i)==4)||(M(i)==5))
        B10SpW(n,:)=NUM(i,:);
        n=n+1;
    elseif (Y(i)==2010) && ((M(i)==6)|| (M(i)==7)||(M(i)==8))
        B10SuW(o,:)=NUM(i,:);
        o=o+1;
    elseif (Y(i)==2010) && ((M(i)==9)|| (M(i)==10)||(M(i)==11))
        B10AuW(p,:)=NUM(i,:);
        p=p+1;
    elseif (Y(i)==2010) && ((M(i)==12)|| (M(i)==1)||(M(i)==2))
        B10WiW(q,:)=NUM(i,:);
        q=q+1;
    elseif (Y(i)==2011) && ((M(i)==3)|| (M(i)==4)||(M(i)==5))
        B11SpW(r,:)=NUM(i,:);
        r=r+1;
    elseif (Y(i)==2011) && ((M(i)==6)|| (M(i)==7)||(M(i)==8))
        B11SuW(s,:)=NUM(i,:);
        s=s+1;
    elseif (Y(i)==2011) && ((M(i)==9)|| (M(i)==10)||(M(i)==11))
        B11AuW(t,:)=NUM(i,:);
        t=t+1;
    elseif (Y(i)==2011) && ((M(i)==12)|| (M(i)==1)||(M(i)==2))
        B11WiW(w,:)=NUM(i,:);
        w=w+1;
    elseif (Y(i)==2012) && ((M(i)==3)|| (M(i)==4)||(M(i)==5))
        B12SpW(x,:)=NUM(i,:);
        x=x+1;
    elseif (Y(i)==2012) && ((M(i)==6)|| (M(i)==7)||(M(i)==8))
        B12SuW(y,:)=NUM(i,:);
        y=y+1;
    elseif (Y(i)==2012) && ((M(i)==9)|| (M(i)==10)||(M(i)==11))
        B12AuW(z,:)=NUM(i,:);
        z=z+1;
    elseif (Y(i)==2012) && ((M(i)==12)|| (M(i)==1)||(M(i)==2))
        B12WiW(ii,:)=NUM(i,:);
        ii=ii+1;
    elseif (Y(i)==2013) && ((M(i)==3)|| (M(i)==4)||(M(i)==5))
        B13SpW(jj,:)=NUM(i,:);
        jj=jj+1;
    elseif (Y(i)==2013) && ((M(i)==6)|| (M(i)==7)||(M(i)==8))
        B13SuW(kk,:)=NUM(i,:);
        kk=kk+1;
    elseif (Y(i)==2013) && ((M(i)==9)|| (M(i)==10)||(M(i)==11))
        B13AuW(ll,:)=NUM(i,:);
        ll=ll+1;
```

```
elseif (Y(i)==2013) && ((M(i)==12)|| (M(i)==1)||(M(i)==2))
    B13WiW(mm,:)=NUM(i,:);
    mm=mm+1;
elseif (Y(i)==2014) && ((M(i)==3)|| (M(i)==4)||(M(i)==5))
    B14SpW(nn,:)=NUM(i,:);
    nn=nn+1;
elseif (Y(i)==2014) && ((M(i)==6)|| (M(i)==7)||(M(i)==8))
    B14SuW(oo,:)=NUM(i,:);
    oo=oo+1;
elseif (Y(i)==2014) && ((M(i)==9)|| (M(i)==10)||(M(i)==11))
    B14AuW(pp,:)=NUM(i,:);
    pp=pp+1;
elseif (Y(i)==2014) && ((M(i)==12)|| (M(i)==1)||(M(i)==2))
    B14WiW(qq,:)=NUM(i,:);
    qq=qq+1;
elseif (Y(i)==2015) && ((M(i)==3)|| (M(i)==4)||(M(i)==5))
    B15SpW(rr,:)=NUM(i,:);
    rr=rr+1;
elseif (Y(i)==2015) && ((M(i)==6)|| (M(i)==7)||(M(i)==8))
    B15SuW(ss,:)=NUM(i,:);
    ss=ss+1;
elseif (Y(i)==2015) && ((M(i)==9)|| (M(i)==10)||(M(i)==11))
    B15AuW(tt,:)=NUM(i,:);
    tt=tt+1;
elseif (Y(i)==2015) && ((M(i)==12)|| (M(i)==1)||(M(i)==2))
    B15WiW(ww,:)=NUM(i,:);
    ww=ww+1;
elseif (Y(i)==2016) && ((M(i)==3)|| (M(i)==4)||(M(i)==5))
    B16SpW(xx,:)=NUM(i,:);
    xx=xx+1;
elseif (Y(i)==2016) && ((M(i)==6)|| (M(i)==7)||(M(i)==8))
    B16SuW(yy,:)=NUM(i,:);
    yy=yy+1;
elseif (Y(i)==2016) && ((M(i)==9)|| (M(i)==10)||(M(i)==11))
    B16AuW(zz,:)=NUM(i,:);
    zz=zz+1;
elseif (Y(i)==2016) && ((M(i)==12)|| (M(i)==1)||(M(i)==2))
    B16WiW(a,:)=NUM(i,:);
    a=a+1;
elseif (Y(i)==2017) && ((M(i)==3)|| (M(i)==4)||(M(i)==5))
    B17SpW(b,:)=NUM(i,:);
    b=b+1;
elseif (Y(i)==2017) && ((M(i)==6)|| (M(i)==7)||(M(i)==8))
    B17SuW(c,:)=NUM(i,:);
    c=c+1;
elseif (Y(i)==2017) && ((M(i)==9)|| (M(i)==10)||(M(i)==11))
    B17AuW(d,:)=NUM(i,:);
    d=d+1;
elseif (Y(i)==2017) && ((M(i)==12)|| (M(i)==1)||(M(i)==2))
    B17WiW(e,:)=NUM(i,:);
    e=e+1;
elseif (Y(i)==2018) && ((M(i)==3)|| (M(i)==4)||(M(i)==5))
    B18SpW(f,:)=NUM(i,:);
    f=f+1;
elseif (Y(i)==2018) && ((M(i)==6)|| (M(i)==7)||(M(i)==8))
    B18SuW(g,:)=NUM(i,:);
    g=g+1;
elseif (Y(i)==2018) && ((M(i)==9)|| (M(i)==10)||(M(i)==11))
    B18AuW(h,:)=NUM(i,:);
    h=h+1;
elseif (Y(i)==2018) && ((M(i)==12)|| (M(i)==1)||(M(i)==2))
```

```
        B18WiW(aa,:)=NUM(i,:);
        aa=aa+1;
    elseif (Y(i)==2019) && ((M(i)==3)|| (M(i)==4)||(M(i)==5))
        B19SpW(bb,:)=NUM(i,:);
        bb=bb+1;
    elseif (Y(i)==2019) && ((M(i)==6)|| (M(i)==7)||(M(i)==8))
        B19SuW(cc,:)=NUM(i,:);
        cc=cc+1;
    elseif (Y(i)==2019) && ((M(i)==9)|| (M(i)==10)||(M(i)==11))
        B19AuW(dd,:)=NUM(i,:);
        dd=dd+1;
    elseif (Y(i)==2019) && ((M(i)==12)|| (M(i)==1)||(M(i)==2))
        B19WiW(ee,:)=NUM(i,:);
        ee=ee+1;
    end
end

r=[0.8500 0.3250 0.0980];b=[0 0.4470 0.7410];

figure(4)
sz=20;
% subplot(411)
% scatter(B09SpE(:,16),B09SpE(:,17),sz,'filled');
% title('Breakage in East Side (Mar-May 2009)')
% subplot(812)
% scatter(B09SpW(:,16),B09SpW(:,17),sz,'filled');
% title('Breakage in West Side (Mar-May 2009)')
% subplot(813)
% scatter(B09SuE(:,16),B09SuE(:,17),sz,'filled');
% title('Breakage in East Side (Jun-Aug 2009)')
% subplot(814)
% scatter(B09SuW(:,16),B09SuW(:,17),sz,'filled');
% title('Breakage in West Side (Jun-Aug 2009)')
% subplot(815)
% scatter(B09AuE(:,16),B09AuE(:,17),sz,'filled');
% title('Breakage in East Side (Sep-Nov 2009)')
% subplot(816)
% scatter(B09AuW(:,16),B09AuW(:,17),sz,'filled');
% title('Breakage in West Side (Sep-Nov 2009)')
% subplot(211)
scatter(B09WiE(:,16),B09WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B09WiW(:,16),B09WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
title('Breakage in Dec-Feb 2009')
legend('Eastside','Westside','Location','Best')

figure(5)
sz=20;
subplot(411)
scatter(B10SpE(:,16),B10SpE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B10SpW(:,16),B10SpW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
title('Breakage in Mar-May 2010')
legend('Eastside','Westside','Location','Best')
subplot(412)
scatter(B10SuE(:,16),B10SuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
```

```
% hold on
% scatter(B10SuW(:,16),B10SuW(:,17),sz,'filled');
% axis([-350 400 0 110]);
title('Breakage in Jun-Aug 2010')
legend('Eastside','Westside','Location','Best')
subplot(413)
scatter(B10AuE(:,16),B10AuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B10AuW(:,16),B10AuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
title('Breakage in Sep-Nov 2010')
legend('Eastside','Westside','Location','Best')
subplot(414)
scatter(B10WiE(:,16),B10WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B10WiW(:,16),B10WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
title('Breakage in Dec-Feb 2010')
legend('Eastside','Westside','Location','Best')

figure(6)
sz=20;
subplot(411)
scatter(B11SpE(:,16),B11SpE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B11SpW(:,16),B11SpW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
title('Breakage in Mar-May 2011')
legend('Eastside','Westside','Location','Best')
subplot(412)
scatter(B11SuE(:,16),B11SuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B11SuW(:,16),B11SuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
title('Breakage in Jun-Aug 2011')
legend('Eastside','Westside','Location','Best')
subplot(413)
scatter(B11AuE(:,16),B11AuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B11AuW(:,16),B11AuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
title('Breakage in Sep-Nov 2011')
legend('Eastside','Westside','Location','Best')
subplot(414)
scatter(B11WiE(:,16),B11WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B11WiW(:,16),B11WiW(:,17),sz,r,'filled');
title('Breakage in Dec-Feb 2011')
legend('Eastside','Westside','Location','Best')

figure(7)
sz=20;
subplot(411)
scatter(B12SpE(:,16),B12SpE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
```

```
hold on
scatter(B12SpW(:,16),B12SpW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
title('Breakage in Mar-May 2012')
legend('Eastside','Westside','Location','Best')
subplot(412)
scatter(B12SuE(:,16),B12SuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B12SuW(:,16),B12SuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
title('Breakage in Jun-Aug 2012')
legend('Eastside','Westside','Location','Best')
subplot(413)
scatter(B12AuE(:,16),B12AuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B12AuW(:,16),B12AuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
title('Breakage in Sep-Nov 2012')
legend('Eastside','Westside','Location','Best')
subplot(414)
scatter(B12WiE(:,16),B12WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B12WiW(:,16),B12WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
title('Breakage in Dec-Feb 2012')
legend('Eastside','Westside','Location','Best')

figure(8)
sz=20;
subplot(411)
scatter(B13SpE(:,16),B13SpE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B13SpW(:,16),B13SpW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
title('Breakage in Mar-May 2013')
legend('Eastside','Westside','Location','Best')
subplot(412)
scatter(B13SuE(:,16),B13SuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B13SuW(:,16),B13SuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
title('Breakage in Jun-Aug 2013')
legend('Eastside','Westside','Location','Best')
subplot(413)
scatter(B13AuE(:,16),B13AuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B13AuW(:,16),B13AuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
title('Breakage in Sep-Nov 2013')
legend('Eastside','Westside','Location','Best')
subplot(414)
scatter(B13WiE(:,16),B13WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B13WiW(:,16),B13WiW(:,17),sz,r,'filled');
```

```
axis([-350 400 0 110]);
title('Breakage in Dec-Feb 2013')
legend('Eastside','Westside','Location','Best')


figure(9)
sz=20;
subplot(411)
scatter(B14SpE(:,16),B14SpE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B14SpW(:,16),B14SpW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
title('Breakage in Mar-May 2014')
legend('Eastside','Westside','Location','Best')
subplot(412)
% scatter(B14SuE(:,16),B14SuE(:,17),sz,'filled');
% axis([-350 400 0 110]);
% hold on
% scatter(B14SuW(:,16),B14SuW(:,17),sz,'filled');
axis([-350 400 0 110]);
title('Breakage in Jun-Aug 2014')
subplot(413)
% scatter(B14AuE(:,16),B14AuE(:,17),sz,'filled');
% axis([-350 400 0 110]);
%  hold on
% scatter(B14AuW(:,16),B14AuW(:,17),sz,'filled');
axis([-350 400 0 110]);
title('Breakage in Sep-Nov 2014')
subplot(414)
scatter(B14WiE(:,16),B14WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B14WiW(:,16),B14WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
title('Breakage in Dec-Feb 2014')
legend('Eastside','Westside','Location','Best')

figure(10)
sz=20;
subplot(411)
% scatter(B15SpE(:,16),B15SpE(:,17),sz,'filled');
% axis([-350 400 0 110]);
% hold on
% scatter(B15SpW(:,16),B15SpW(:,17),sz,'filled');
axis([-350 400 0 110]);
title('Breakage in Mar-May 2015')
subplot(412)
% scatter(B15SuE(:,16),B15SuE(:,17),sz,'filled');
% axis([-350 400 0 110]);
% hold on
% scatter(B15SuW(:,16),B15SuW(:,17),sz,'filled');
axis([-350 400 0 110]);
title('Breakage in Jun-Aug 2015')
subplot(413)
scatter(B15AuE(:,16),B15AuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
% hold on
% scatter(B15AuW(:,16),B15AuW(:,17),sz,'filled');
% axis([-350 400 0 110]);
title('Breakage in Sep-Nov 2015')
```

```
legend('Eastside','Location','Best')
subplot(414)
% scatter(B15WiE(:,16),B15WiE(:,17),sz,'filled');
% axis([-350 400 0 110]);
% hold on
scatter(B15WiW(:,16),B15WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
title('Breakage in Dec-Feb 2015')
legend('Westside','Location','Best')

figure(11)
sz=20;
subplot(411)
scatter(B16SpE(:,16),B16SpE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B16SpW(:,16),B16SpW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
title('Breakage in Mar-May 2016')
legend('Eastside','Westside','Location','Best')
subplot(412)
% scatter(B16SuE(:,16),B16SuE(:,17),sz,'filled');
% axis([-350 400 0 110]);
% hold on
% scatter(B16SuW(:,16),B16SuW(:,17),sz,'filled');
axis([-350 400 0 110]);
title('Breakage in Jun-Aug 2016')
subplot(413)
% scatter(B16AuE(:,16),B16AuE(:,17),sz,'filled');
% axis([-350 400 0 110]);
% hold on
% scatter(B16AuW(:,16),B16AuW(:,17),sz,'filled');
axis([-350 400 0 110]);
title('Breakage in Sep-Nov 2016')
subplot(414)
scatter(B16WiE(:,16),B16WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B16WiW(:,16),B16WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
title('Breakage in Dec-Feb 2016')
legend('Eastside','Westside','Location','Best')

figure(12)
sz=20;
subplot(411)
% scatter(B17SpE(:,16),B17SpE(:,17),sz,'filled');
% axis([-350 400 0 110]);
% hold on
% scatter(B17SpW(:,16),B17SpW(:,17),sz,'filled');
axis([-350 400 0 110]);
title('Breakage in Mar-May 2017')
subplot(412)
% scatter(B17SuE(:,16),B17SuE(:,17),sz,'filled');
% axis([-350 400 0 110]);
% hold on
% scatter(B17SuW(:,16),B17SuW(:,17),sz,'filled');
axis([-350 400 0 110]);
title('Breakage in Jun-Aug 2017')
subplot(413)
% scatter(B17AuE(:,16),B17AuE(:,17),sz,'filled');
```

```
% axis([-350 400 0 110]);
% hold on
scatter(B17AuW(:,16),B17AuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
title('Breakage in Sep-Nov 2017')
legend('Westside','Location','Best')
subplot(414)
% scatter(B17WiE(:,16),B17WiE(:,17),sz,'filled');
% axis([-350 400 0 110]);
% hold on
% scatter(B17WiW(:,16),B17WiW(:,17),sz,'filled');
axis([-350 400 0 110]);
title('Breakage in Dec-Feb 2017')

figure(13)
sz=20;
subplot(411)
scatter(B18SpE(:,16),B18SpE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
% hold on
% scatter(B18SpW(:,16),B18SpW(:,17),sz,'filled');
% axis([-350 400 0 110]);
title('Breakage in Mar-May 2018')
legend('Eastside','Location','Best')
subplot(412)
% scatter(B18SuE(:,16),B18SuE(:,17),sz,'filled');
% axis([-350 400 0 110]);
% hold on
% scatter(B18SuW(:,16),B18SuW(:,17),sz,'filled');
axis([-350 400 0 110]);
title('Breakage in Jun-Aug 2018')
subplot(413)
% scatter(B18AuE(:,16),B18AuE(:,17),sz,'filled');
% axis([-350 400 0 110]);
% hold on
% scatter(B18AuW(:,16),B18AuW(:,17),sz,'filled');
axis([-350 400 0 110]);
title('Breakage in Sep-Nov 2018')
subplot(414)
scatter(B18WiE(:,16),B18WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
% hold on
% scatter(B18WiW(:,16),B18WiW(:,17),sz,'filled');
% axis([-350 400 0 110]);
title('Breakage in Dec-Feb 2018')
legend('Eastside','Location','Best')

figure(14)
sz=20;
subplot(411)
% scatter(B19SpE(:,16),B19SpE(:,17),sz,'filled');
% axis([-350 400 0 110]);
% hold on
% scatter(B19SpW(:,16),B19SpW(:,17),sz,'filled');
axis([-350 400 0 110]);
title('Breakage in Mar-May 2019')
subplot(412)
% scatter(B19SuE(:,16),B19SuE(:,17),sz,'filled');
% axis([-350 400 0 110]);
% hold on
% scatter(B19SuW(:,16),B19SuW(:,17),sz,'filled');
```

```
axis([-350 400 0 110]);
title('Breakage in Jun-Aug 2019')
subplot(413)
% scatter(B19AuE(:,16),B19AuE(:,17),sz,'filled');
% axis([-350 400 0 110]);
% hold on
% scatter(B19AuW(:,16),B19AuW(:,17),sz,'filled');
axis([-350 400 0 110]);
title('Breakage in Sep-Nov 2019')
subplot(414)
scatter(B19WiE(:,16),B19WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B19WiW(:,16),B19WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
title('Breakage in Dec-Feb 2019')
legend('Eastside','Westside','Location','Best')

figure(15)
sz=20;
subplot(411)
scatter(B10SpE(:,16),B10SpE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B10SpW(:,16),B10SpW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B11SpE(:,16),B11SpE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B11SpW(:,16),B11SpW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B12SpE(:,16),B12SpE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B12SpW(:,16),B12SpW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B13SpE(:,16),B13SpE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B13SpW(:,16),B13SpW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B14SpE(:,16),B14SpE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B14SpW(:,16),B14SpW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
% scatter(B15SpW(:,16),B15SpW(:,17),sz,'filled');
axis([-350 400 0 110]);
% hold on
scatter(B16SpE(:,16),B16SpE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B16SpW(:,16),B16SpW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B18SpE(:,16),B18SpE(:,17),sz,b,'filled');
```

```
axis([-350 400 0 110]);
hold on
% scatter(B19SpE(:,16),B19SpE(:,17),sz,'filled');
% hold on
% scatter(B19SpW(:,16),B19SpW(:,17),sz,'filled');
% hold on
axis([-350 400 0 110]);
title('Breakage in Mar-May')
legend('Eastside','Westside','Location','Best')
subplot(412)
scatter(B10SuE(:,16),B10SuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
% scatter(B10SuW(:,16),B10SuW(:,17),sz,'filled');
axis([-350 400 0 110]);
% hold on
scatter(B11SuE(:,16),B11SuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B11SuW(:,16),B11SuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B12SuE(:,16),B12SuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B12SuW(:,16),B12SuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B13SuE(:,16),B13SuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B13SuW(:,16),B13SuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
% scatter(B14SuE(:,16),B14SuE(:,17),sz,'filled');
% hold on
% scatter(B16SuE(:,16),B16SuE(:,17),sz,'filled');
% hold on
% scatter(B16SuW(:,16),B16SuW(:,17),sz,'filled');
% hold on

title('Breakage in Jun-Aug')
legend('Eastside','Westside','Location','Best')
subplot(413)
scatter(B09AuE(:,16),B09AuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B09AuW(:,16),B09AuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B10AuE(:,16),B10AuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B10AuW(:,16),B10AuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B11AuE(:,16),B11AuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B11AuW(:,16),B11AuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
```

```
hold on
scatter(B12AuE(:,16),B12AuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B12AuW(:,16),B12AuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B13AuE(:,16),B13AuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B13AuW(:,16),B13AuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B15AuE(:,16),B15AuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B17AuW(:,16),B17AuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on

title('Breakage in Sep-Nov')
legend('Eastside','Westside','Location','Best')
subplot(414)
scatter(B09WiE(:,16),B09WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B09WiW(:,16),B09WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B10WiE(:,16),B10WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B10WiW(:,16),B10WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B11WiE(:,16),B11WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B11WiW(:,16),B11WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B12WiE(:,16),B12WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B12WiW(:,16),B12WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B13WiE(:,16),B13WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B13WiW(:,16),B13WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B14WiE(:,16),B14WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B14WiW(:,16),B14WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B15WiW(:,16),B15WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
```

```
hold on
scatter(B16WiE(:,16),B16WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B16WiW(:,16),B16WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B18WiE(:,16),B18WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B19WiE(:,16),B19WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B19WiW(:,16),B19WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on

title('Breakage in Dec-Feb')
legend('Eastside','Westside','Location','Best')

figure(16)
sz=20;
subplot(411)
scatter(B10SpE(:,16),B10SpE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B11SpE(:,16),B11SpE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B12SpE(:,16),B12SpE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B13SpE(:,16),B13SpE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B14SpE(:,16),B14SpE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B16SpE(:,16),B16SpE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B18SpE(:,16),B18SpE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on

title('Breakage in Mar-May (East side)')
subplot(412)
scatter(B10SuE(:,16),B10SuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B11SuE(:,16),B11SuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B12SuE(:,16),B12SuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B13SuE(:,16),B13SuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on

title('Breakage in Jun-Aug (East side)')
```

```
subplot(413)
scatter(B09AuE(:,16),B09AuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B10AuE(:,16),B10AuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B11AuE(:,16),B11AuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B12AuE(:,16),B12AuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B13AuE(:,16),B13AuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B15AuE(:,16),B15AuE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on

title('Breakage in Sep-Nov (East side)')
subplot(414)
scatter(B09WiE(:,16),B09WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B10WiE(:,16),B10WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B11WiE(:,16),B11WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B12WiE(:,16),B12WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B13WiE(:,16),B13WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B14WiE(:,16),B14WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B16WiE(:,16),B16WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B18WiE(:,16),B18WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on
scatter(B19WiE(:,16),B19WiE(:,17),sz,b,'filled');
axis([-350 400 0 110]);
hold on

title('Breakage in Dec-Feb (East side)')


figure(17)
sz=20;
subplot(411)
scatter(B10SpW(:,16),B10SpW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B11SpW(:,16),B11SpW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
```

```
hold on
scatter(B12SpW(:,16),B12SpW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B13SpW(:,16),B13SpW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B14SpW(:,16),B14SpW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B16SpW(:,16),B16SpW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on

title('Breakage in Mar-May (West side)')
subplot(412)
scatter(B11SuW(:,16),B11SuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B12SuW(:,16),B12SuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B13SuW(:,16),B13SuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on

title('Breakage in Jun-Aug (West side)')
subplot(413)
scatter(B09AuW(:,16),B09AuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B10AuW(:,16),B10AuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B11AuW(:,16),B11AuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B12AuW(:,16),B12AuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B13AuW(:,16),B13AuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B17AuW(:,16),B17AuW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on

title('Breakage in Sep-Nov (West side)')
subplot(414)
scatter(B09WiW(:,16),B09WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B10WiW(:,16),B10WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B11WiW(:,16),B11WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B12WiW(:,16),B12WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
```

```
scatter(B13WiW(:,16),B13WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B14WiW(:,16),B14WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B15WiW(:,16),B15WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B16WiW(:,16),B16WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on
scatter(B19WiW(:,16),B19WiW(:,17),sz,r,'filled');
axis([-350 400 0 110]);
hold on

title('Breakage in Dec-Feb (West side)')
```

# Appendix C. Data related to temperatures and wind speeds at stations near the bridge

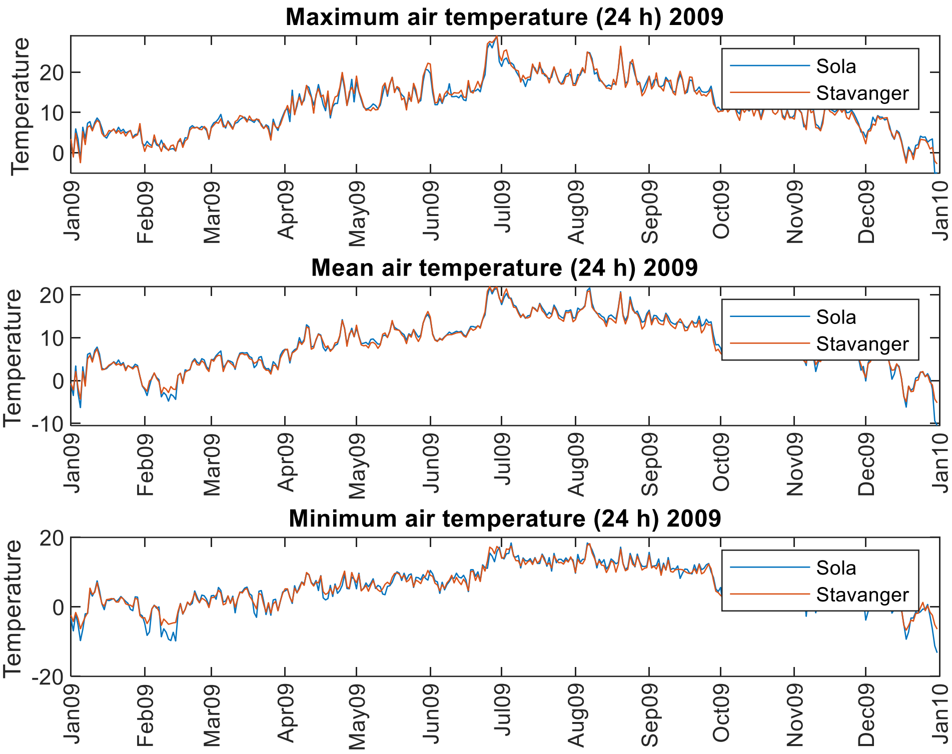


*Figure 65. Data related to temperatures at stations near the bridge in 2009*

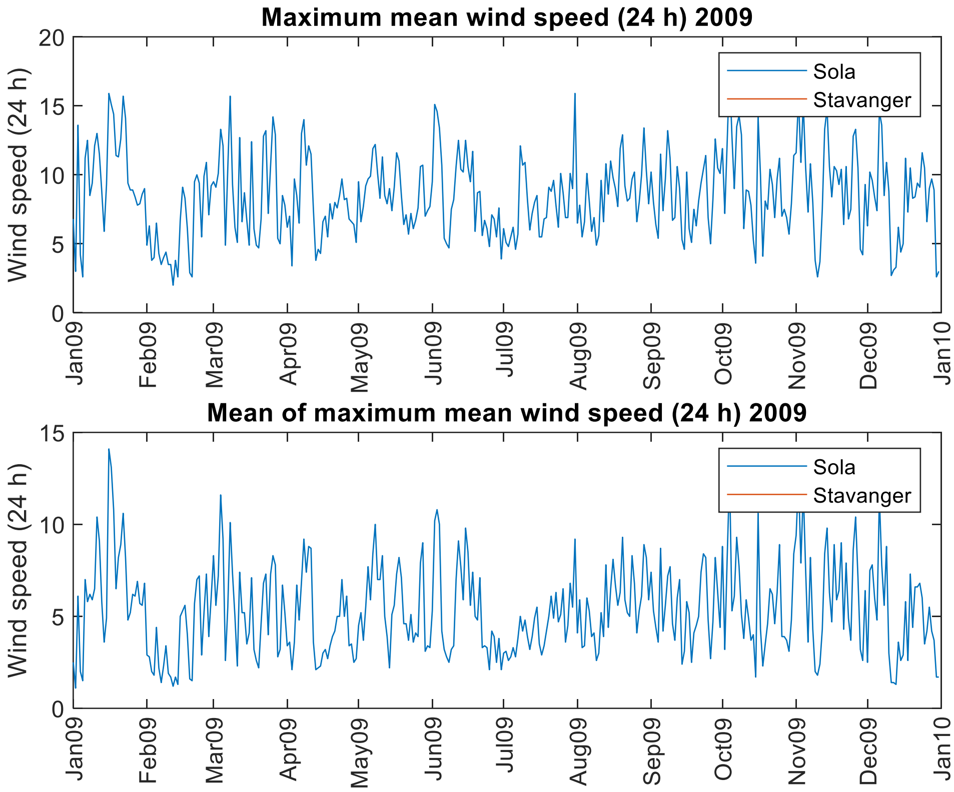


*Figure 66. Data related to wind speeds at stations near the bridge in 2009*

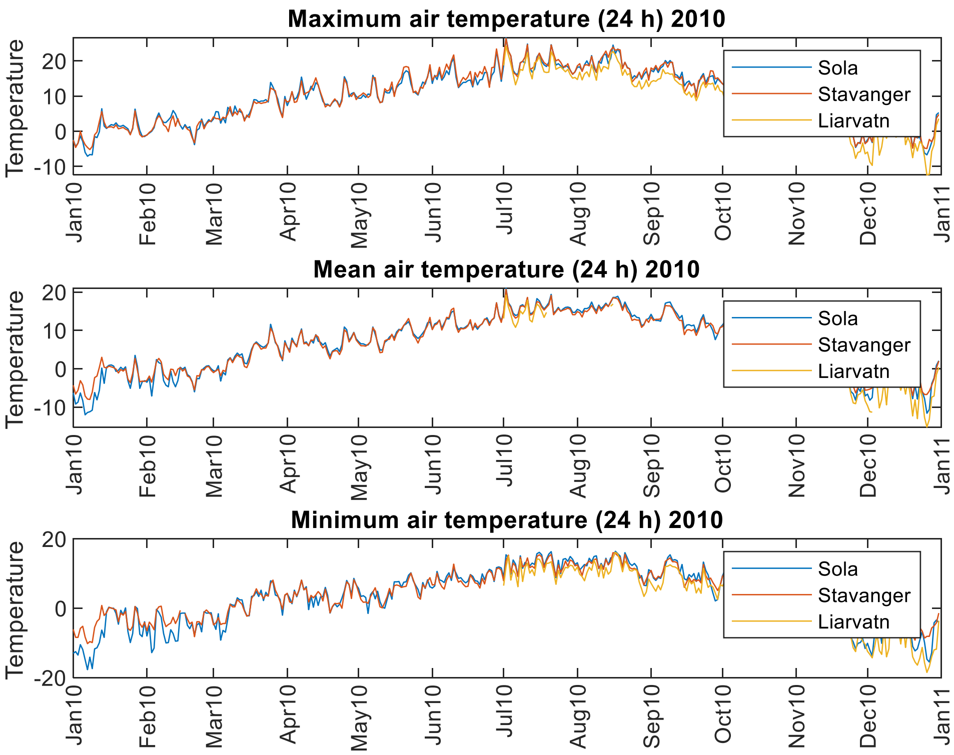


*Figure 67. Data related to temperatures at stations near the bridge in 2010*

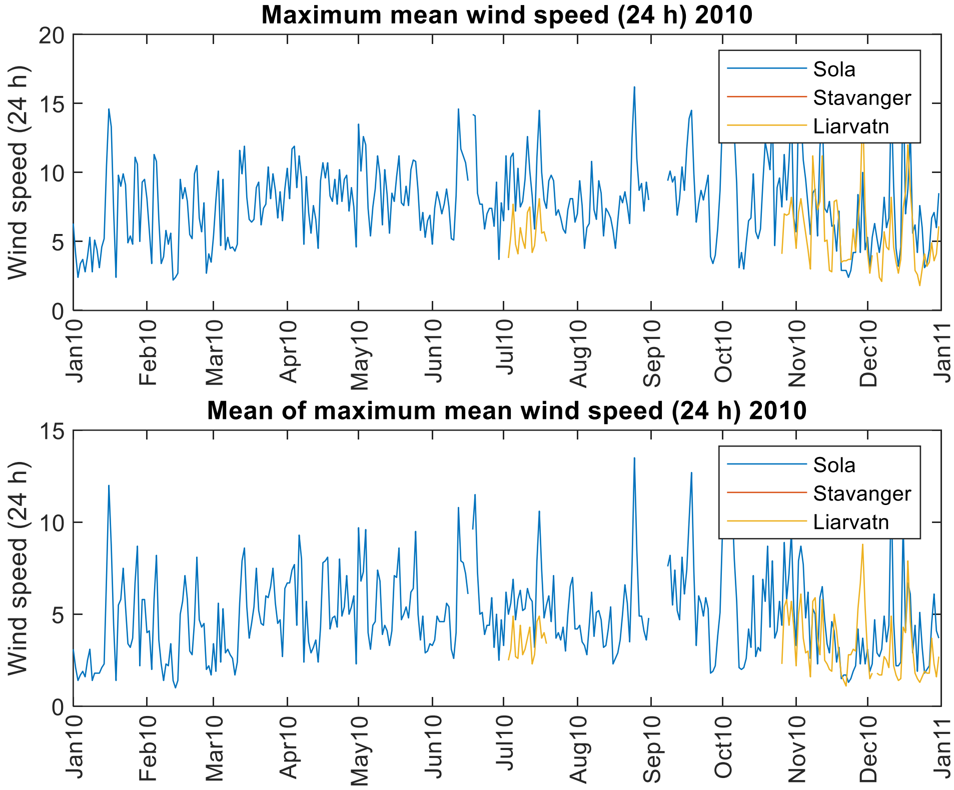


*Figure 68. Data related to wind speeds at stations near the bridge in 2010*

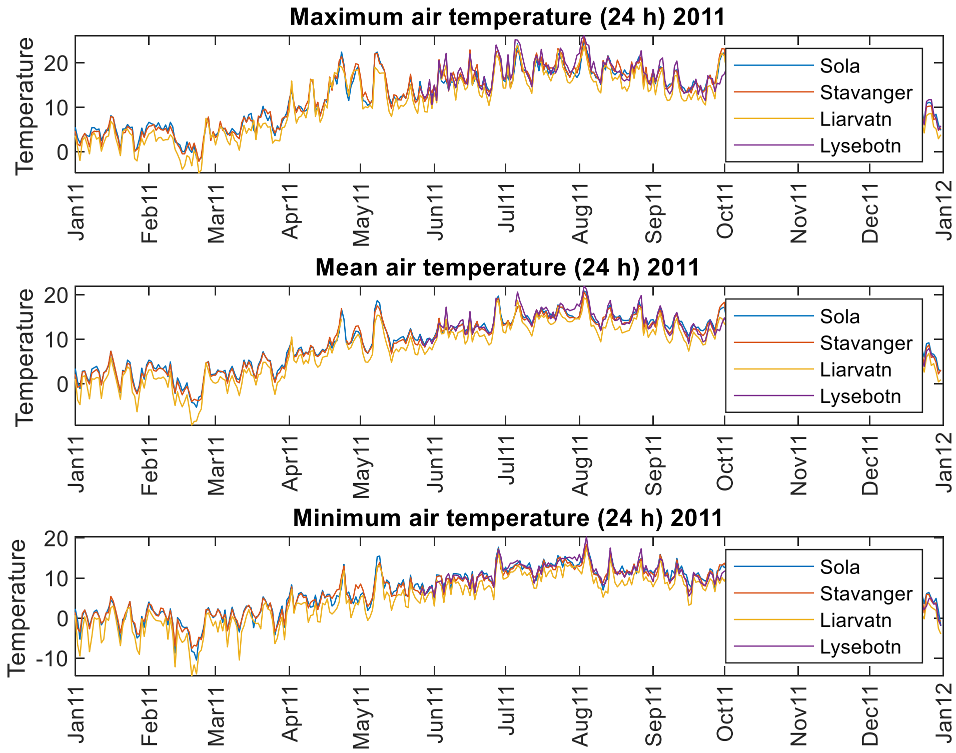


*Figure 69. Data related to temperatures at stations near the bridge in 2011*

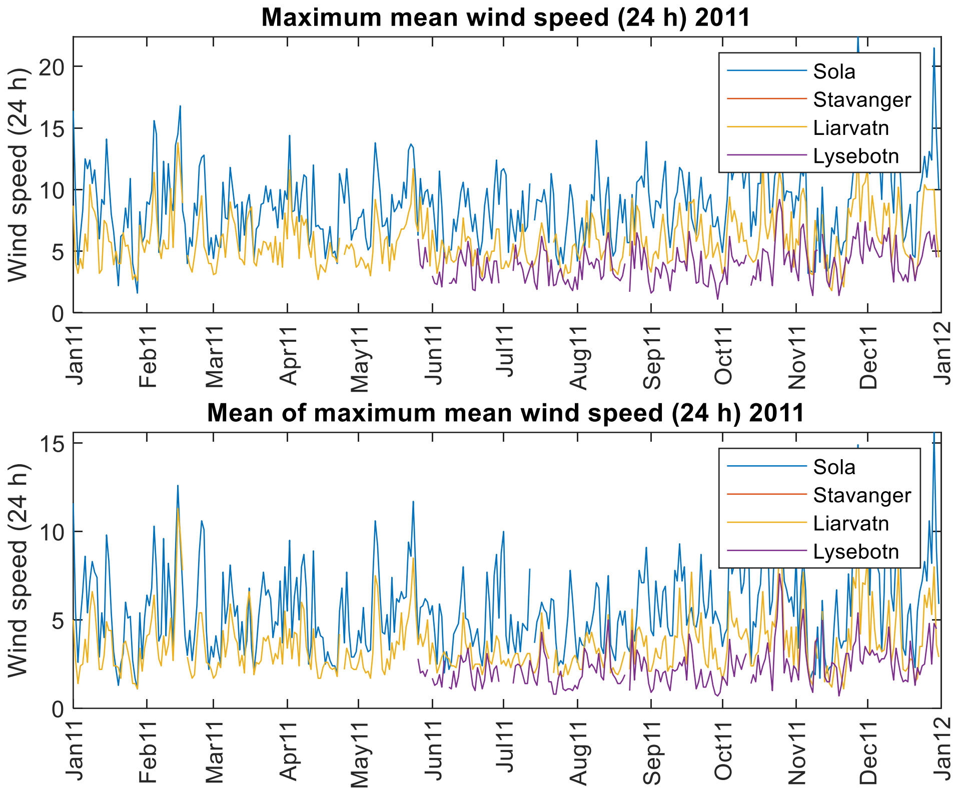


*Figure 70. Data related to wind speeds at stations near the bridge in 2011*

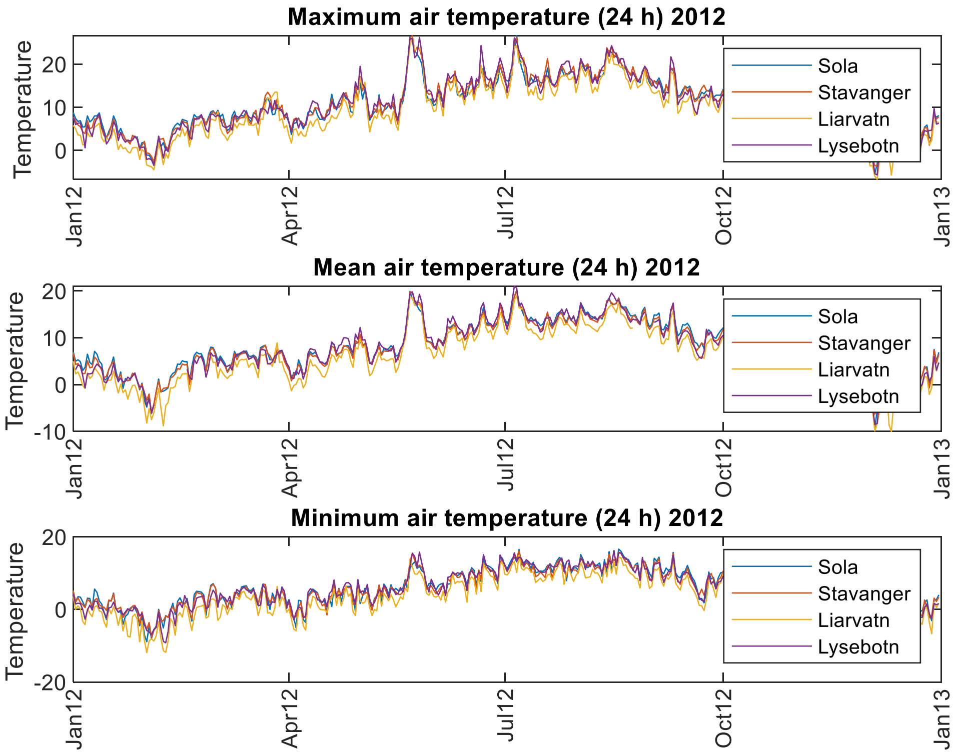


*Figure 71. Data related to temperatures at stations near the bridge in 2012*

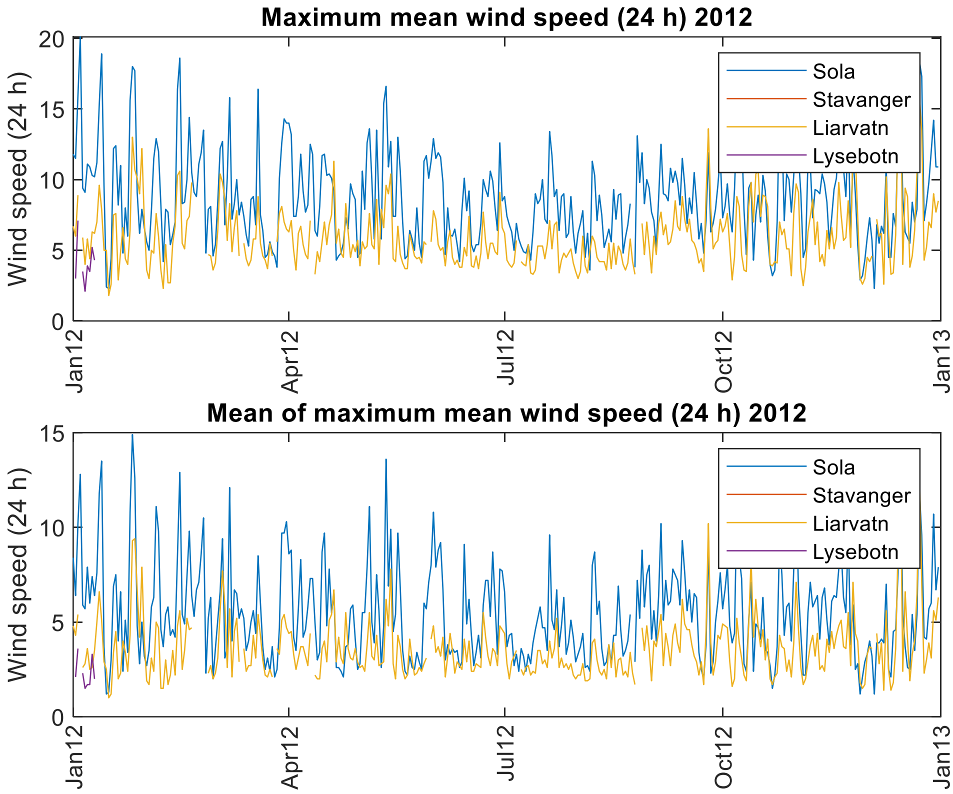


*Figure 72. Data related to wind speeds at stations near the bridge in 2012*

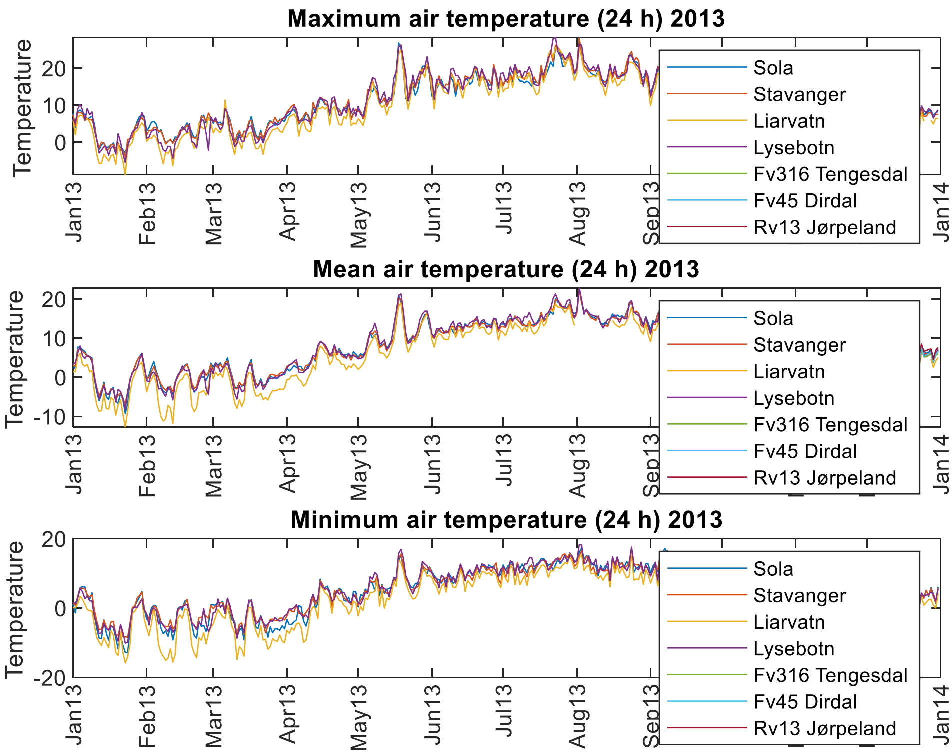


*Figure 73. Data related to temperatures at stations near the bridge in 2013*

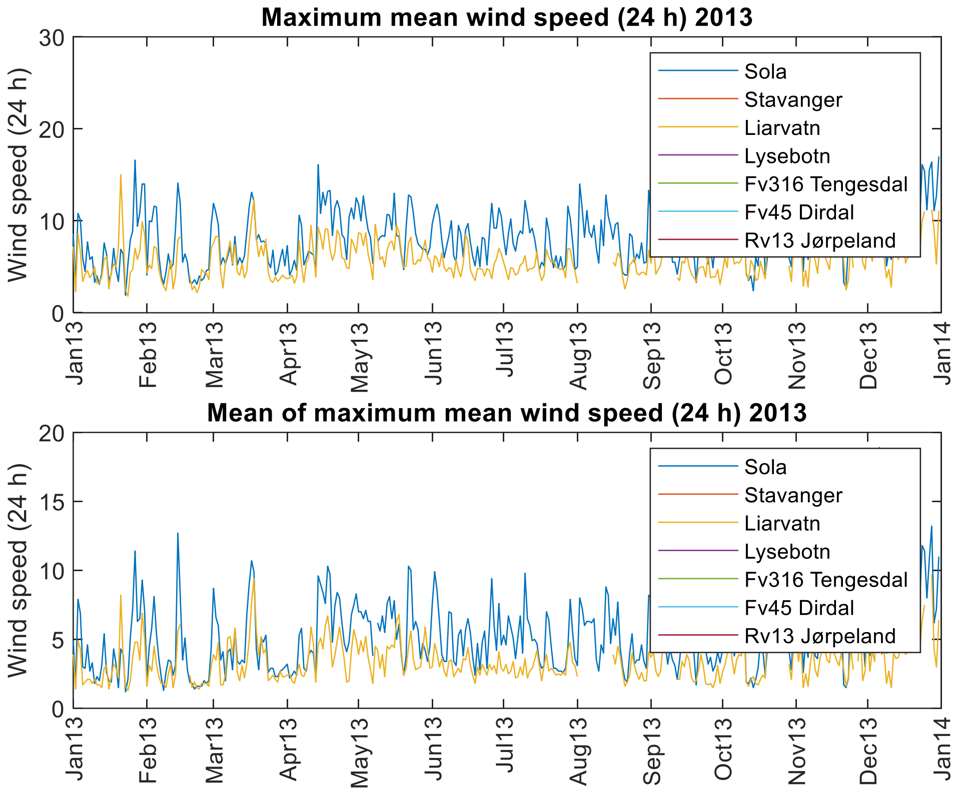


*Figure 74. Data related to wind speeds at stations near the bridge in 2013*

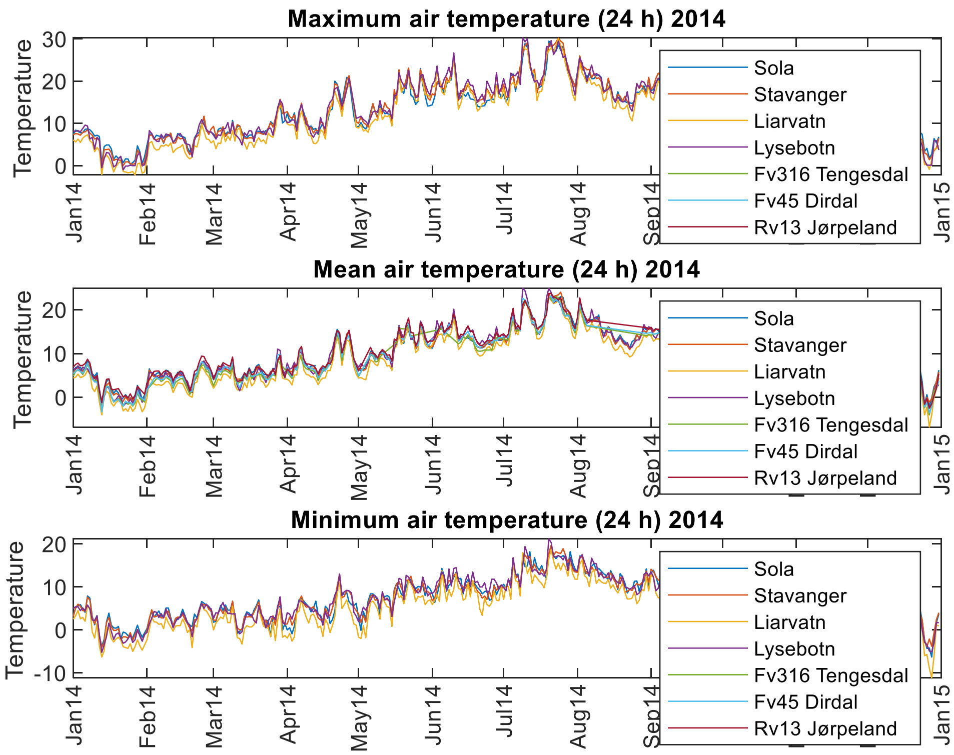


*Figure 75. Data related to temperatures at stations near the bridge in 2014*

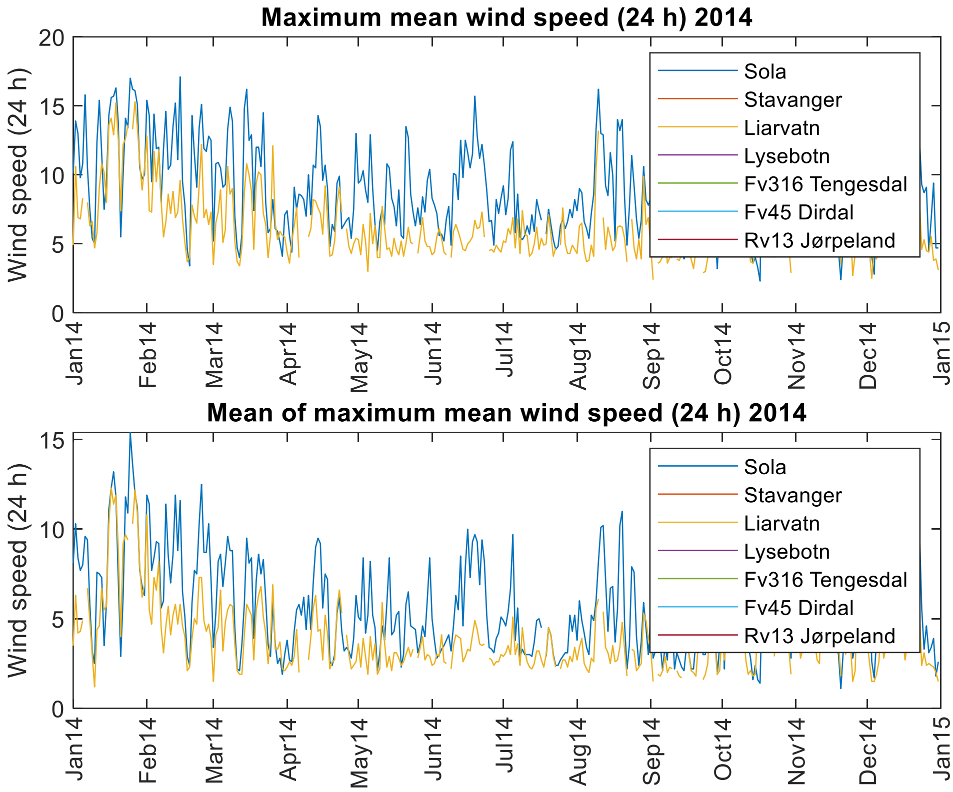


*Figure 76. Data related to wind speeds at stations near the bridge in 2014*

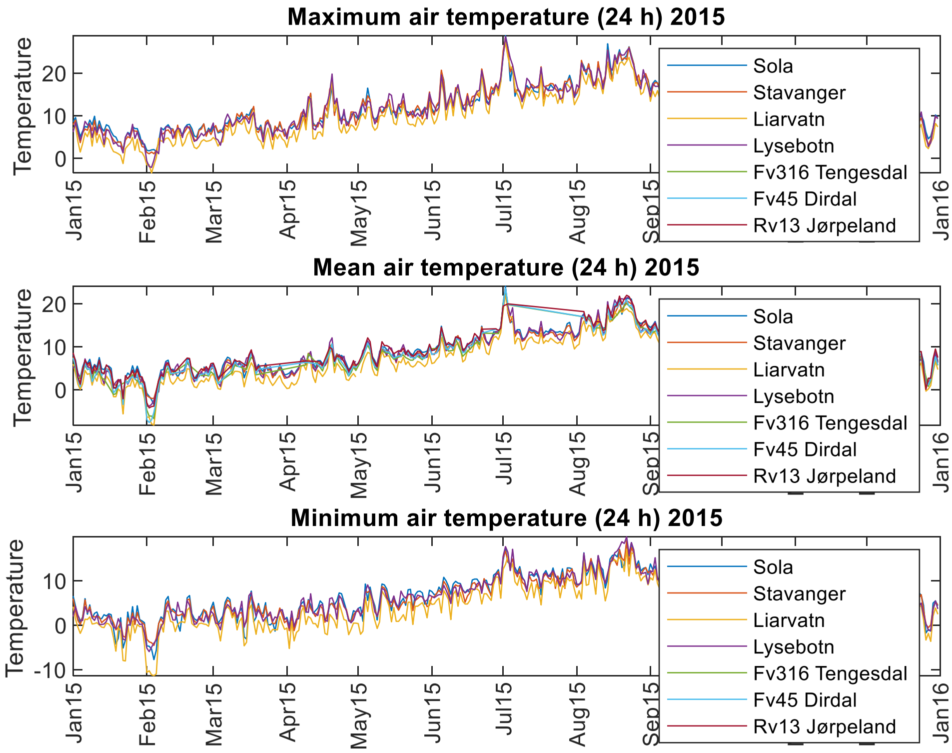


*Figure 77. Data related to temperatures at stations near the bridge in 2015*

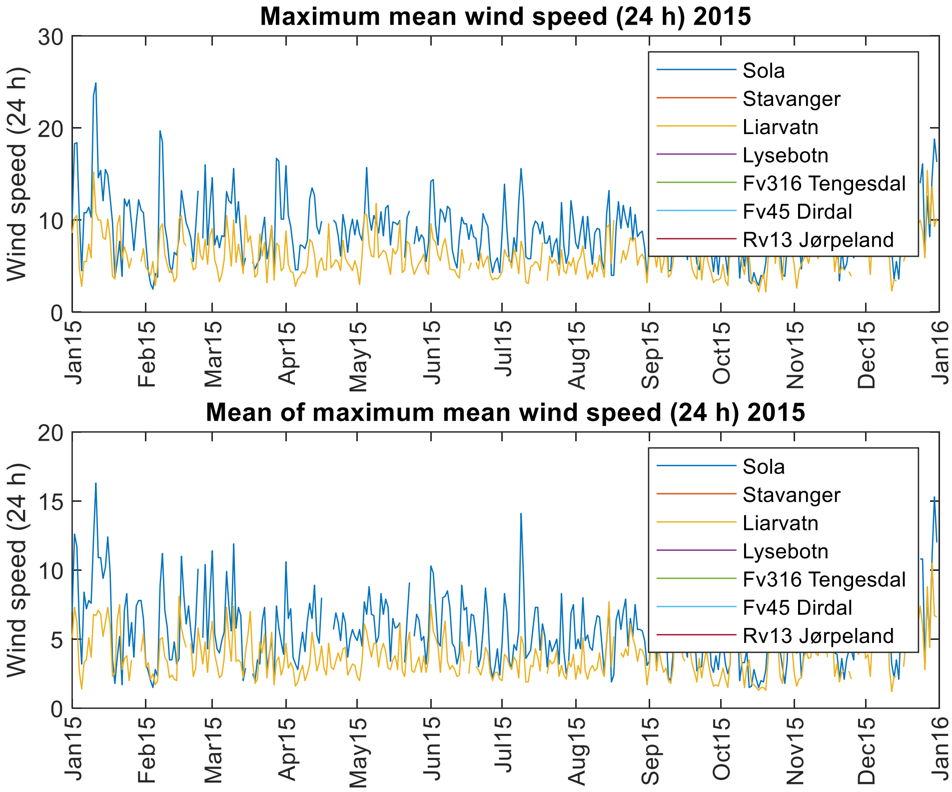


*Figure 78. Data related to wind speeds at stations near the bridge in 2015*

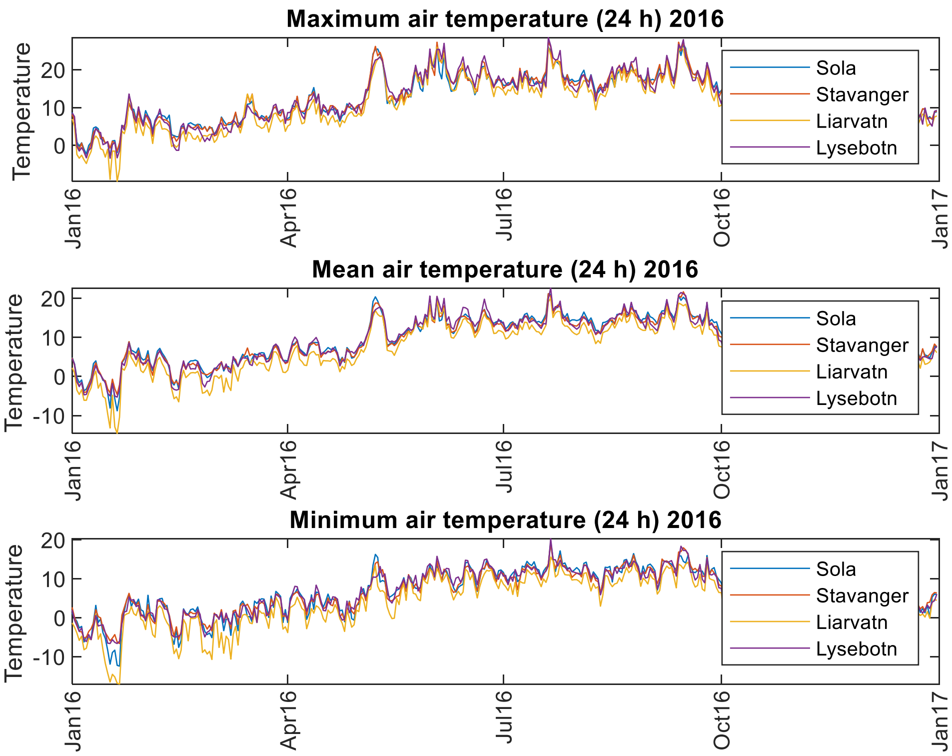


*Figure 79. Data related to temperatures at stations near the bridge in 2016*

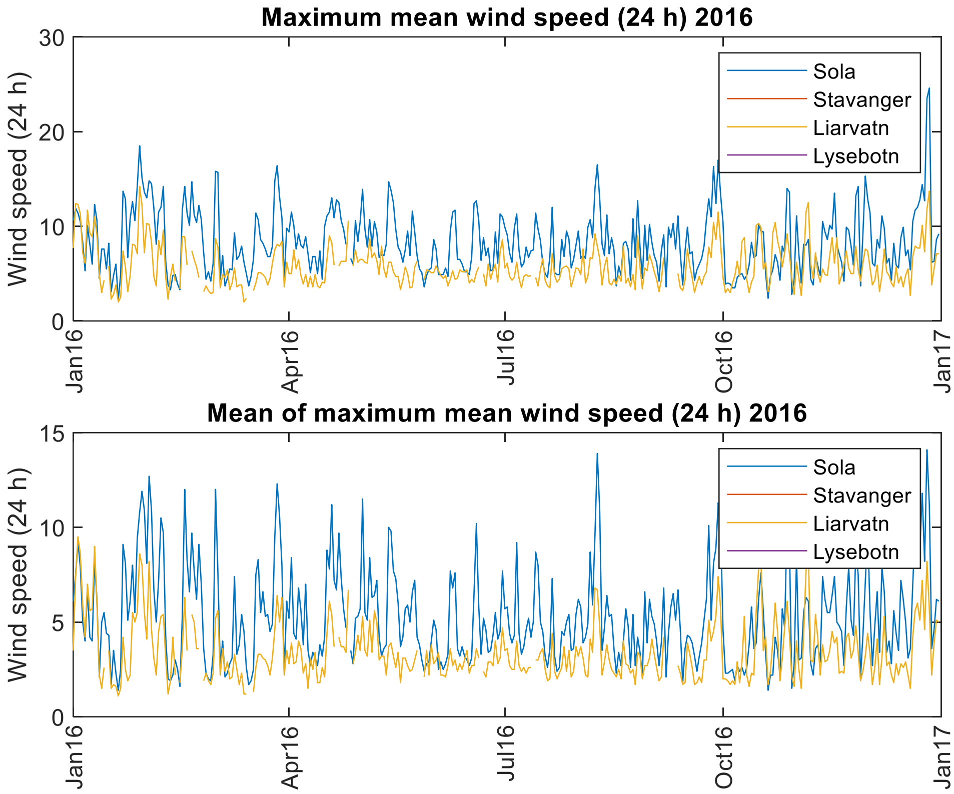


*Figure 80. Data related to wind speeds at stations near the bridge in 2016*

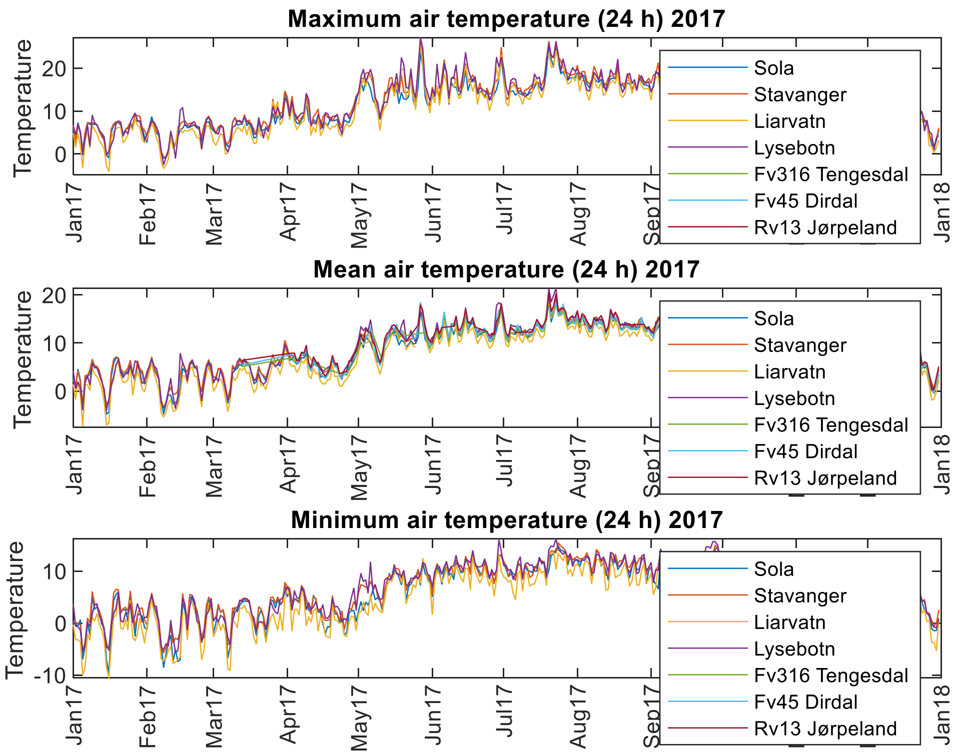


*Figure 81. Data related to temperatures at stations near the bridge in 2017*

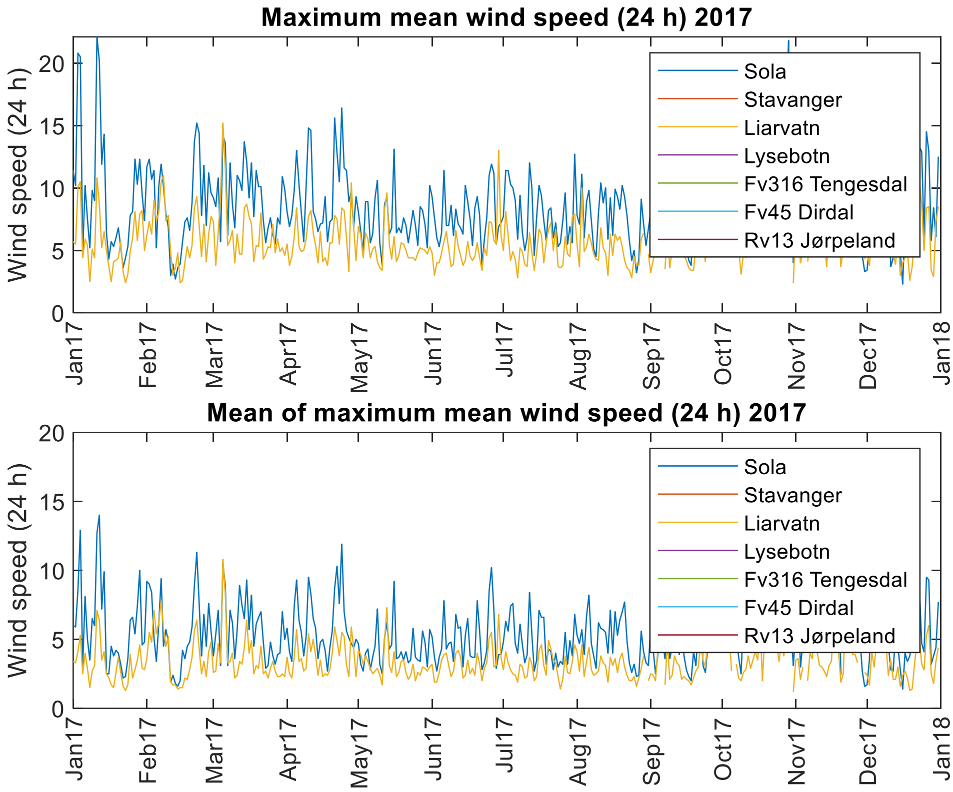


*Figure 82. Data related to wind speeds at stations near the bridge in 2017*

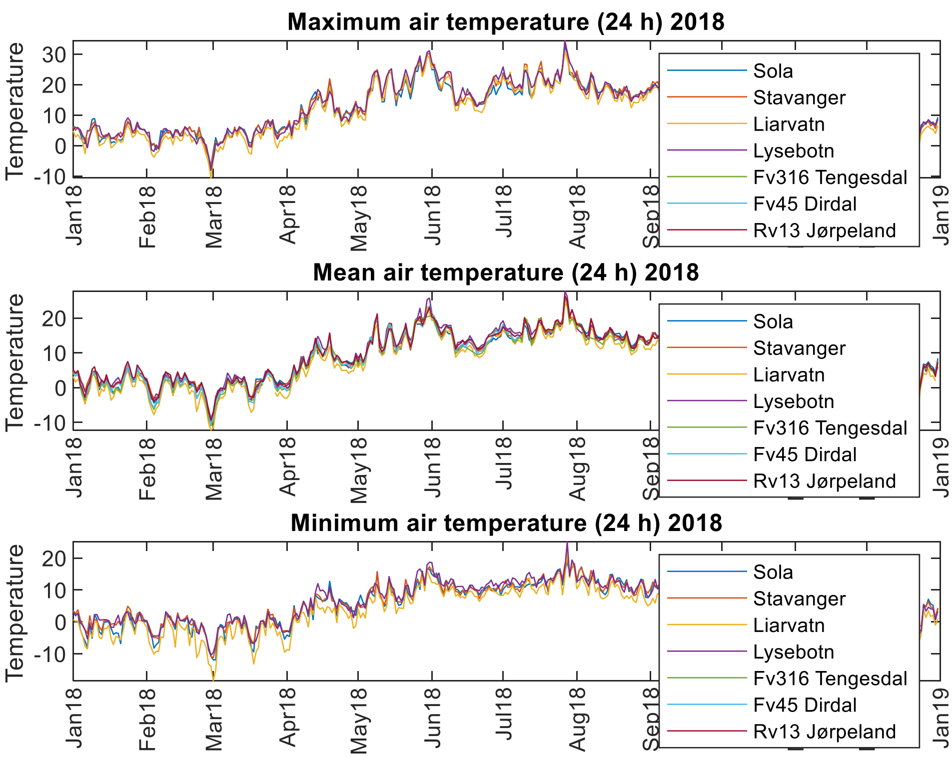


*Figure 83. Data related to temperatures at stations near the bridge in 2018*

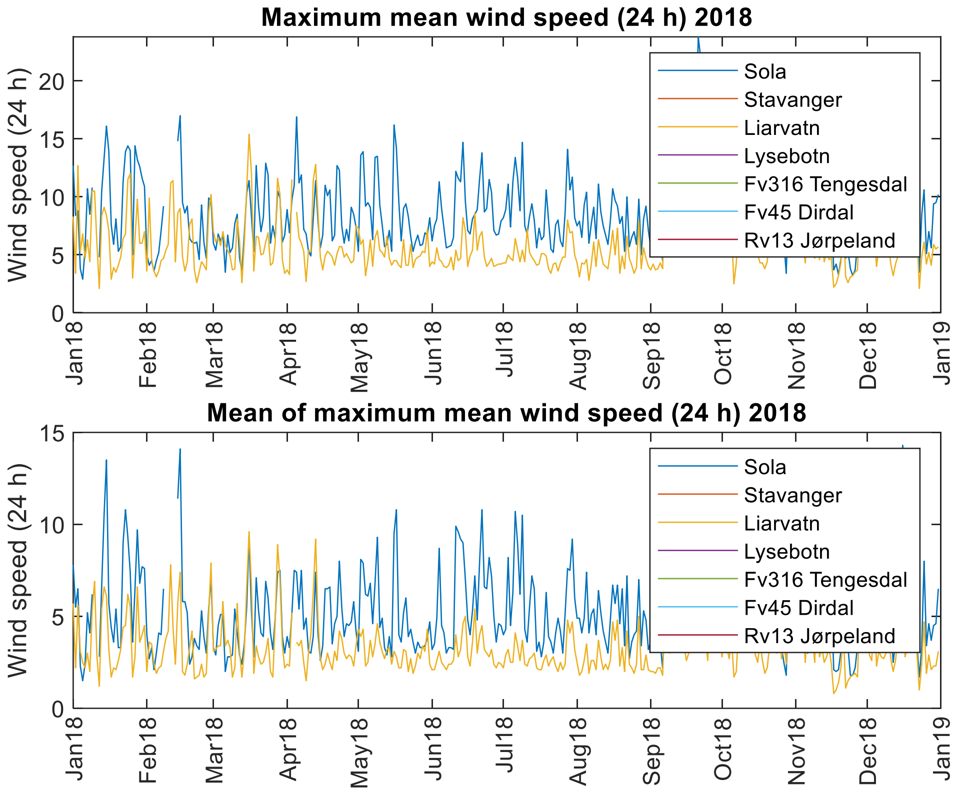


*Figure 84. Data related to wind speeds at stations near the bridge in 2018*

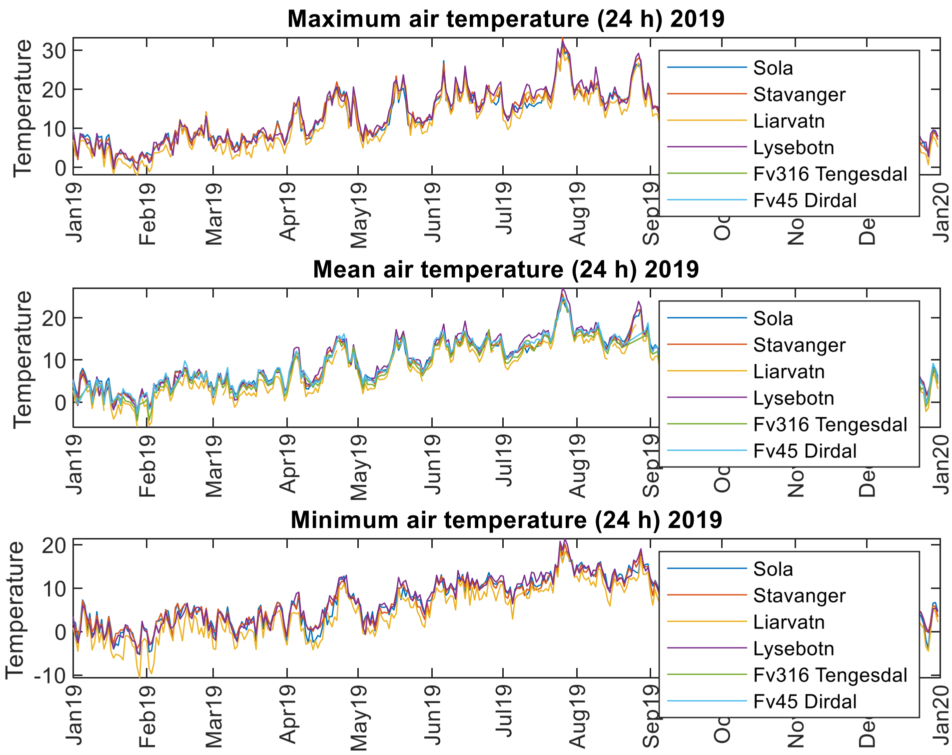


*Figure 85. Data related to temperatures at stations near the bridge in 2019*

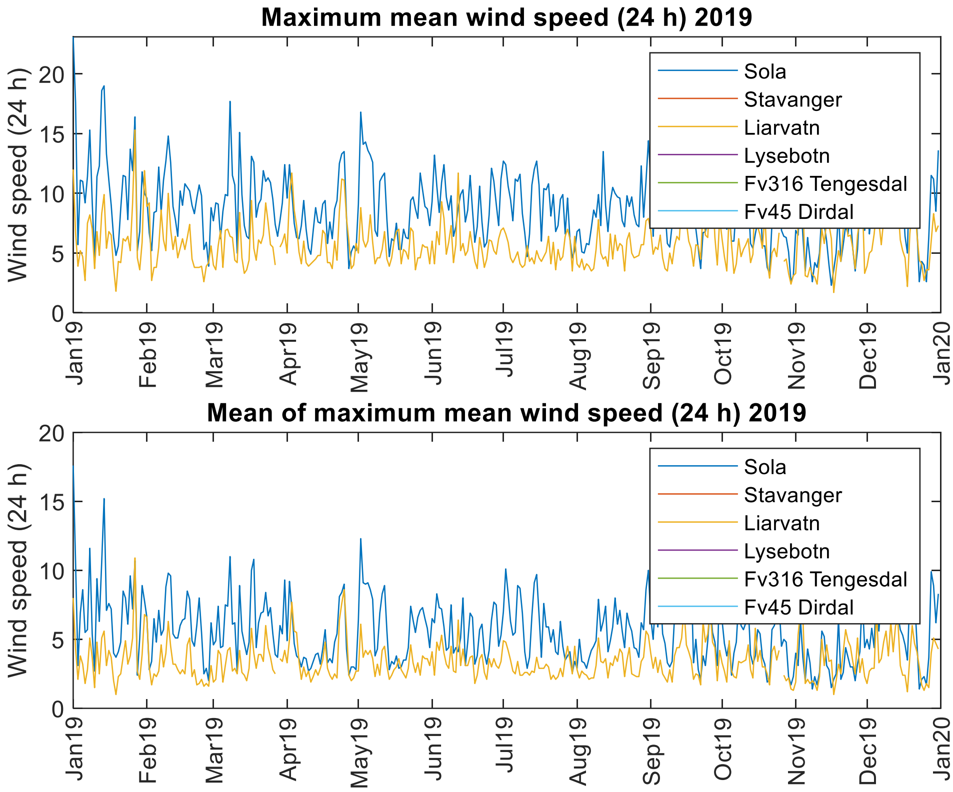


*Figure 86. Data related to wind speeds at stations near the bridge in 2019*

# Appendix D. The MATLAB code for extracting environmental conditions from stations' data

```
clear all

close all

clc


[NUM,TXT,RAW]=xlsread('CableBreakageTEMPhourly');

[NUMs,TXTs,RAWs]=xlsread('SolaH');

[NUMl,TXTl,RAWl]=xlsread('LiarvatnH');

x=datetime(RAW(3:end,5),'InputFormat','dd.MM.yyyy HH:mm');

y=datetime(RAWs(2:end-1,3),'InputFormat','dd.MM.yyyy HH:mm');

L=datetime(RAWl(2:end-1,3),'InputFormat','dd.MM.yyyy HH:mm');

SolaTemp=NUMs(:,1);SolaTempMax=NUMs(:,2);SolaTempMin=NUMs(:,3);SolaWindSpeed=NUMs(:,4
);

LiarvatnTemp=NUMl(:,1);LiarvatnTempMax=NUMl(:,2);LiarvatnTempMin=NUMl(:,3);LiarvatnTempW
ind=NUMl(:,4);


for i=1:297

  if find(y==x(i,1))

  idx=find(y==x(i,1));

  t(i,1)=NUMs(idx,1);%temperature

  t(i,2)=NUMs(idx,4);%windvelocity

  for j=0:12

    for k=1:3

    A(j+1,k)=NUMs(idx-j,k);

    end

  end

  t(i,3)=min(A,[],'all','omitnan');%min12htemperature

  t(i,4)=max(A,[],'all','omitnan');%max12htemperature

  for j=0:24

    for k=1:3

    A(j+1,k)=NUMs(idx-j,k);
```

```
    end
  end
  t(i,5)=min(A,[],'all','omitnan');%min24htemperature
  t(i,6)=max(A,[],'all','omitnan');%man24htemperature
  for j=0:48
    for k=1:3
    A(j+1,k)=NUMs(idx-j,k);
    end
  end
  t(i,7)=min(A,[],'all','omitnan');%min48htemperature
  t(i,8)=max(A,[],'all','omitnan');%max48htemperature
  A=0;
  else
    t(i,1:8)=NaN;
  end
end

TemperatureBreakageSola=t(:,1);
WindSpeedBreakageSola=t(:,2);
H12GradSola=t(:,4)-t(:,3);
H24GradSola=t(:,6)-t(:,5);
H48GradSola=t(:,8)-t(:,7);

for i=1:297
  if find(L==x(i,1))
  idx=find(L==x(i,1));
  tl(i,1)=NUMl(idx,1);%temperature
  tl(i,2)=NUMl(idx,4);%windvelocity
  for j=0:12
    for k=1:3
    A(j+1,k)=NUMl(idx-j,k);
```

```
    end
  end
  tl(i,3)=min(A,[],'all','omitnan');%min12htemperature
  tl(i,4)=max(A,[],'all','omitnan');%max12htemperature
  for j=0:24
    for k=1:3
    A(j+1,k)=NUMl(idx-j,k);
    end
  end
  tl(i,5)=min(A,[],'all','omitnan');%min24htemperature
  tl(i,6)=max(A,[],'all','omitnan');%man24htemperature
  for j=0:48
    for k=1:3
    A(j+1,k)=NUMl(idx-j,k);
    end
  end
  tl(i,7)=min(A,[],'all','omitnan');%min48htemperature
  tl(i,8)=max(A,[],'all','omitnan');%max48htemperature
  A=0;
  else
    tl(i,1:8)=NaN;
  end
end
TemperatureBreakageLiarvatn=tl(:,1);
WindSpeedBreakageLiarvatn=tl(:,2);
H12GradLiarvatn=tl(:,4)-tl(:,3);
H24GradLiarvatn=tl(:,6)-tl(:,5);
H48GradLiarvatn=tl(:,8)-tl(:,7);
```

# Appendix E. ABAQUS output

```
*Heading
** Job name: Job-2 Model name: Lysefjord bridge
** Generated by: Abaqus/CAE 2017x
*Preprint, echo=NO, model=NO, history=NO, contact=NO
**
** PARTS
**
*Part, name="Lysefjord bridge"
*Node
      1, -296.906006,      -5.125,   53.4646988
      2, -223.336304,      -5.125,   102.260002
      3, -223.277405,  -5.1947999,   99.9768982
      4, -223.218491,  -5.2645998,   97.6938019
      5, -223.218491,  -3.5114882,   97.6938019
      6, -223.218491,  -1.7557441,   97.6938019
      7, -223.218491,          0.,   97.6938019
      8, -223.218491,  1.75311184,   97.6938019
      9, -223.218491,  3.50885582,   97.6938019
     10, -223.218491,   5.2645998,   97.6938019
     11, -223.277405,   5.1947999,   99.9768982
     12, -223.336304,       5.125,   102.260002
     13, -296.906006,       5.125,   53.4646988
     14,       -204.,      -5.125,   95.3752975
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*Elset, elset=Set-1
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*Nset, nset=MainCables
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 215, 216, 217, 218, 230, 233, 238, 239, 281, 286
*Elset, elset=MainCables
 13,  16,  17,  27,  38,  41,  49,  54,  55,  72,  73,  74,  99, 102, 111, 115
 119, 129, 130, 131, 132, 144, 154, 156, 157, 158, 159, 164, 167, 171, 179, 196
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 248, 264, 265, 266, 274, 277, 289, 293, 312, 320, 323, 327, 332, 333, 334, 335
 336, 337, 352, 360, 369, 370, 422, 433
*Nset, nset=Hangers
 14,  17,  18,  19,  23,  25,  26,  27,  28,  29,  30,  36,  37,  40,  41,  42
 43,  44,  45,  46,  50,  51,  54,  55,  57,  59,  60,  61,  62,  63,  83,  84
 85,  86,  87,  88,  89,  90,  91,  92,  93,  94,  95,  96,  97,  98,  99, 100
 101, 102, 103, 104, 105, 108, 109, 113, 115, 116, 117, 118, 119, 120, 122, 123
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198, 199, 201, 202, 205, 206, 209, 210, 212, 213, 214, 215, 216, 217, 218, 219
220, 222, 223, 226, 229, 230, 231, 232, 237, 238, 239, 281

*Elset, elset=Hangers

18, 26, 28, 39, 42, 50, 53, 56, 71, 80, 101, 110, 112, 114, 116, 118
120, 122, 126, 128, 133, 142, 145, 150, 160, 163, 165, 168, 170, 178, 180, 191
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*Nset, nset=Boundary

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*Elset, elset=Boundary

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*Nset, nset=Dummy2

19, 20, 21, 22, 23, 24, 31, 32, 33, 40, 47, 48, 49, 50, 51, 52
53, 54, 55, 56, 57, 58, 59, 63, 84, 93, 98, 104, 105, 106, 107, 108
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162, 163, 164, 171, 188, 193, 194, 195, 196, 197, 198, 200, 203, 204, 209, 211
221, 222, 223, 224, 225, 229, 234, 236, 237, 280

*Elset, elset=Dummy2

20, 22, 24, 60, 62, 64, 66, 68, 70, 75, 76, 104, 135, 137, 153, 161
173, 184, 187, 201, 224, 234, 243, 272, 278, 282, 296, 302, 306, 319, 326, 341
343, 373, 375, 418, 420

*Nset, nset=Dummy1

21, 22, 24, 25, 28, 29, 30, 31, 32, 33, 36, 39, 42, 46, 47, 48
49, 52, 53, 56, 58, 85, 86, 87, 88, 106, 107, 109, 114, 115, 118, 121
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220, 221, 224, 225, 226, 231, 232, 234, 235, 236

*Elset, elset=Dummy1

25, 31, 40, 44, 51, 57, 77, 100, 106, 113, 124, 125, 139, 162, 166, 175

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 345, 353, 361, 363, 376
*Nset, nset=Girder
  21,  22,  24,  31,  32,  33,  47,  48,  49,  52,  53,  56,  58, 106, 107, 114
 121, 129, 130, 134, 140, 145, 146, 151, 152, 163, 164, 193, 200, 203, 204, 211
 221, 224, 225, 234, 236
*Elset, elset=Girder
  21,  32,  33,  34,  35,  58,  59,  63,  67,  69, 105, 136, 155, 174, 183, 188
 189, 190, 202, 209, 217, 223, 235, 270, 271, 300, 303, 304, 307, 324, 328, 344
 364, 365, 366, 374
*Nset, nset=Dummy4
  19,  20,  23,  25,  28,  29,  30,  36,  39,  40,  42,  46,  50,  51,  54,  55
  57,  59,  63,  84,  85,  86,  87,  88,  93,  98, 104, 105, 108, 109, 115, 118
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 165, 171, 188, 191, 192, 194, 195, 196, 197, 198, 201, 202, 205, 209, 212, 219
 220, 222, 223, 226, 229, 231, 232, 235, 237, 280
*Elset, elset=Dummy4
  19,  23,  29,  30,  45,  46,  47,  48,  52,  61,  65, 103, 107, 108, 109, 117
 121, 123, 127, 134, 138, 140, 141, 143, 146, 151, 152, 169, 172, 176, 177, 181
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 285, 286, 287, 291, 292, 298, 309, 310, 314, 317, 318, 325, 330, 339, 342, 350
 354, 358, 362, 367, 372, 377, 378, 421
*Nset, nset=NIVA
   2,   3,  11,  12, 233, 243, 285, 286
*Elset, elset=NIVA
   2,  11, 382, 427
*Nset, nset=_PickedSet15, internal
 278, 303, 320, 329
*Nset, nset=Towerleg
   3,   4,   5,   6,   7,   8,   9,  10,  11,  15,  16,  34,  35,  38,  64,  65
  66,  67,  68,  69,  70,  71,  72,  73,  74,  75,  76,  77,  78,  79,  80,  81
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82, 110, 111, 112, 135, 136, 137, 174, 175, 176, 177, 178, 179, 180, 181, 182
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266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 282, 283
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318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329

*Elset, elset=Towerleg

3, 4, 5, 6, 7, 8, 9, 10, 14, 15, 36, 37, 78, 79, 81, 82
83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98
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447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462
463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474

*Nset, nset=Set-14

21, 22, 24, 31, 32, 33, 47, 48, 49, 52, 53, 56, 58, 106, 107, 114
121, 129, 130, 134, 140, 145, 146, 151, 152, 163, 164, 193, 200, 203, 204, 211
221, 224, 225, 234, 236

*Elset, elset=Set-14

21, 32, 33, 34, 35, 58, 59, 63, 67, 69, 105, 136, 155, 174, 183, 188
189, 190, 202, 209, 217, 223, 235, 270, 271, 300, 303, 304, 307, 324, 328, 344
364, 365, 366, 374

*Nset, nset=Set-15

21, 22, 24, 25, 28, 29, 30, 31, 32, 33, 36, 39, 42, 46, 47, 48
49, 52, 53, 56, 58, 85, 86, 87, 88, 106, 107, 109, 114, 115, 118, 121
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152, 163, 164, 165, 191, 192, 193, 200, 201, 202, 203, 204, 205, 211, 212, 219
220, 221, 224, 225, 226, 231, 232, 234, 235, 236

*Elset, elset=Set-15
25, 31, 40, 44, 51, 57, 77, 100, 106, 113, 124, 125, 139, 162, 166, 175
182, 203, 208, 210, 216, 218, 222, 236, 250, 279, 281, 297, 299, 308, 329, 340
345, 353, 361, 363, 376
*Nset, nset=Set-16
21, 22, 24, 31, 32, 33, 47, 48, 49, 52, 53, 56, 58, 106, 107, 114
121, 129, 130, 134, 140, 145, 146, 151, 152, 163, 164, 193, 200, 203, 204, 211
221, 224, 225, 234, 236
*Elset, elset=Set-16
21, 32, 33, 34, 35, 58, 59, 63, 67, 69, 105, 136, 155, 174, 183, 188
189, 190, 202, 209, 217, 223, 235, 270, 271, 300, 303, 304, 307, 324, 328, 344
364, 365, 366, 374
*Nset, nset=Set-17
21, 22, 24, 31, 32, 33, 47, 48, 49, 52, 53, 56, 58, 106, 107, 114
121, 129, 130, 134, 140, 145, 146, 151, 152, 163, 164, 193, 200, 203, 204, 211
221, 224, 225, 234, 236
*Elset, elset=Set-17
21, 32, 33, 34, 35, 58, 59, 63, 67, 69, 105, 136, 155, 174, 183, 188
189, 190, 202, 209, 217, 223, 235, 270, 271, 300, 303, 304, 307, 324, 328, 344
364, 365, 366, 374
*Nset, nset=Set-18
19, 20, 21, 22, 23, 24, 31, 32, 33, 40, 47, 48, 49, 50, 51, 52
53, 54, 55, 56, 57, 58, 59, 63, 84, 93, 98, 104, 105, 106, 107, 108
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162, 163, 164, 171, 188, 193, 194, 195, 196, 197, 198, 200, 203, 204, 209, 211
221, 222, 223, 224, 225, 229, 234, 236, 237, 280
*Elset, elset=Set-18
20, 22, 24, 60, 62, 64, 66, 68, 70, 75, 76, 104, 135, 137, 153, 161
173, 184, 187, 201, 224, 234, 243, 272, 278, 282, 296, 302, 306, 319, 326, 341
343, 373, 375, 418, 420
*Nset, nset=Set-19

19, 20, 23, 25, 28, 29, 30, 36, 39, 40, 42, 46, 50, 51, 54, 55
57, 59, 63, 84, 85, 86, 87, 88, 93, 98, 104, 105, 108, 109, 115, 118
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165, 171, 188, 191, 192, 194, 195, 196, 197, 198, 201, 202, 205, 209, 212, 219
220, 222, 223, 226, 229, 231, 232, 235, 237, 280
*Elset, elset=Set-19
19, 23, 29, 30, 45, 46, 47, 48, 52, 61, 65, 103, 107, 108, 109, 117
121, 123, 127, 134, 138, 140, 141, 143, 146, 151, 152, 169, 172, 176, 177, 181
185, 186, 192, 197, 205, 207, 214, 215, 225, 245, 246, 269, 276, 280, 283, 284
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354, 358, 362, 367, 372, 377, 378, 421
*Nset, nset=Set-20
21, 38, 236, 279
*Elset, elset=Set-20
43, 419
*Nset, nset=Set-21
14, 17, 18, 19, 23, 25, 26, 27, 28, 29, 30, 36, 37, 40, 41, 42
43, 44, 45, 46, 50, 51, 54, 55, 57, 59, 60, 61, 62, 63, 83, 84
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198, 199, 201, 202, 205, 206, 209, 210, 212, 213, 214, 215, 216, 217, 218, 219
220, 222, 223, 226, 229, 230, 231, 232, 237, 238, 239, 281
*Elset, elset=Set-21
18, 26, 28, 39, 42, 50, 53, 56, 71, 80, 101, 110, 112, 114, 116, 118
120, 122, 126, 128, 133, 142, 145, 150, 160, 163, 165, 168, 170, 178, 180, 191
200, 204, 206, 213, 219, 221, 226, 233, 237, 244, 247, 249, 267, 268, 273, 275
288, 290, 294, 295, 301, 305, 311, 313, 315, 316, 331, 338, 346, 349, 351, 355
356, 357, 359, 368, 371, 430

*Nset, nset=Set-22
2, 12, 14, 17, 18, 26, 27, 37, 41, 43, 44, 45, 60, 61, 62, 83
89, 90, 91, 92, 94, 95, 96, 97, 99, 100, 101, 102, 103, 113, 116, 117
119, 125, 126, 138, 139, 141, 142, 148, 149, 155, 156, 157, 158, 159, 160, 161
166, 167, 168, 169, 170, 172, 173, 186, 187, 189, 190, 199, 206, 210, 213, 214
215, 216, 217, 218, 230, 233, 238, 239, 281, 286
*Elset, elset=Set-22
13, 16, 17, 27, 38, 41, 49, 54, 55, 72, 73, 74, 99, 102, 111, 115
119, 129, 130, 131, 132, 144, 154, 156, 157, 158, 159, 164, 167, 171, 179, 196
198, 199, 211, 212, 220, 227, 228, 229, 230, 231, 232, 238, 239, 240, 241, 242
248, 264, 265, 266, 274, 277, 289, 293, 312, 320, 323, 327, 332, 333, 334, 335
336, 337, 352, 360, 369, 370, 422, 433
*Nset, nset=Set-23
1, 2, 12, 13, 233, 242, 286, 287
*Elset, elset=Set-23
1, 12, 381, 428
*Nset, nset=Set-24
2, 3, 4, 10, 11, 12, 15, 16, 34, 35, 64, 65, 69, 70, 71, 72
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302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317
318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329
*Elset, elset=Set-24
2, 3, 10, 11, 14, 15, 36, 37, 78, 79, 85, 86, 87, 88, 89, 90
91, 92, 93, 94, 95, 96, 97, 98, 147, 149, 193, 195, 251, 252, 253, 254
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 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466
 467, 468, 469, 470, 471, 472, 473, 474
*Nset, nset=Set-25
   4,   5,   6,   7,   8,   9,  10,  38,  66,  67,  68,  69, 111, 136, 244, 245
 246, 247, 248, 249, 250, 267, 279, 288, 289, 293, 297, 301
*Elset, elset=Set-25
   4,   5,   6,   7,   8,   9,  81,  82,  83,  84, 148, 194, 384, 385, 386, 387
 388, 389, 429, 431, 432, 437, 441, 445
** Section: BackStayedCables  Profile: BackStayCables
*Beam General Section, elset=Set-1, density=7120., section=GENERAL
0.05, 2.6e-06, 0., 2.6e-06, 5.2e-06
0.,1.,0.
 1.8e+11, 8.07e+10,    1e-05
** Section: Niva30  Profile: Niva30
*Beam General Section, elset=NIVA, density=1e-05, section=GENERAL
5.9503, 3.9378, 0.1, 14.1549, 11.3331
1.,0.,0.
 4e+10, 1.67e+10,       0.
** Region: (Niva30:Towerleg), (Beam Orientation:Set-24)
*Elset, elset=_I3, internal
   3,  10,  14,  15,  36,  37,  78,  79,  85,  86,  87,  88,  89,  90,  91,  92
  93,  94,  95,  96,  97,  98, 147, 149, 193, 195, 251, 252, 253, 254, 255, 256
 257, 258, 259, 260, 261, 262, 263, 321, 322, 347, 348, 379, 380, 383, 390, 391
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 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470
 471, 472, 473, 474
** Section: Niva30  Profile: Niva30
*Beam General Section, elset=_I3, density=1e-05, section=GENERAL
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5.9503, 3.9378, 0.1, 14.1549, 11.3331
1.,0.,0.
 4e+10, 1.67e+10,      0.
** Region: (Niva30:Towerleg), (Beam Orientation:Set-25)
*Elset, elset=_I4, internal
   4,   5,   6,   7,   8,   9,  81,  82,  83,  84, 148, 194, 384, 385, 386, 387
 388, 389, 429, 431, 432, 437, 441, 445
** Section: Niva30  Profile: Niva30
*Beam General Section, elset=_I4, density=1e-05, section=GENERAL
5.9503, 3.9378, 0.1, 14.1549, 11.3331
0.,0.,1.
 4e+10, 1.67e+10,      0.
** Section: MainCables  Profile: MainCables
*Beam General Section, elset=MainCables, density=8160., section=GENERAL
0.05, 2.6e-06, 0., 2.6e-06, 5.2e-06
0.,1.,0.
 1.8e+11, 8.07e+10,    1e-05
** Section: Hangers  Profile: Hangers
*Beam General Section, elset=Hangers, density=0.001, section=GENERAL
0.0018, 2.6e-09, 0., 2.6e-09, 5.2e-09
1.,1.,0.
 1.8e+11, 6.3077e+10,      1e-05
** Section: Dummy4  Profile: Dummy4
*Beam General Section, elset=Dummy4, density=1e-05, section=GENERAL
0.36, 0.429, 0., 4.952, 0.929, 0., 4.762
0.,1.,0.
 2.1e+06,807000.,  1e-05
** Section: Dummy2  Profile: Dummy2
*Beam General Section, elset=Dummy2, density=1e-12, section=GENERAL
1000., 1000., 0., 1000., 1000.
0.,0.,1.
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 2.1e+11, 8.07e+10,    1e-05
** Section: Girder  Profile: Girder
*Beam General Section, elset=Girder, density=0.001, section=GENERAL
0.36, 0.429, 0., 4.952, 0.929, 0., 4.762
0.,1.,0.
 2.1e+11, 8.07e+10,    1e-05
** Section: Dummy1  Profile: Dummy1
*Beam General Section, elset=Dummy1, density=1e-12, section=GENERAL
1000., 1000., 0., 1000., 1000.
0.,0.,-1.
 2.1e+11, 8.07e+10,    1e-05
** Section: Boundary  Profile: Boundary
*Beam General Section, elset=Boundary, density=1e-06, section=GENERAL
100., 1000., 0., 1000., 1000.
1.,0.,0.
 4e+10, 1.67e+10,      0.
*Spring, elset=Springs/Dashpots-1-spring
6
1e+12
*Element, type=Spring1, elset=Springs/Dashpots-1-spring
475, 278
476, 303
477, 320
478, 329
*End Part
**
**
** ASSEMBLY
**
*Assembly, name=Assembly
**
```

```
*Instance, name="Lysefjord bridge-1", part="Lysefjord bridge"
*End Instance
**
*Node
      1,   -223.10144,  -7.34660006,         47.5
*Node
      2,   -223.10144,   7.34660006,         47.5
*MPC
TIE, 1, 2
*MPC
TIE, "Lysefjord bridge-1".10, "Lysefjord bridge-1".4
*MPC
TIE, "Lysefjord bridge-1".301, "Lysefjord bridge-1".267
*MPC
TIE, "Lysefjord bridge-1".244, "Lysefjord bridge-1".250
*Nset, nset=BackstayCables, instance="Lysefjord bridge-1"
   1,   2,  12,  13, 233, 242, 286, 287
*Elset, elset=BackstayCables, instance="Lysefjord bridge-1"
   1,  12, 381, 428
*Nset, nset=End, instance="Lysefjord bridge-1"
  21, 236
*Nset, nset=Main_Cables, instance="Lysefjord bridge-1"
   2,  12,  14,  17,  18,  26,  27,  37,  41,  43,  44,  45,  60,  61,  62,  83
  89,  90,  91,  92,  94,  95,  96,  97,  99, 100, 101, 102, 103, 113, 116, 117
 119, 125, 126, 138, 139, 141, 142, 148, 149, 155, 156, 157, 158, 159, 160, 161
 166, 167, 168, 169, 170, 172, 173, 186, 187, 189, 190, 199, 206, 210, 213, 214
 215, 216, 217, 218, 230, 233, 238, 239, 281, 286
*Elset, elset=Main_Cables, instance="Lysefjord bridge-1"
  13,  16,  17,  27,  38,  41,  49,  54,  55,  72,  73,  74,  99, 102, 111, 115
 119, 129, 130, 131, 132, 144, 154, 156, 157, 158, 159, 164, 167, 171, 179, 196
 198, 199, 211, 212, 220, 227, 228, 229, 230, 231, 232, 238, 239, 240, 241, 242
```

```
 248, 264, 265, 266, 274, 277, 289, 293, 312, 320, 323, 327, 332, 333, 334, 335
 336, 337, 352, 360, 369, 370, 422, 433
*Nset, nset=Rock, instance="Lysefjord bridge-1"
   1,  13, 242, 287
*Nset, nset=Set-24, instance="Lysefjord bridge-1"
  21,  22,  24,  31,  32,  33,  47,  48,  49,  52,  53,  56,  58, 106, 107, 114
 121, 129, 130, 134, 140, 145, 146, 151, 152, 163, 164, 193, 200, 203, 204, 211
 221, 224, 225, 234, 236
*Elset, elset=Set-24, instance="Lysefjord bridge-1"
  21,  32,  33,  34,  35,  58,  59,  63,  67,  69, 105, 136, 155, 174, 183, 188
 189, 190, 202, 209, 217, 223, 235, 270, 271, 300, 303, 304, 307, 324, 328, 344
 364, 365, 366, 374
*Nset, nset=Side, instance="Lysefjord bridge-1"
  19,  23,  25,  28,  29,  30,  36,  40,  42,  46,  50,  51,  54,  55,  57,  59
  63,  84,  85,  86,  87,  88,  93,  98, 104, 105, 108, 109, 115, 118, 120, 122
 123, 124, 127, 128, 131, 132, 133, 143, 144, 147, 150, 153, 154, 162, 165, 171
 188, 191, 192, 194, 195, 196, 197, 198, 201, 202, 205, 209, 212, 219, 220, 222
 223, 226, 229, 231, 232, 237
*Nset, nset=ToerLegs, instance="Lysefjord bridge-1"
 278, 303, 320, 329
*Nset, nset=Towelegload, instance="Lysefjord bridge-1"
   2,   3,   4,   5,   6,   7,   8,   9,  10,  11,  12,  15,  16,  34,  35,  38
  64,  65,  66,  67,  68,  69,  70,  71,  72,  73,  74,  75,  76,  77,  78,  79
  80,  81,  82, 110, 111, 112, 135, 136, 137, 174, 175, 176, 177, 178, 179, 180
 181, 182, 183, 184, 185, 207, 208, 227, 228, 233, 240, 241, 243, 244, 245, 246
 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261, 262
 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278
 279, 282, 283, 284, 285, 286, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297
 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313
 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329
*Elset, elset=Towelegload, instance="Lysefjord bridge-1"
```

```
 2,   3,   4,   5,   6,   7,   8,   9,  10,  11,  14,  15,  36,  37,  78,  79
 81,  82,  83,  84,  85,  86,  87,  88,  89,  90,  91,  92,  93,  94,  95,  96
 97,  98, 147, 148, 149, 193, 194, 195, 251, 252, 253, 254, 255, 256, 257, 258
259, 260, 261, 262, 263, 321, 322, 347, 348, 379, 380, 382, 383, 384, 385, 386
387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402
403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 423
424, 425, 426, 427, 429, 431, 432, 434, 435, 436, 437, 438, 439, 440, 441, 442
443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458
459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474
*Nset, nset=Under, instance="Lysefjord bridge-1"
 22,  24,  31,  32,  33,  47,  48,  49,  52,  53,  56,  58, 106, 107, 114, 121
129, 130, 134, 140, 145, 146, 151, 152, 163, 164, 193, 200, 203, 204, 211, 221
224, 225, 234
*Nset, nset=Wire-1-Set-1, instance="Lysefjord bridge-1"
 4, 10
*Nset, nset=Wire-2-Set-1, instance="Lysefjord bridge-1"
 4, 10
*Nset, nset=Wire-3-Set-1, instance="Lysefjord bridge-1"
 69, 136
*Nset, nset=Wire-4-Set-1, instance="Lysefjord bridge-1"
 69, 136
*Nset, nset=Wire-5-Set-1, instance="Lysefjord bridge-1"
244, 250
*Nset, nset=Wire-6-Set-1, instance="Lysefjord bridge-1"
244, 250
*Nset, nset=Wire-7-Set-1, instance="Lysefjord bridge-1"
267, 301
*Nset, nset=Wire-8-Set-1, instance="Lysefjord bridge-1"
267, 301
*Nset, nset=Wire-9-Set-1
1, 2
```

```
*Nset, nset=Wire-10-Set-1
 1, 2
*Nset, nset=Wire-11-Set-1, instance="Lysefjord bridge-1"
  4, 10
*Nset, nset=Wire-12-Set-1, instance="Lysefjord bridge-1"
 267, 301
*Nset, nset=Wire-13-Set-1, instance="Lysefjord bridge-1"
 244, 250
*Nset, nset=m_Set-4, instance="Lysefjord bridge-1"
 244,
*Nset, nset=s_Set-4, instance="Lysefjord bridge-1"
 250,
*Element, type=MASS, elset=End_End_
1, "Lysefjord bridge-1".21
2, "Lysefjord bridge-1".236
*Mass, elset=End_End_
50825.,
*Element, type=MASS, elset=Side_Side_
3, "Lysefjord bridge-1".19
4, "Lysefjord bridge-1".23
5, "Lysefjord bridge-1".25
6, "Lysefjord bridge-1".28
7, "Lysefjord bridge-1".29
8, "Lysefjord bridge-1".30
9, "Lysefjord bridge-1".36
10, "Lysefjord bridge-1".40
11, "Lysefjord bridge-1".42
12, "Lysefjord bridge-1".46
13, "Lysefjord bridge-1".50
14, "Lysefjord bridge-1".51
15, "Lysefjord bridge-1".54
```

16, "Lysefjord bridge-1".55

17, "Lysefjord bridge-1".57

18, "Lysefjord bridge-1".59

19, "Lysefjord bridge-1".63

20, "Lysefjord bridge-1".84

21, "Lysefjord bridge-1".85

22, "Lysefjord bridge-1".86

23, "Lysefjord bridge-1".87

24, "Lysefjord bridge-1".88

25, "Lysefjord bridge-1".93

26, "Lysefjord bridge-1".98

27, "Lysefjord bridge-1".104

28, "Lysefjord bridge-1".105

29, "Lysefjord bridge-1".108

30, "Lysefjord bridge-1".109

31, "Lysefjord bridge-1".115

32, "Lysefjord bridge-1".118

33, "Lysefjord bridge-1".120

34, "Lysefjord bridge-1".122

35, "Lysefjord bridge-1".123

36, "Lysefjord bridge-1".124

37, "Lysefjord bridge-1".127

38, "Lysefjord bridge-1".128

39, "Lysefjord bridge-1".131

40, "Lysefjord bridge-1".132

41, "Lysefjord bridge-1".133

42, "Lysefjord bridge-1".143

43, "Lysefjord bridge-1".144

44, "Lysefjord bridge-1".147

45, "Lysefjord bridge-1".150

46, "Lysefjord bridge-1".153

47, "Lysefjord bridge-1".154

48, "Lysefjord bridge-1".162

49, "Lysefjord bridge-1".165

50, "Lysefjord bridge-1".171

51, "Lysefjord bridge-1".188

52, "Lysefjord bridge-1".191

53, "Lysefjord bridge-1".192

54, "Lysefjord bridge-1".194

55, "Lysefjord bridge-1".195

56, "Lysefjord bridge-1".196

57, "Lysefjord bridge-1".197

58, "Lysefjord bridge-1".198

59, "Lysefjord bridge-1".201

60, "Lysefjord bridge-1".202

61, "Lysefjord bridge-1".205

62, "Lysefjord bridge-1".209

63, "Lysefjord bridge-1".212

64, "Lysefjord bridge-1".219

65, "Lysefjord bridge-1".220

66, "Lysefjord bridge-1".222

67, "Lysefjord bridge-1".223

68, "Lysefjord bridge-1".226

69, "Lysefjord bridge-1".229

70, "Lysefjord bridge-1".231

71, "Lysefjord bridge-1".232

72, "Lysefjord bridge-1".237

*Mass, elset=Side_Side_

17448.,

*Element, type=MASS, elset=Under_Under_

73, "Lysefjord bridge-1".22

74, "Lysefjord bridge-1".24

75, "Lysefjord bridge-1".31

76, "Lysefjord bridge-1".32

77, "Lysefjord bridge-1".33

78, "Lysefjord bridge-1".47

79, "Lysefjord bridge-1".48

80, "Lysefjord bridge-1".49

81, "Lysefjord bridge-1".52

82, "Lysefjord bridge-1".53

83, "Lysefjord bridge-1".56

84, "Lysefjord bridge-1".58

85, "Lysefjord bridge-1".106

86, "Lysefjord bridge-1".107

87, "Lysefjord bridge-1".114

88, "Lysefjord bridge-1".121

89, "Lysefjord bridge-1".129

90, "Lysefjord bridge-1".130

91, "Lysefjord bridge-1".134

92, "Lysefjord bridge-1".140

93, "Lysefjord bridge-1".145

94, "Lysefjord bridge-1".146

95, "Lysefjord bridge-1".151

96, "Lysefjord bridge-1".152

97, "Lysefjord bridge-1".163

98, "Lysefjord bridge-1".164

99, "Lysefjord bridge-1".193

100, "Lysefjord bridge-1".200

101, "Lysefjord bridge-1".203

102, "Lysefjord bridge-1".204

103, "Lysefjord bridge-1".211

104, "Lysefjord bridge-1".221

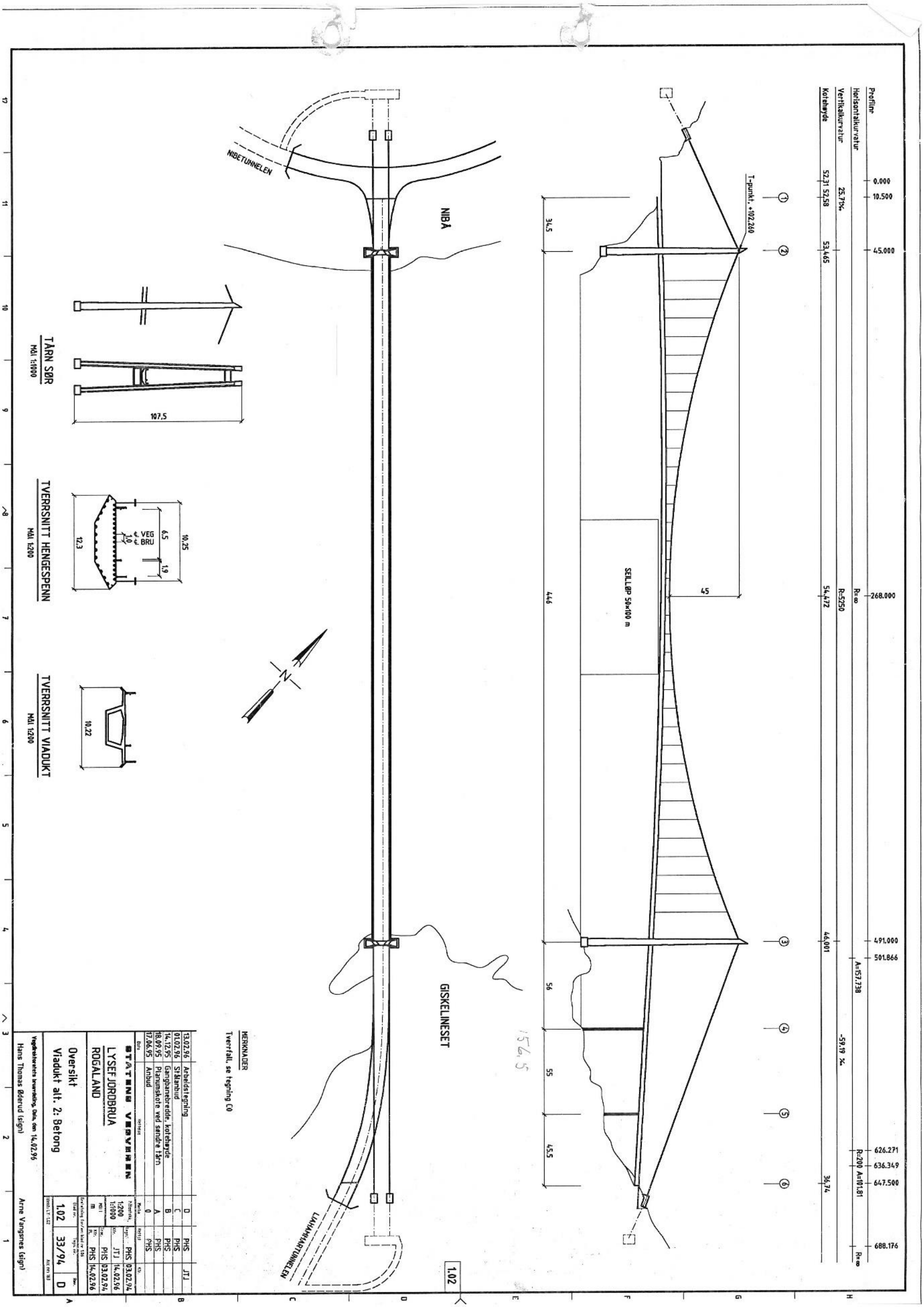
105, "Lysefjord bridge-1".224

```
106, "Lysefjord bridge-1".225
107, "Lysefjord bridge-1".234
*Mass, elset=Under_Under_
29304.,
*End Assembly
**
** BOUNDARY CONDITIONS
**
** Name: BC-1 Type: Displacement/Rotation
*Boundary
Rock, 1, 1
Rock, 2, 2
Rock, 3, 3
** Name: BC-2 Type: Displacement/Rotation
*Boundary
ToerLegs, 1, 1
ToerLegs, 2, 2
ToerLegs, 3, 3
ToerLegs, 4, 4
ToerLegs, 5, 5
** ----------------------------------------------------------------
**
** STEP: EGENVEKT
**
*Step, name=EGENVEKT, nlgeom=NO, inc=5000
*Static, stabilize=1e-10, allsdtol=0, continue=NO
1e-06, 1e-06, 1e-09, 1e-06
**
** LOADS
**
** Name: Gravity-1   Type: Gravity
```

```
*Dload
Main_Cables, GRAV, 8.5595, 0., 0., -1.
** Name: Gravity-2   Type: Gravity
*Dload
BackstayCables, GRAV, 9.81, 0., 0., -1.
** Name: Gravity-3   Type: Gravity
*Dload
Towelegload, GRAV, 9.81, 0., 0., -1.
** Name: LineLoad-4   Type: Line load
*Dload
Set-24, PZ, -52484.
**
** OUTPUT REQUESTS
**
*Restart, write, frequency=0
**
** FIELD OUTPUT: F-Output-1
**
*Output, field, variable=PRESELECT
**
** HISTORY OUTPUT: H-Output-1
**
*Output, history, variable=PRESELECT
*End Step
** ----------------------------------------------------------------
**
** STEP: Step-2
**
*Step, name=Step-2, nlgeom=NO, perturbation
*Frequency, eigensolver=Lanczos, sim=NO, acoustic coupling=on, normalization=displacement
110, , , , ,
```

```
**
** OUTPUT REQUESTS
**
*Restart, write, frequency=0
**
** FIELD OUTPUT: F-Output-2
**
*Output, field, variable=PRESELECT
*End Step
```

# Appendix F. The drawings of the bridge



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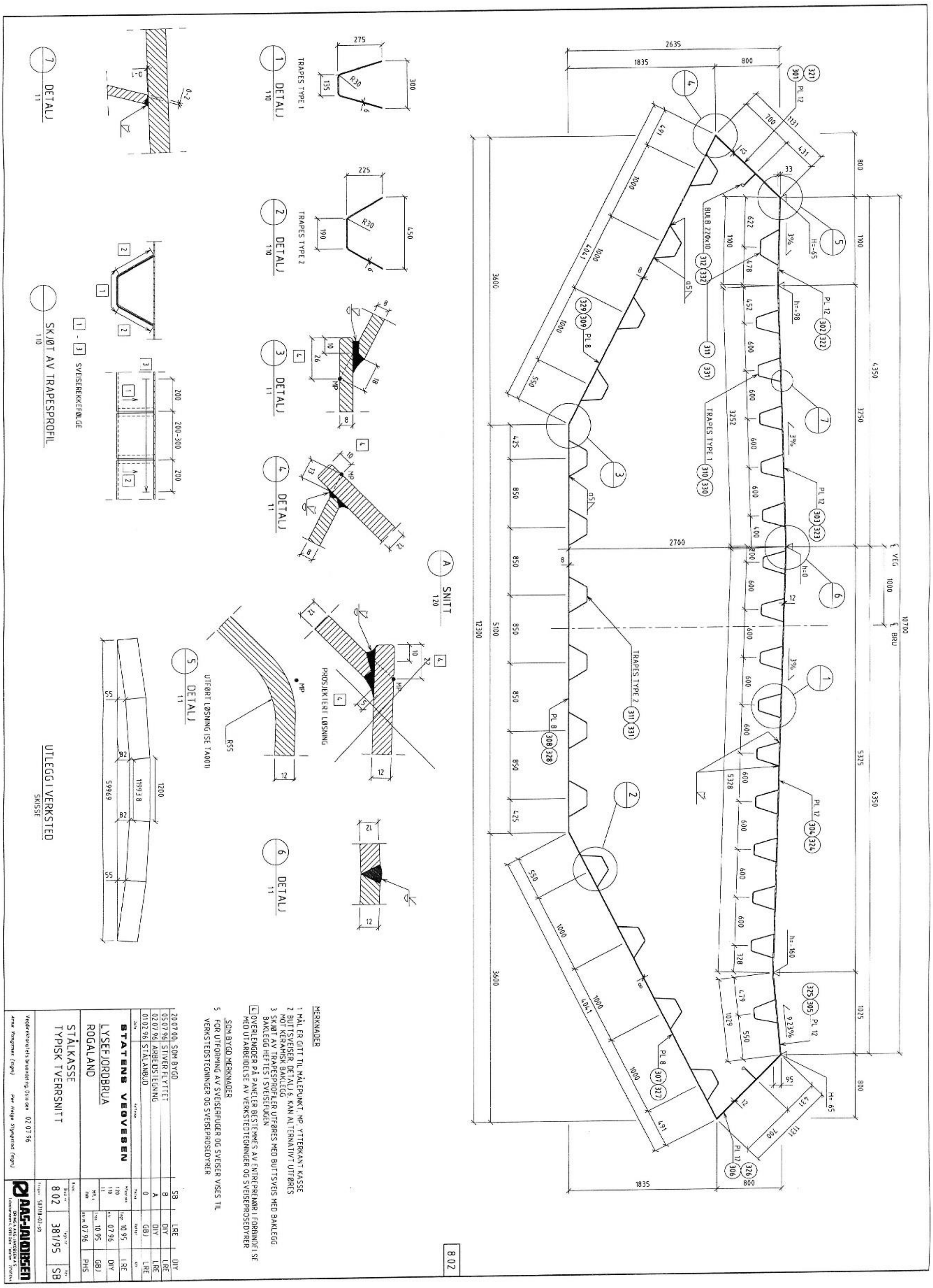

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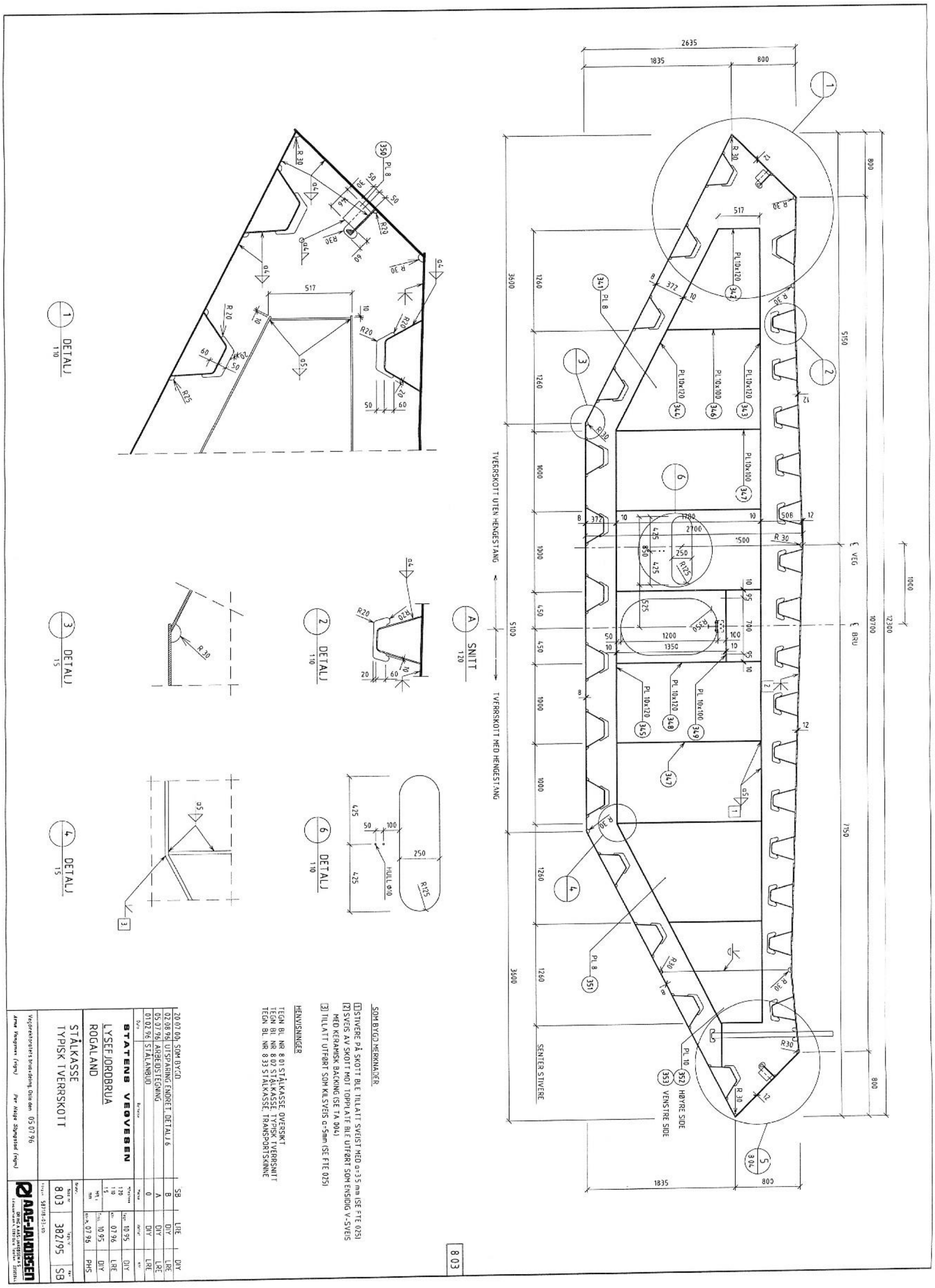

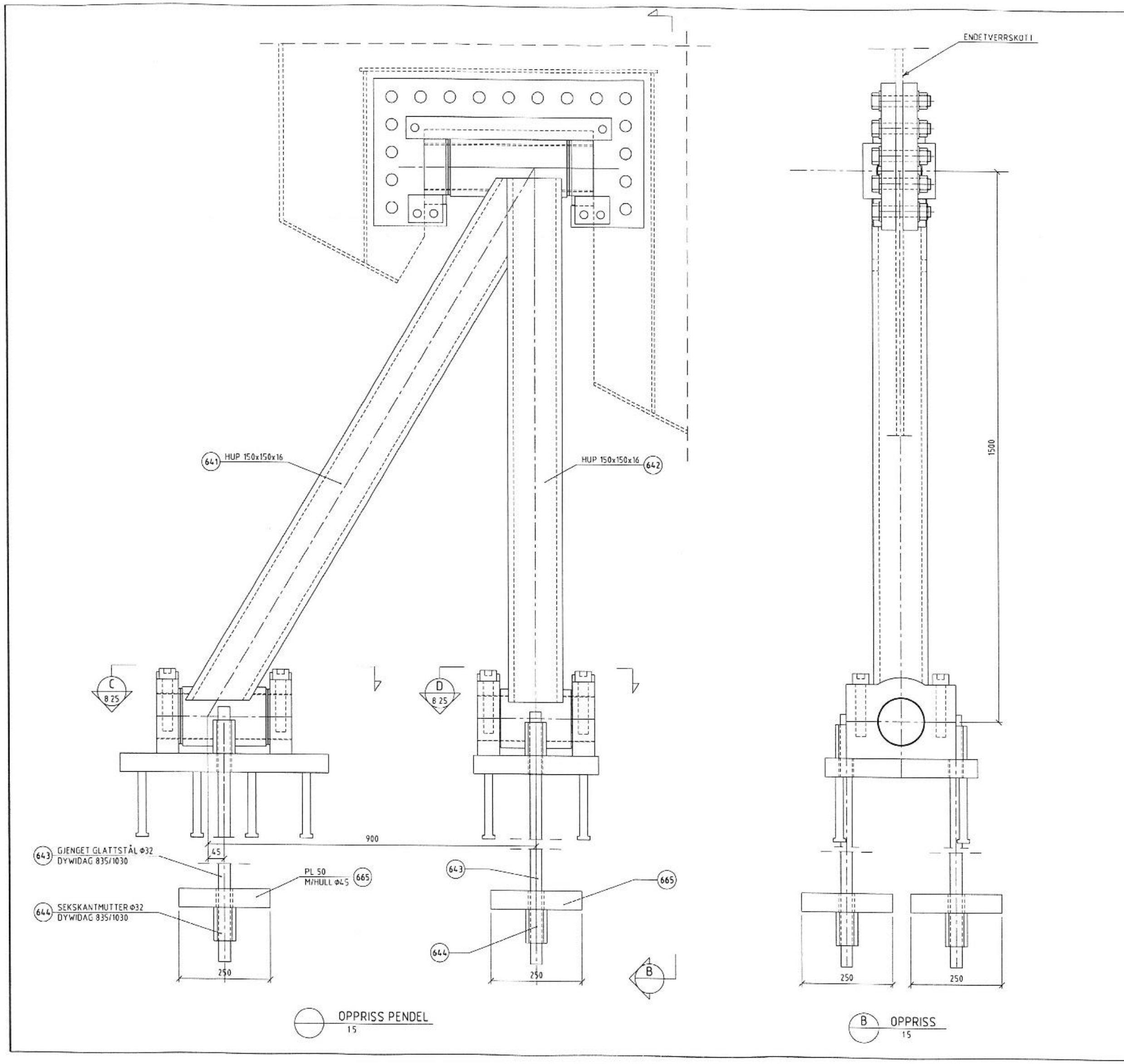


MERKNADER

1. DYWIDAGSTAG BLÅSERENSES LETT MED FIN SAND FØR PÅFØRING AV SYSTEM 4
2. TILLATT LODDAVVIK FERDIG MONTERT PENDEL ± 0.1 %
3. DYWIDAG STRAMMES TIL 300 kN

HENVISNINGER

TEGN BL NR 8.25 STÅLKASSE, PENDEL SØR, DETALJER
TEGN BL NR 9.12 SØNDRE TÅRN, LAGER OG FUGEPLASSERING

| Dato | Rettelse | Merke | Rettet | Kfr |
|---|---|---|---|---|
| 20.07.00 | SOM BYGD | SB | LRE | DIY |
| 20.09.96 | ARBEIDSTEGNING | A | DIY | LRE |
| 20.07.00 | SOM BYGD | SB | LRE | DIY |

STATENS VEGVESEN

LYSEFJORDBRUA
ROGALAND

STÅLKASSE
PENDEL SØR
OVERSIKT

| | | |
|---|---|---|
| Målestokk 1:5 | Tegn 11.95 | DIY |
| | Kfr 09.96 | LRE |
| Mål i mm | Trac 11.95 | GBJ |
| | Ktrpl 09.96 | PHS |

Bru nr

| Side nr | Tegn nr | Rev |
|---|---|---|
| 8.24 | 398/95 | SB |

Filnavn 5871/8-24-sb

Vegdirektoratets bruavdeling, Oslo den 20.09.96

Arne Vangsnes (sign.) Per Helge Siyngstad (sign.)

AAS-JAKOBSEN
DR ING A AAS-JAKOBSEN A S

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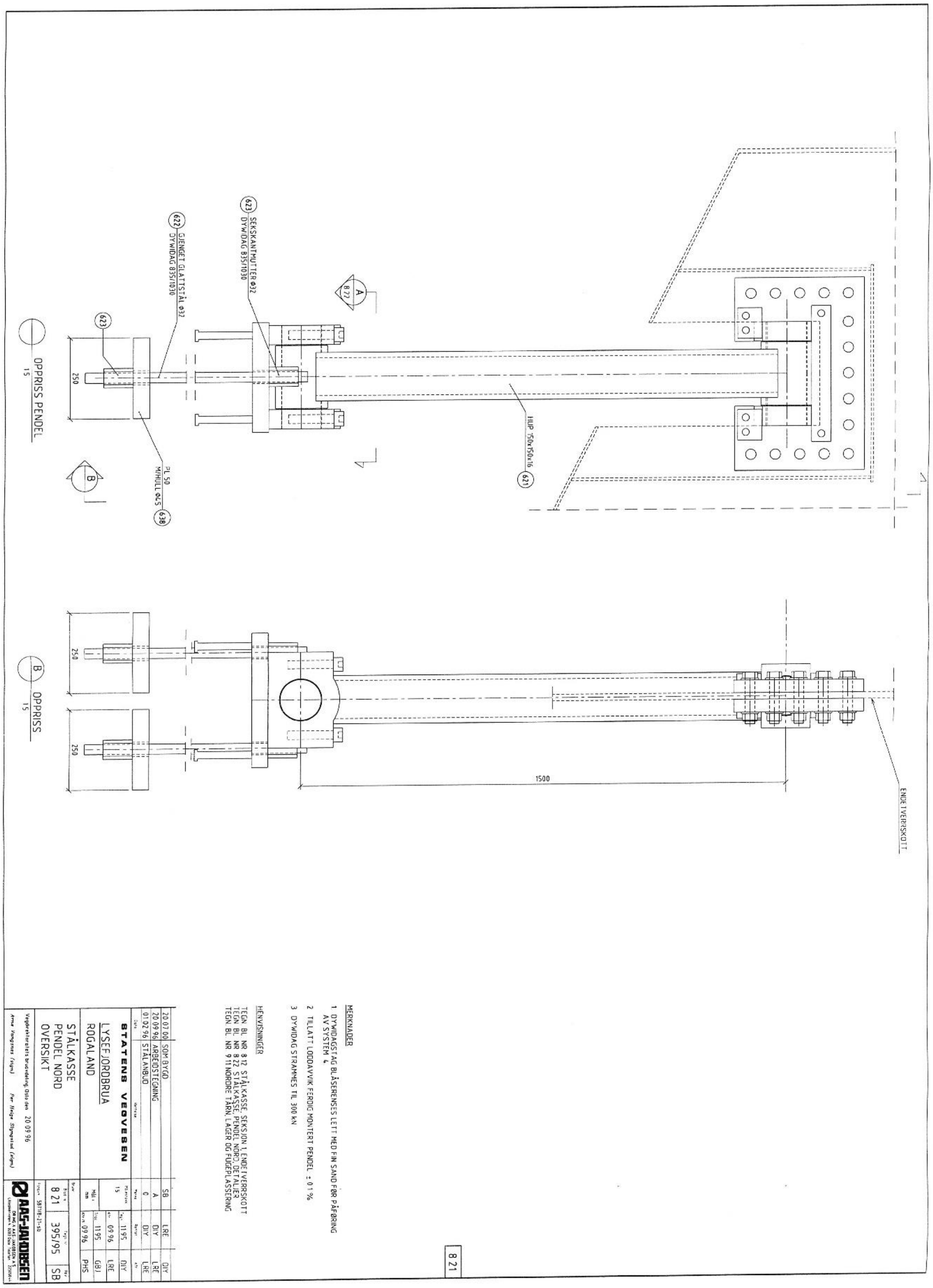
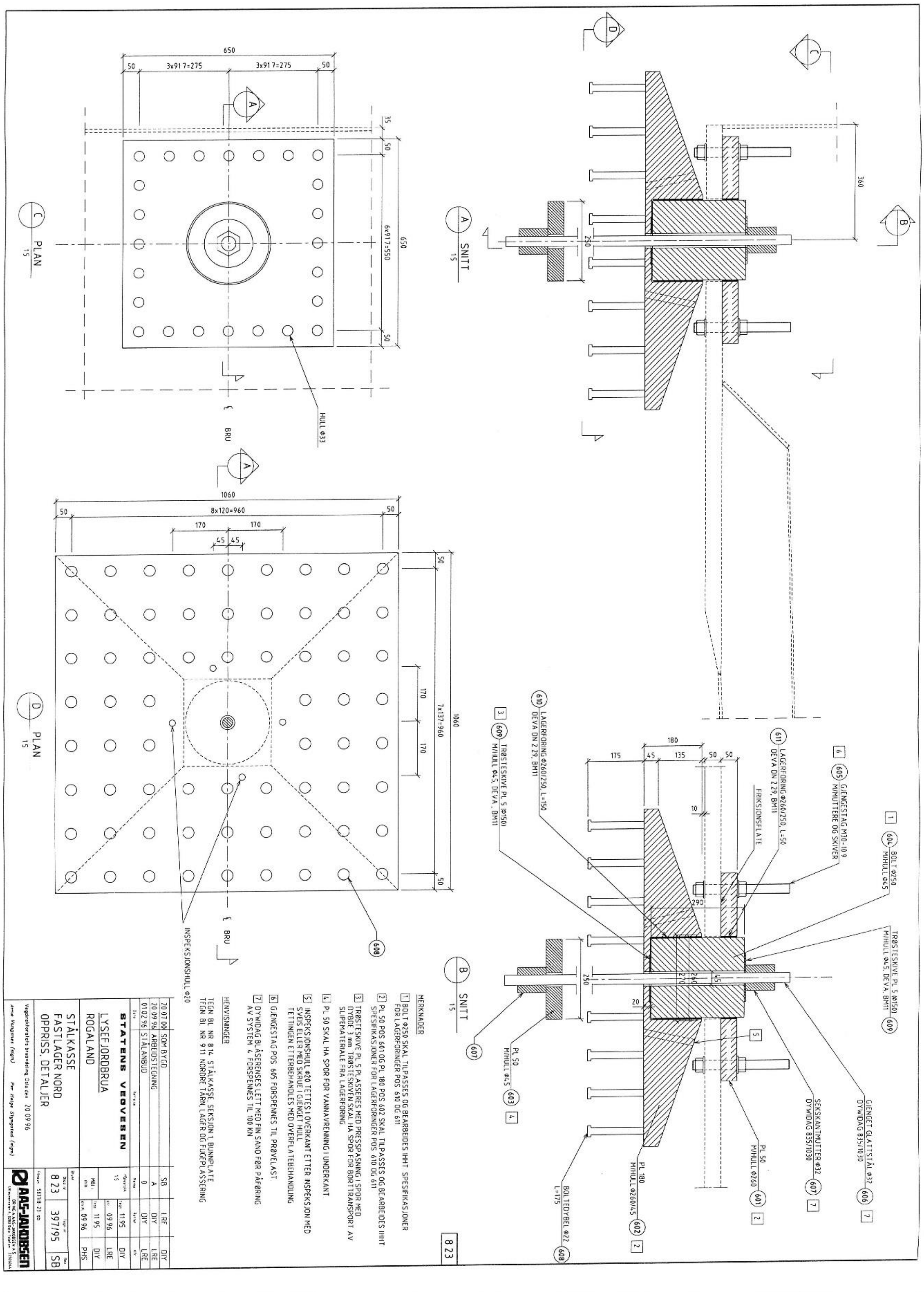
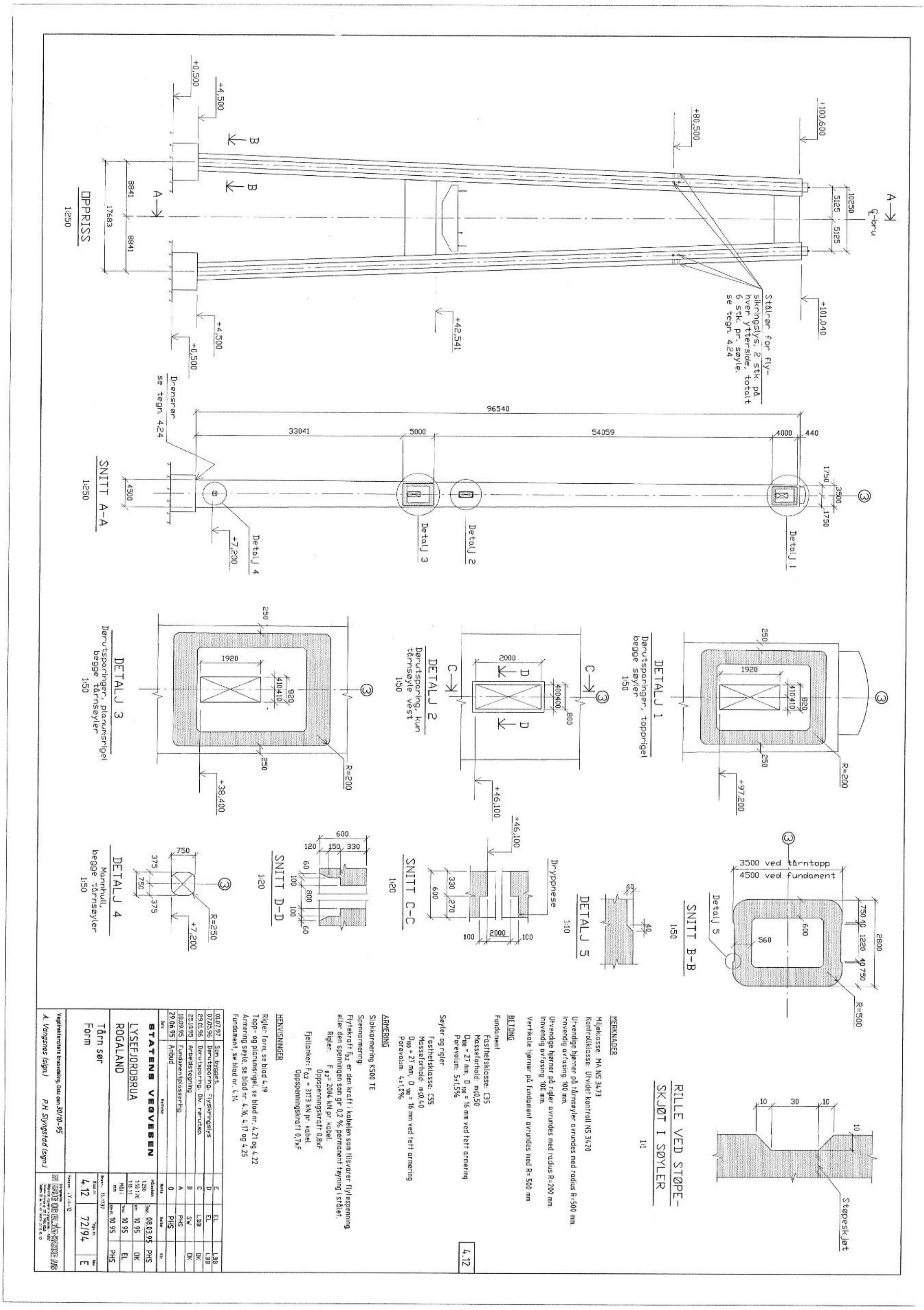



PLAN 1:5
SNITT 1:5
MERKNADER
HENVISNINGER
STATENS VEGVESEN
LYSEFJORDBRUA
ROGALAND
STÅLKASSE
FASTLAGER NORD
OPPRISS, DETALJER
823
397/95
SB



OPPRISS
SNITT A-A
DETALJ 1
DETALJ 2
DETALJ 3
DETALJ 4
DETALJ 5
SNITT B-B
SNITT C-C
SNITT D-D
RILLE VED STØPE-SKJØT I SØYLER
MERKNADER
BETONG
ARMERING
HENVISNINGER
STATENS VEGVESEN
LYSEFJORDBRUA
ROGALAND
Tårn sør
Form