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LABORATORY TESTS ON A POST-TENSIONED TIMBER FRAME

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Zurich

November 2017

Foreword

In the past decades, precast concrete frames were developed using tendons to connect columns and beams. These systems exhibit favourable seismic behaviour, enabling alleviation of post-earthquake residual deformations. The use of post-tensioned timber structures has recently been studied at the Institute of Structural Engineering at the ETH in Zurich in cooperation with the industrial partner Häring & Co. AG. As a result, an innovative post-tensioned beam-column timber joint was developed using glued laminated timber made of spruce and local strengthening of the joint with hardwood.

The present report demonstrates the outcomes of a comprehensive series of static pushover tests and dynamic modal tests conducted on a post-tensioned timber frame within the framework of the doctoral theses of Flavio Wanninger and Claude Leyder, as well as part of the construction process of the House of Natural Resources. The tests presented in this report extend the experimental background and form an important step toward evaluation of the structural behaviour of the developed post-tensioned timber frame under horizontal loading. The test results verify a favourable structural behaviour under horizontal loading, i.e., a large deformation capacity, a self-centring behaviour and a decreasing stiffness under increasing horizontal loading.

We would like to thank Claude Leyder and Flavio Wanninger who have prepared and carefully conducted all tests and further processed and evaluated the large amount of data and edited this report. Additionally, we would like to thank the team of the IBK testing and research lab for their substantial support. Further, we would like to gratefully acknowledge the support by the Commission of Technology and Innovation CTI, ETH Foundation, Climate KIC and the industrial partner Häring & Co. AG.

Zurich, November 2017

Eleni Chatzi and Andrea Frangi

Abstract

Static pushover tests and dynamic modal vibration tests were conducted on a post-tensioned timber frame within the framework of two doctoral theses, as well as part of the construction process of the House of Natural Resources. The post-tensioned timber frame is a hybrid system with hardwood columns and beams made of softwood with local hardwood reinforcement close to the beam-column joint. The connection between columns and beams is materialized via a tendon, which can be post-tensioned to different load levels. The goal of the conducted tests is to study the influence of the tendon force level and the influence of two bottom support types for the column on the structural behaviour under horizontal loading.

The pushover tests on the post-tensioned timber frame showed a stiffness dependency on the tendon force. The tests additionally showed a favourable behaviour under horizontal loading, i.e., a large deformation capacity, a self-centering behaviour and a decreasing stiffness under increasing horizontal loading.

For the modal vibration tests, the frame was equipped with three different sensor sets: acceleration, tilt, and strain sensors. Furthermore, two different excitation techniques were implemented (impact hammer and shaker). Details on the test setup, excitation techniques, and the testing process are documented herein. During the dynamic tests, frequencies, damping ratios and mode shapes of the timber frame were investigated. To process the dynamic data an automated evaluation framework for dynamic vibration data is presented. The framework is able to determine eigenfrequencies of the frame structure with a low coefficient of variation, whereas the coefficient of variation is more than an order of magnitude higher for damping ratios. Additionally, mode shapes are identifiable with high consistency. Furthermore, the influence of the post-tension load and the bottom column support on the dynamic characteristics was analysed. From the dynamic point of view, there is a significant influence of the support condition, whereas the influence of the tendon force is negligible.

Contents

Chapter 1

Introduction

In the past decades, precast concrete frames were developed using tendons to connect columns and beams [1–3]. These systems exhibit a favourable seismic behaviour and alleviate residual deformations after an earthquake. Furthermore, a model, named the monolithic beam analogy, was developed to describe the connection behaviour [4]. A similar system for timber was introduced in New Zealand at the University of Canterbury [5–11]. A timber frame, made of laminated veneer lumber was post-tensioned, resulting in a favourable structural behaviour. Design proposals were published [12–16] and buildings using the post-tensioned timber frames were constructed [17].

Post-tensioned timber joints are additionally studied at the institute of structural engineering at the ETH Zürich [18]. An innovative post-tensioned beam-column timber joint has been developed using glued laminated timber (spruce, picea abies) and local strengthening of the joint with hardwood (ash, fraxinus excelsior). No further steel elements are required for the moment-resisting timber joint with the exception of a single straight tendon placed in a cavity in the middle of the beam. The developed post-tensioned beam-column timber joint is characterised by a high degree of pre-fabrication and easy assembly on site. The moment-rotation behaviour of the joint has been studied extensively in the past [19]. The focus in that investigation was on vertical loads, only some tests were conducted with an asymmetrical loading leading to shear deformations in the column.

This report describes the experimental investigations on a three bay post-tensioned timber frame (cf. Figure 1.1), conducted to further study the behaviour of post-tensioned timber structures. Several pushover-tests were performed, subjecting the post-tensioned timber frame to horizontal loading up to 300 kN. In addition, a series of dynamic tests were carried out to quantify the dynamic parameters of the frame. All tests were performed with different tendon forces and connections at the bottom of the columns, i.e., the columns were pinned or fixed to the strong floor of the testing facility. In the current report, all tests are documented, including details of the test setup, measurement instrumentation, and conduction of the tests.

The testing report is organized as follows: In chapter 2, the frame specimen and the test setup are described. The experimental investigations are described in chapter 3 and chapter 4 presents an overview of the methods implemented for experimental analysis. The results of the tests are given in chapter 5 and are then discussed in chapter 6. Chapter 7 provides a short summary of the main findings from the tests.

Fig. 1.1: Three-bay post-tensioned frame test setup on the strong floor at the ETH Zurich

Chapter 2

Specimen and test setup

2.1 Material and dimensions

The post-tensioned timber frame consists of three beams and four columns made of glulam, as illustrated in Figure 2.1. The beams are made of spruce except for the four lower lamellae close to the beam-column interface, which are made of ash. The beams have a dimension of 6.12×0.72×0.28 m. The lamella thickness is 0.4 m. The columns are made entirely of ash and have a dimension of 3.3×0.38×0.38 m. The ash hardwood satisfies the properties of the timber grading class D40, according to EN 338 [20], whereas the spruce glulam corresponds to the grading class GL24h, according to SIA 265 [21].

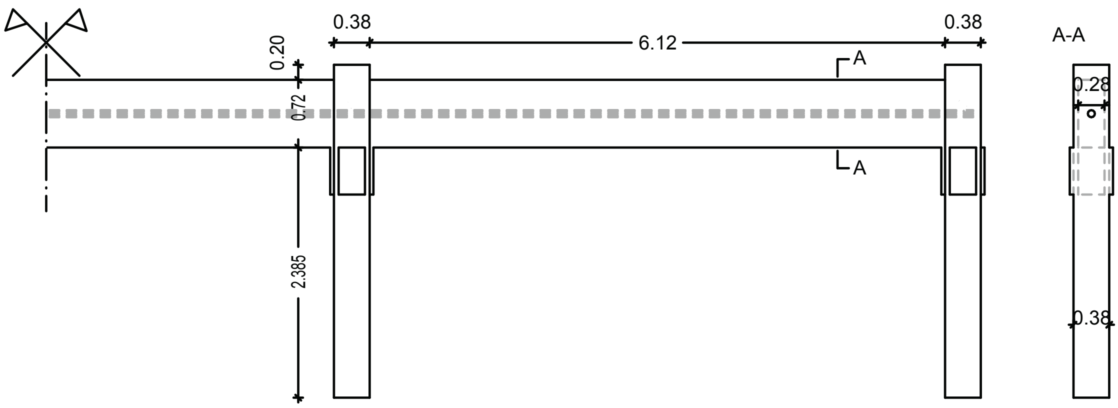


Fig. 2.1: Right half of the specimen (dimensions in [m])

The hardwood is used in areas, where high stresses perpendicular to the grain occur, namely in the connection between the column and the beam (cf. Figure 2.2). No further steel elements, except the tendon and its anchorage, are required for the connection. The tendon consists of four single strands that run over the entire length of the specimen (3 × 6.5 m). The tendon is classified as Y1170 406, according to the specifications of the manufacturer [22].

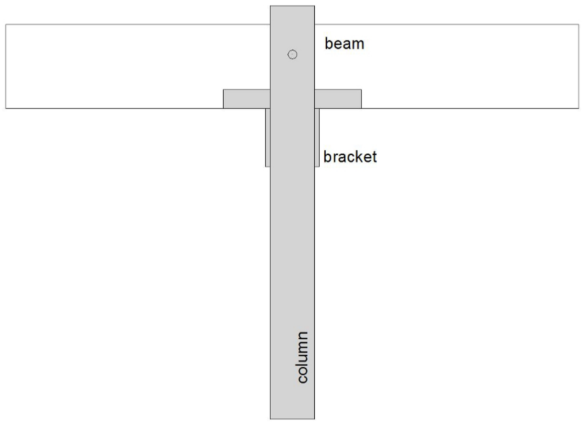


Fig. 2.2: Connection area of the specimen, grey shaded areas are made of hardwood (ash) [23]

The strength and stiffness values of the two timber grades are summarised in Table 2.1. The properties of the tendon are summarised in Table 2.2. A thick steel plate is mounted at both ends of the specimen to transmit the tendon force from the tendon to the timber frame. The shear force between the beams and columns is transferred via friction. A small support element under each beam to column interface was added for safety reasons in case the friction should not be sufficient. The support element was created by gluing a timber console to the column at the beam-column interface, as can be seen in Figure 2.2. These console elements additionally simplify the assembly of the frame during the construction process.

The three-bay frame specimen is almost identical to the frame structure implemented in the ETH House of Natural Resources [24]. However, the specimen tested in the lab consists of a single three-bay frame that spans in one direction (referred to as the 2D frame structure), whereas in the building a total of eight frames (4 per principal direction) constitute the main load carrying system for vertical and horizontal loads (referred to as the 3D frame structure).

Tab. 2.1: Strength and stiffness properties in [MPa] and density in [kg/m^3] for strength grade GL24h [21] and D40 [20]

Abbreviation	Strength grade	
	GL24h	D40
$f_{c,0,k}$	22	26
$f_{c,90,k}$	3	8.3
$E_{0,mean}$	11000	13000
$E_{90,mean}$	300	860
G_{mean}	500	810
ρ_k	380	550

Tab. 2.2: Tendon properties according to [22].

Abbreviation	Y1770 4-06
N_s	4
A_p	600 mm^2
L_p	4200 mm
E_p	197000 MPa
$f_\mathrm{p,k}$	1770 MPa
P_max	850 kN

2.2 Test setup

The tests were performed at the ETH Zürich on the strong floor of the structural engineering laboratory (refer to Figure 2.3 for a drawing of the entire test setup).

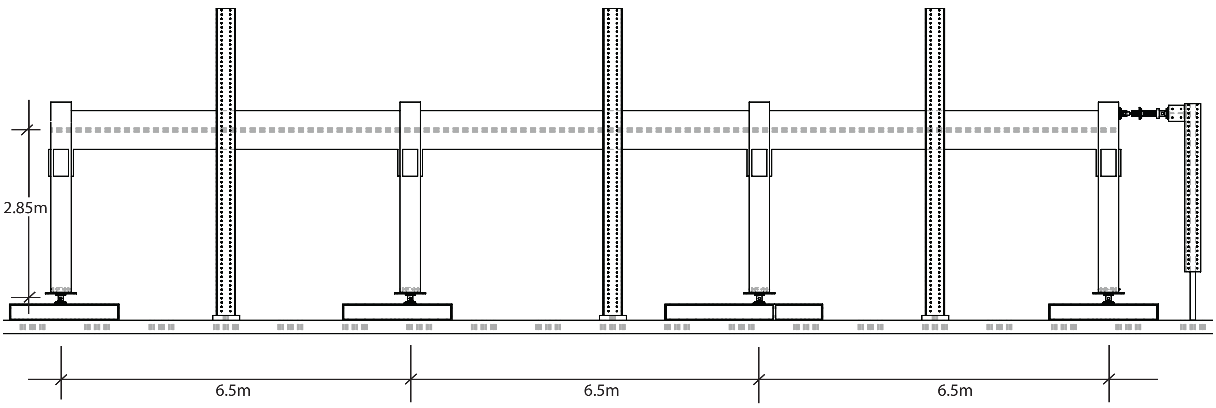


Fig. 2.3: Drawing of the test setup

The columns were connected to the strong floor with steel profiles, as illustrated in Figure 2.4(a). The column bases were constructed to allow for a change of the boundary conditions, i.e., the column bases could be allowed to rotate freely (as illustrated in Figure 2.4(a)) or the amount of possible rotation could be reduced by adding supports (as illustrated in Figure 2.4(b)). The first configuration will be referred to as “pinned column connection”, and the second will be referred to as “semi-rigid column collection”, henceforward.
The test setup figured six large steel columns, which were connected to the strong floor. A special rolling support was attached to each of these columns, allowing the specimen to move in direction of the load application but not perpendicular to that. This support was implemented to prevent out-of plane buckling of the beam. One of these supports is depicted in Figure 2.4(c). For the pushover tests, the force is applied via two hydraulic cylinders, which are attached to a steel frame (cf. Figure 2.4(d)). To connect the timber column base to the pinned or semi-rigid column base, a steel plate was inserted into a pre-cut cavity in the timber at the column base and fixed to the timber with eight steel dowels of diameter 12 mm. This steel plate is illustrated in Figure 2.5(a). Additional fixation elements were added to the test frame for the pushover

tests with high lateral forces, to increase the rigidity of the test setup (cf. Figure 2.5(b)). In a preliminary pushover test, without the reinforcement of the test frame, a displacement of nearly 1 cm of the test frame itself was measured with a lateral load of 250 kN and a tendon force of 510 kN.
Two pumps of the type Bieri HP 2.2 D-15110 were used during the tests. One pump was implemented to pre-stress the tendon. The second one was implemented for the application of the horizontal force. The oil pressure of each press was measured separately. These values were utilized to calculate the forces in the load application cylinders and the tendon, respectively.
The specimen is post-tensioned manually via the hydraulic pump, which is connected to a hollow plunge cylinder (Enerpac RCH-123). The hollow plunge cylinder was mounted between the thick steel anchorage plate, fixed to the column and the anchorage of the tendon (cf. Figure 2.13(a)).

2.3 Measuring instrumentation

To investigate the structural behaviour of the post-tensioned timber frame under horizontal and dynamic loading the following selection of measurement equipment was implemented.

Overview instrumentation:

- linear variable differential transformers (LVDTs)
- inclinometers
- infra-red LEDs (NDI - Northern Digital Inc.) / optical 3D measurement system
- hydraulic pressuremeters
- moisture measurement equipment
- temperature and relative humidity sensor
- accelerometers
- tiltmeters
- fibre optical strain sensors
- image-assisted theodolite system QDaedalus (dynamic displacement measurements)

Overview data acquisition units (DAQs):

- Gantner QStation: accelerometers and tiltmeters
- Optical sensing acquisition module (MicronOptics): fibre optical sensors
- National Instruments NI cDAQ: pressuremeters (post-tension force and horizontal force), temperature, relative humidity, LVDTs, and inclinometers

An overview regarding range and precision of the instrumentation is given in Table 2.3.

2.3.1 Instrumentation

Tab. 2.3: Measuring equipment including measuring range and precision

Equipment	Product Name	Range	Precision
LVDTs	Precisor TK-100-E-2	100 mm	0.25 %
Inclinometers	NS-5/P	±5°	±0.01°
NDI - 3D measurement		varies	0.01 mm
Hydraulic pressure-meters	Bieri HP 2.2D-15110	700 bar (1002.4 kN)	1bar (1.432kN)
Moisture measurement	BES Bollmann Combo 200	4-120%	0.1%
Temperature Sensor	DKRF4001	-20–80°C	±0.6°C
Relative humidity Sensor	DKRF4001	0-100%	±3%
Accelerometers	LIS344ALH	±2g or ±6g	$50\mu g/\sqrt{Hz}$
Tiltmeters	SCA100T-D01	±30°	0.0035°
Fibre optical strain sensors	SOFO deformation sensor	0.5% shortening, 1% elongation	0.2% of the measured deformation
QDaedalus	varies	varies	$< 10\mu m/m$

Linear variable differential transformers

The LVDTs recorded the horizontal displacements of the two outer beams. The LVDTs were mounted in the middle of each beam and measured the deformation with regard to the steel columns fixed to the strong floor (cf. Figure 2.6).

Inclinometers

Several inclinometers of the type NS-5/P were positioned on top of each column and on the two beams (cf. Figure 2.7). The inclination was measured directly in degrees inclination with regard to the horizon.

Optical 3D measurement system

An optical 3D measurement system was implemented to measure the position of several infrared LEDs attached in the area of the beam-column interface. The system (NDI Certus HD) works with three cameras and is able to measure the position of every LED. Several LEDs were mounted at the beam-column interface of one inner and one outer column as visualized in Figure 2.8(a) and Figure 2.8(b), respectively.
The single LEDs are used to visualize the behaviour of the beam-column connection. The connection behaviour is key for predicting the horizontal stiffness of the system and is a very important component for validating the analytical model introduced by the authors [25].

Hydraulic pressuremeters

Two hydraulic pumps of the type Bieri HP 2.2D-15110 were implemented during the tests. One pump was used to pre-stress the tendon. The second one applied the horizontal load on the frame during the pushover tests. The oil pressure from both pumps was measured separately. The tendon force and the applied horizontal load can be derived from theses measurements directly.

Moisture measurements

The moisture content of the timber was recorded before the tests at several locations in the ash (columns) and spruce (beams) lamellae. The moisture measurement was carried out with an electrical resistance measurement, using the BES Bollmann Combo 200 device and needle electrodes.

Temperature and relative humidity

A single temperature and relative humidity sensor was connected to the NI cDAQ to record the climate data during the tests.

Accelerometers

The laboratory frame was equipped with 11 accelerometers, 8 of which were placed on the columns and 3 at the mid-span of the beams (cf. Figures 2.9(a) and 2.9(b)). For each column, one accelerometer was placed at the height of the beam axis and one at mid-height of the column. Tri-axial MEMs accelerometers (LIS344ALH) were used, however only two axes (in-plane horizontal (y-direction) and vertical (x-direction)) were recorded. As the setup of the frame was two-dimensional, no significant accelerations out-of plane were expected. One additional accelerometer was attached to the shaker, which was used for the dynamic excitation of the frame. All accelerometers were connected to an amplifier box (4 sensors per box), which provided the possibility to set a signal gain and/or calibrate the sensor offset. The box additionally functioned as a power supply for the sensors.

Tiltmeters

In addition to the accelerometers, 12 dynamic MEMs tiltmeters (Model SCA100T-D01 from Murata Electronics) were installed on the frame in positions close to the joint regions of the column and the beam (cf. Figures 2.10(a), 2.10(a)). The tiltmeters measured rotations of the joints in- and out-of plane. The out-of plane measurements will be used to verify the assumption, that the frame behaves mostly as a 2D frame (no out-of plane movements). The tiltmeters were not connected to an amplifier box, but were directly connected to the dynamic data acquisition unit and a power supply. The output signal is in Volt and was then converted into angular degrees. The measurement range was $\pm 30°$.

Fibre optical sensors

During the dynamic tests, fibre bragg grating sensors were implemented. In total four SOFO deformation sensors from Smartec were attached to the frame (Figure 2.11(a), 2.11(b)) (serial numbers: FBG1 (10'001), FBG2 (10'000), FBG3 (10'005), FBG4 (10'004)). With the addition of strain measurements to the acceleration measurements further information about the system can be gained and the determination of actual displacements is facilitated. The optical strain gages measure changes in wavelength of an optical fibre between to fixed points, which were in this case 20 cm apart (cf. Figure 2.11(b)). The optical sensing acquisition module is able to capture dynamic data at a maximum sampling frequency (f_s) of 1'000Hz.

Image-assisted theodolite system QDaedalus (dynamic deformation measurements)

QDeadalus is an image-assisted theodolite measurement system, developed by the Geodesy and Geodynamics Lab of ETH Zürich. Further details on this measurement technique can be found in [26, 27]. For the laboratory tests on the 2D frame two small light bulbs were positioned on top of the two outer columns of the timber frame (cf. Figure 2.12). The movement of the lights was recorded with a high-speed camera mounted on a theodolite. The high-speed camera is able to capture movements of the light bulbs with a speed of 60Hz. In total 4 signals were recorded (horizontal and vertical movement of the two light bulbs).

2.3.2 Data acquisition units

For the recording of the static and dynamic data, three different data acquisition (DAQs) systems were implemented, which were not synchronized.

QStation for dynamic data acquisition

For the dynamic data acquisition, a Gantner Qstation 101 was used. The QStation is able to record data at frequencies above 10'000 Hz. For the dynamic tests a sampling frequency of 2'000 Hz was used. All accelerometers and tiltmeters were attached to the QStation. During sampling, a low pass filter of 200 Hz was implemented for the shaker tests and a low pass filter of 500 Hz for the impact tests.

Optical sensing acquisition module (MicronOptics)

For the acquisition of the data of the Fibre Bragg Grating strain gages (FBGs), a micron optics optical sensing interrogator sm 130 was used. The sampling rate was set to 1'000 Hz (no additional filter during sampling).

National Instruments NI cDAQ-9188

The National Instruments cDAQ-9188 data acquisition unit with an NI9205 module was implemented during the static and the dynamic tests to acquire data from the hydraulic pumps (tendon force and horizontal pushover force, via the pressure-meters) and the climate data (temperature and relative humidity). For the dynamic and static tests the sampling rate of the NI was set to 1 Hz.

2.4 Load application / Excitation

2.4.1 Pushover tests

Hydraulic cylinder and manual pump

For the horizontal load application a parker 82.6 TC cylinder was applied to the outer column (cf. Figure 2.4(d)). The load application cylinder was connected to one of the two hydraulic pumps (Bieri HP2.2D-15110) and the load was applied via manual pumping.

2.4.2 Dynamic tests

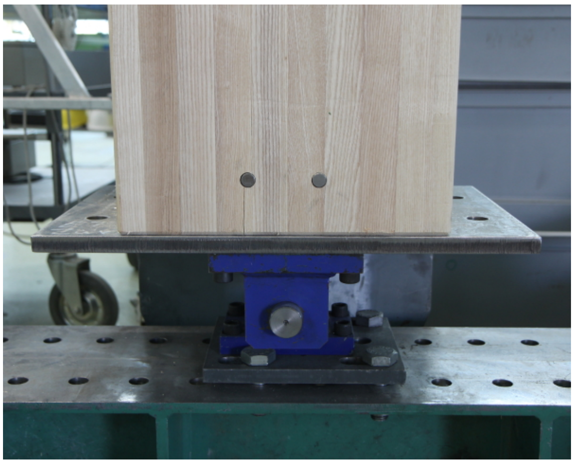
For the dynamic tests, two different excitation methods were used. Both techniques were used in different positions and directions (horizontal and vertical).

Impact hammer

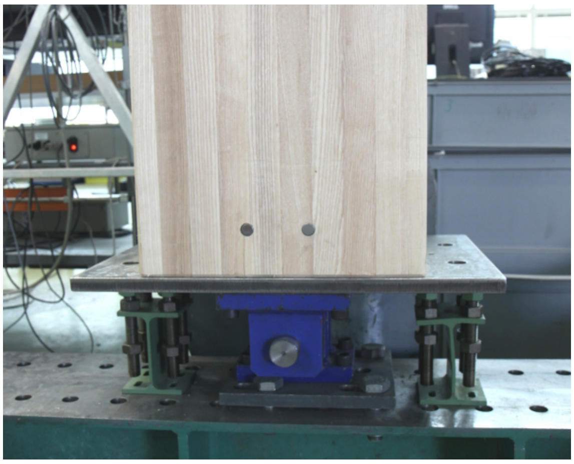
A Quartz impulse force hammer from Kistler (Type 9728A) was used to excite the frame. The grey tip (soft rubber) was mounted on the hammer. Figure 2.13(a) presents a picture of the application of the hammer. The hammer was connected to the Gantner QStation DAQ, which recorded the dynamic force that was applied to the system in Volt.

Electro-mechanical Shaker

As a second excitation technique, an electro-mechanical shaker, model ET-139 from Labworks Inc., was implemented (cf. Figure 2.13(b)). The shaker was operated in sine sweep mode, continuously sweeping from a low excitation frequency to a higher one. The mounting base of the shaker was attached to the timber frame with four screws. The shaker could be rotated on its mounting base, so that the horizontal and vertical direction could be excited. The shaker was used without a cooling blower, so the maximum reachable force was 40 lbf, which corresponds to 177 N. Two small masses (total added mass = 2 kg) were added to the shaker to improve the shaker's performance in the low frequency range, where its performance is limited by the maximum possible displacement of the moving coil.



(a)

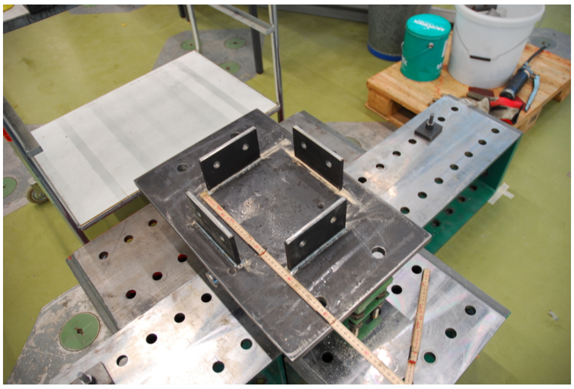


(b)

(c)

(d)

Fig. 2.4: 2.4(a): Support of the column for a pinned connection 2.4(b): Support of the column for a semi-rigid connection 2.4(c): One of the six lateral supports for the frame specimen 2.4(d): Load application for pushover tests and infrared LEDs at the beam-column interface



(a)

(b)

Fig. 2.5: 2.5(a): Column-base plate 2.5(b): Steel elements for lateral reinforcement of the test setup

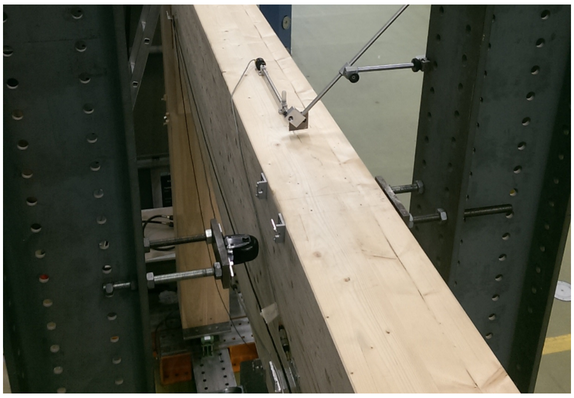


Fig. 2.6: LVDT attached on top of a beam, measuring the horizontal displacement of the beam

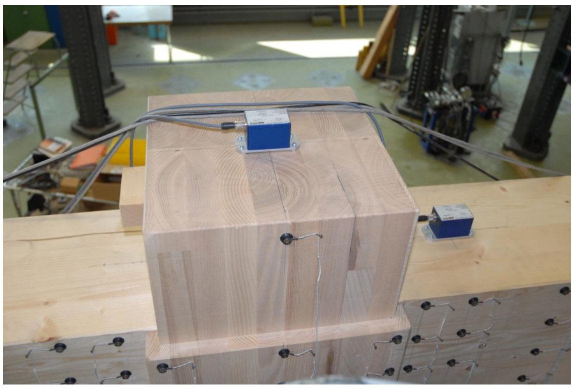
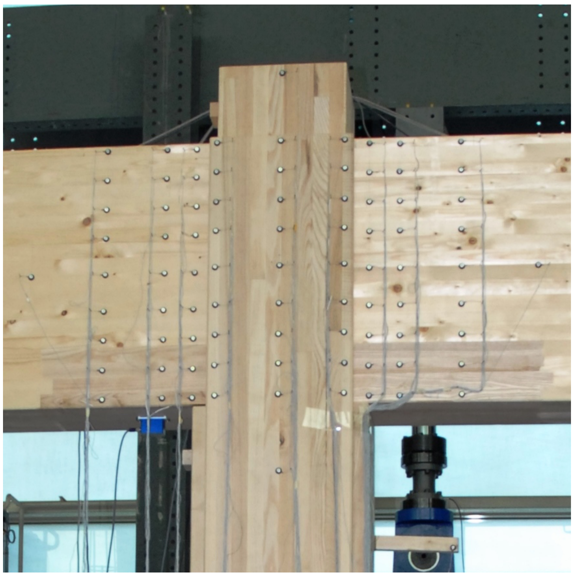
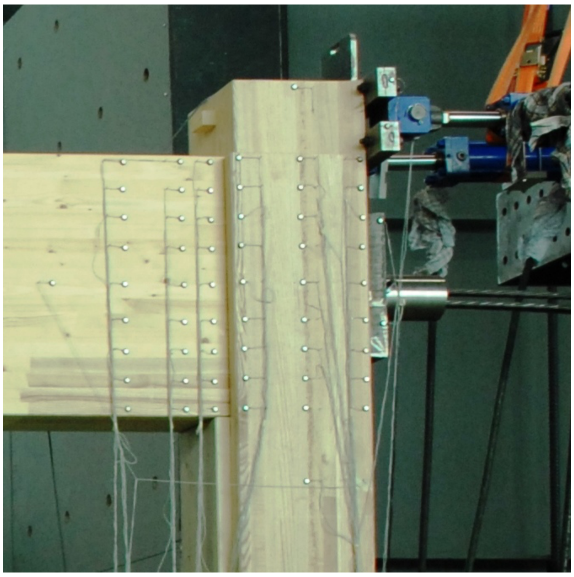


Fig. 2.7: Inclinometers attached to the column and the adjacent beam

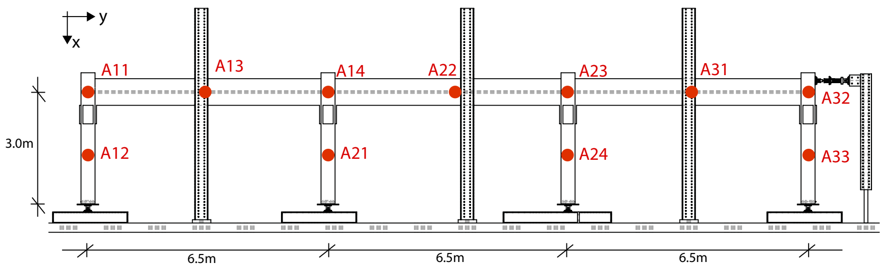


(a)



(b)

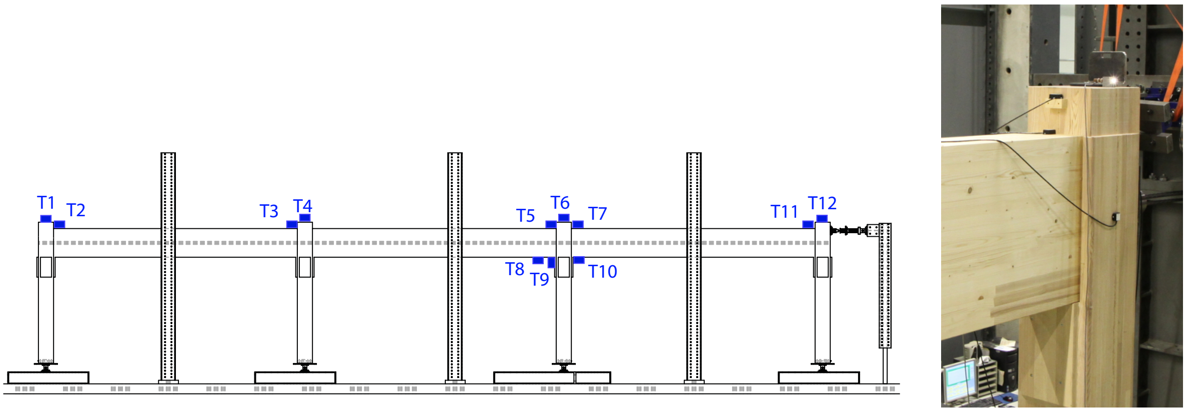
Fig. 2.8: 2.8(a): LEDs at the inner column and adjacent beams 2.8(b): LEDs at the outer column and adjacent beam



(a)

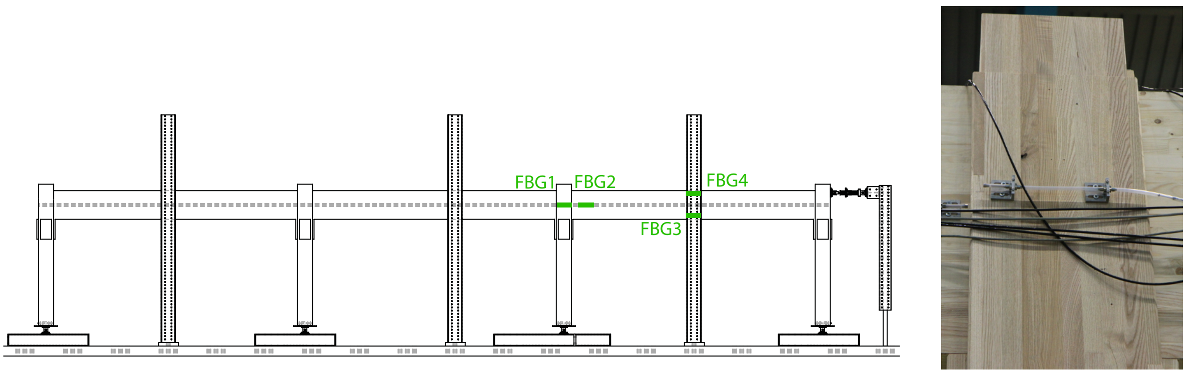
(b)

Fig. 2.9: 2.9(a): Accelerometer setup 2.9(b): Picture of a 3-axial MEMs accelerometer attached to a column



(a) (b)

Fig. 2.10: 2.10(a): Tiltmeter setup 2.10(b): Picture of tiltmeters T1 and T2, the upper-one (T1) attached to the column and the lower-one (T2) to the top of the beam



(a) (b)

Fig. 2.11: 2.11(a): FBG setup 2.11(b): Picture of the fixation of FBG1

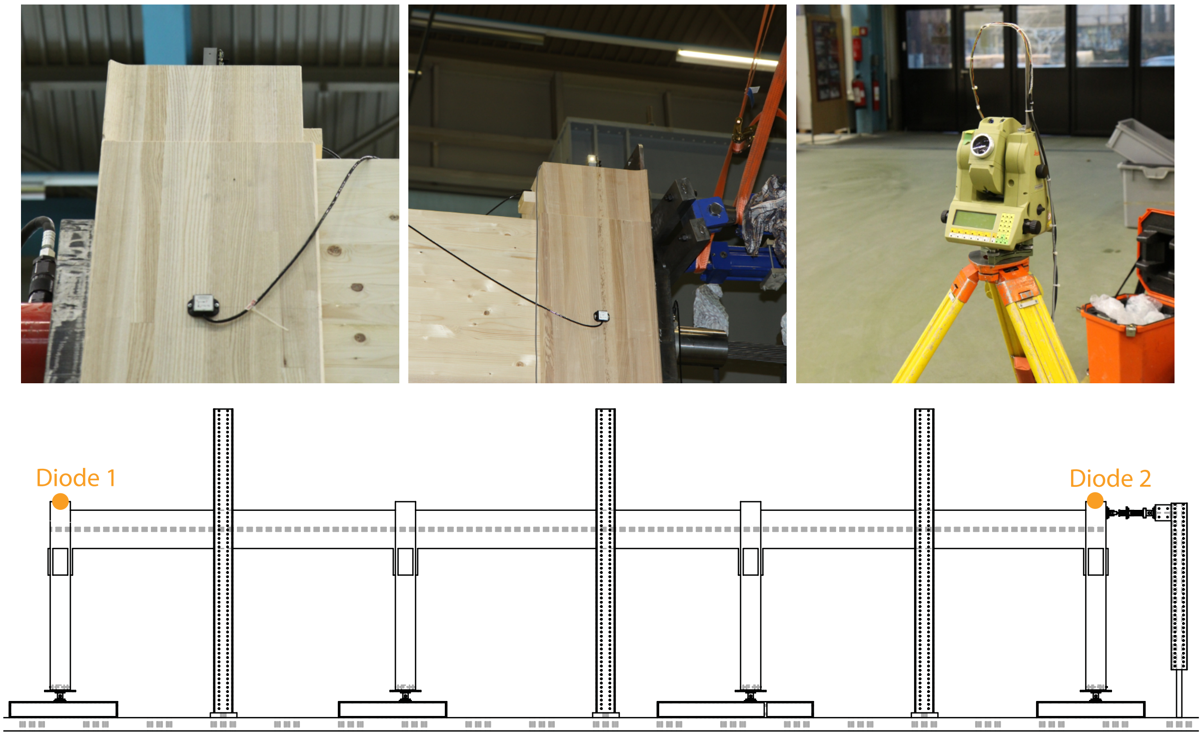
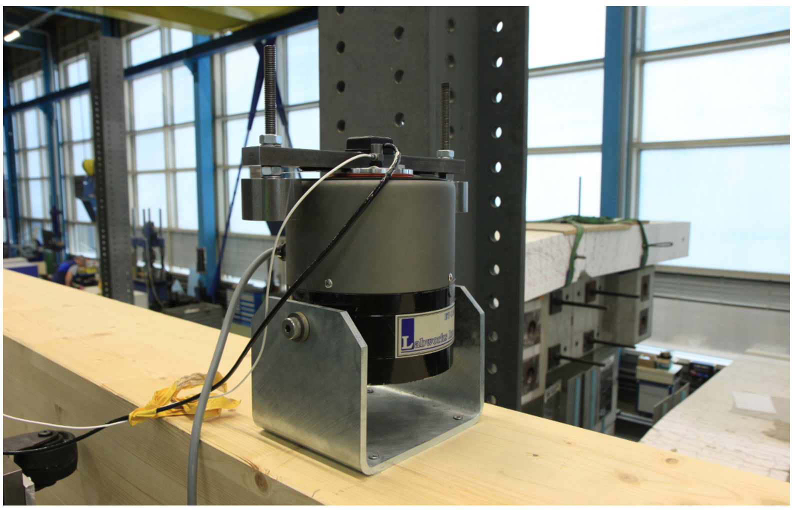


Fig. 2.12: QDeadalus setup: pictures of the two diodes (light bulbs), picture of the implemented theodolite with high-speed camera and drawing of the positions of the two diodes

(a)



(b)

Fig. 2.13: 2.13(a): Impact hammer application and hollow plunge cylinder at the tendon anchorage 2.13(b): Electro-mechanical shaker

Chapter 3

Experimental investigations

In this chapter, the experimental investigations conducted on the specimen described in the previous chapter, will be explained. First, some general data will be presented, followed by a section describing the static pushover tests, and concluded by a section describing the dynamic modal vibration tests.

3.1 General data

3.1.1 Dimensions of the specimen

The following table summarizes the measured dimensions of the specimen and its related steel elements:

Tab. 3.1: Dimensions of the timber frame and attached steel elements

Element	#	Material	b [mm]	t[mm]	l[mm]
Column	4	ash	380	380	3300
Column consoles	6	ash	280	40	500
Beams	3	spruce	280	720	6120
Column base plate	4	steel	580	20	380
Column base interior plates	16	steel	100	10	150
Column anchorage plate	2	steel	325	60	400

3.1.2 Climate conditions and moisture content

The indoor climate during the testing series is documented in Table 3.2. The moisture content of the specimen was measured on the 10.2.2014 in five different locations. Three of these locations were in the beam and two in the column. The beam moisture content was measured as 8.0, 8.4 and 8.1%, whereas the moisture content in the columns was measured as 9.7 and 10.0%.

Tab. 3.2: Climatic conditions during the dynamic and static tests

Date	tests	Temp [°C]	RH [%]
28.11.2013	Impact (QDeadalus)	17.5	27.2
29.11.2013	Impact & Shaker (QDeadalus)	18.0	30.5
6.12.2013	Shaker (QDeadalus)	17.7	32.6
5.2.2014	Shaker (all other)	18.1	33.5
10.2.2014	Impact (all other)	17.9	31.6
26.03.2014	Puhover	22.8	32.1

3.1.3 Weight of the specimen

The weight of the entire specimen was measured with a crane scale. The column-base steel plate and the anchorage plate were not removed. The density of the timber was derived by subtracting the weight of the steel parts from the measured weight, assuming a density for steel of 7'850 kg/m^3. The measured weights and calculated densities of the timber elements are documented in the Table 3.3. For comparison the table additionally presents the mean densities indicated in literature [20, 21] for climatic conditions with a temperature of 20°C and a relative humidity of 65%. It can be noted that ash has a significantly higher density than spruce.

Tab. 3.3: Weight, measured density and literature values of density [20, 21]

Element	Timber weight [kg]	Timber density ρ_{meas} [kg/m^3]	Timber density ρ_{mean} [kg/m^3]
Beam (spruce)	564	430	420
Column (ash)	314	660	660

3.2 Pushover tests

Twenty-nine pushover tests were performed as summarised in Table 3.4. The tests were performed with different tendon forces and different load levels applied to the frame. Some tests were performed with fixed column bases and some tests were performed with a combined vertical and horizontal load case, where in addition to the horizontal pushover load, a gravity load was applied to the beams. Three large steel profiles were attached at mid-span to the beams to simulate the gravity loads, adding a weight of nearly 10 kN (980 kg) to each beam as illustrated in Figure 3.1.

Tab. 3.4: Performed pushover tests

Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
1	500	x			215		x
2	550	x			210		x

Tab. 3.4: Performed pushover tests

Test No.	P_0 [kN]	Columns pinned	fixed	Gravity load 10 kN	F_{max} [kN]	Position NDI Col.1	Col.2
3	600	x			190		x
4	650	x			110		x
5	515		x		230		x
6	510		x		205	x	
7	520	x			180	x	
8	550	x			180	x	
9	600	x			180	x	
10	660	x			180	x	
11	410	x			200	x	
12	320	x			205	x	
13	215	x			170	x	
14	220	x			180		x
15	420	x			205		x
16	325	x			230		x
17	520	x		x	130		x
18	610	x		x	155		x
19	675	x		x	135		x
20	680	x		x	140	x	
21	620	x		x	160	x	
22	535	x		x	140	x	
23	510	x			250		x
24	420	x			250		x
25	320	x			240		x
26	410	x			270		x
27	325	x			-		x
28	260	x			295		x
29	400	x			295		x

Since only one camera was available for the 3D measurement system (NDI), each test had to be performed at least twice to measure the positions of the LEDs at two different columns. The outer column is labelled as Col. 1 and corresponds to the column next to the steel frame, where the load application is positioned. The inner column is labelled as Col. 2 and is the next column with two adjacent beams.

An error occurred during test 27 where the data acquisition unit crashed so that all data, except the NDI measurements, was lost. Furthermore, it was observed, that the applied horizontal force during test 27 reached nearly 300 kN.

Fig. 3.1: Post-tensioned timber frame with attached steel profile for gravity loading

3.3 Modal vibration tests

All dynamic tests were carried out prior to the pushover tests, to assure that the frame structure was undamaged. The dynamic tests were carried out for different configurations (different levels of tendon force, column fixations: pinned or semi-rigid, load application positions). Two types of dynamic tests were carried out: dynamic shaker tests (on the 5th of February 2014), using the labworks ET-139 electro-mechanical shaker (sine-sweep), and dynamic impulse tests with an impulse hammer (on the 10th of February 2014).

In total, 48 shaker tests and 70 impact hammer tests were carried out. The dynamic behaviour of the frame was measured via 11 accelerometers, 12 tiltmeters, and 4 FBGs. In addition, several tests were carried out with the QDeadalus system, in a previous testing campaign (November / December 2013). The preliminary testing campaign is herein only presented with regard to the results from the QDeadalus measurement system, and not from the other sensors since some issues occurred with the DAQ, that were only resolved for the later shaker and impact hammer tests.

The acceleration and tiltmeter sensors recorded at a sampling frequency of 2'000Hz. The FBG sensors, were attached to a different DAQ and were measured at a sampling frequency of 1'000Hz. The test duration was around 20 to 60 seconds for the impact hammer tests and 1-2 minutes for the shaker excitation tests. The impact hammer tests contain the system response to a single hit, whereas the shaker tests contain the system response to an entire cycle (frequency increase and decrease) and the free vibration response after the shaker was turned off.

Figure 3.2 presents the different positions where either the impact hammer or the shaker force was applied to the system. Tables 3.5, 3.6 and 3.7 present an overview of the tests. The impact hammer was always applied with the grey soft rubber tip; for half of the tests an additional weight was attached to the hammer (indicated with weight yes or no in Table 3.5).

The shaker excitation was measured with an additional accelerometer attached to the moving coil of the shaker and the impact force was measured via an internal load cell inside the hammer. Both excitation signals were recorded with the same DAQ as the other accelerometers and

tiltmeters. Thus, these signals were time-synchronised. The FBG sensors and QDeadalus measurements were recorded via different acquisition units and were therefore not time-synchronised. The tables additionally indicate the tendon force (P_0), the bottom fixation of the columns, and the position (P1 to P7, according to Figure 3.2) and direction (vertical/horizontal) of the load application.
The shaker operated in sine sweep mode. The sweep frequencies and rates are indicated in Appendix B. Only the first part of the sweep cycle (increasing frequency) is documented, although during the tests always an entire cycle (frequency increase and decrease) was applied.

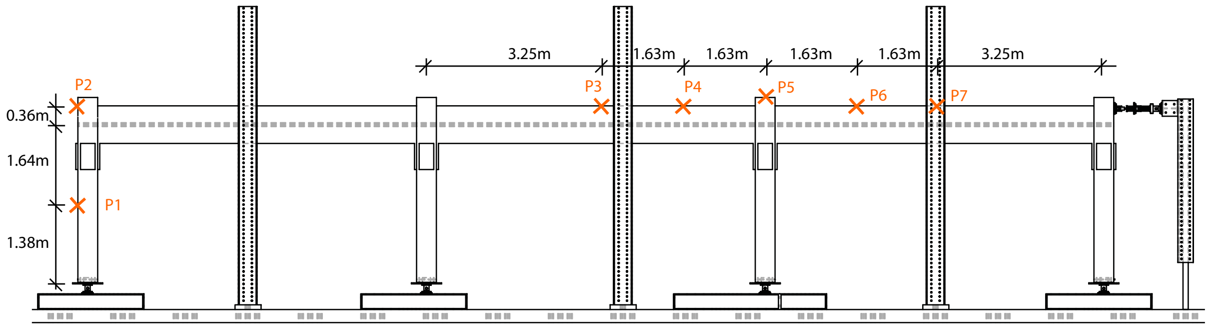


Fig. 3.2: Positions of load application during the dynamic tests

Tab. 3.5: Impact Hammer tests

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
1	P3	v	yes	400		x
2	P3	v	no	400		x
3	P5	v	yes	400		x
4	P5	v	no	400		x
5	P7	v	yes	400		x
6	P7	v	no	400		x
7	P2	h	yes	400		x
8	P2	h	no	400		x
9	P1	h	yes	400		x
10	P1	h	no	400		x
11	P1	h	yes	400	x	
12	P1	h	no	400	x	
13	P2	h	yes	400	x	
14	P2	h	no	400	x	
15	P7	v	yes	400	x	
16	P7	v	no	400	x	
17	P6	v	yes	400	x	
18	P6	v	no	400	x	

Tab. 3.5: Impact Hammer tests

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
19	P3	v	yes	400	x	
20	P3	v	no	400	x	
21	P4	v	yes	400	x	
22	P4	v	no	400	x	
23	P4	v	yes	500	x	
24	P4	v	no	500	x	
25	P3	v	yes	500	x	
26	P3	v	no	500	x	
27	P5	v	yes	500	x	
28	P5	v	no	500	x	
29	P7	v	yes	500	x	
30	P7	v	no	500	x	
31	P2	h	yes	500	x	
32	P2	h	no	500	x	
33	P1	h	yes	500	x	
34	P1	h	no	500	x	
35	P1	h	yes	500		x
36	P1	h	no	500		x
37	P2	h	yes	500		x
38	P2	h	no	500		x
39	P7	v	yes	500		x
40	P7	v	no	500		x
41	P6	v	yes	500		x
42	P6	v	no	500		x
43	P4	v	yes	500		x
44	P4	v	no	500		x
45	P3	v	yes	500		x
46	P3	v	no	500		x
47	P3	v	yes	650		x
48	P3	v	no	650		x
49	P5	v	yes	650		x
50	P5	v	no	650		x
51	P3	v	yes	650		x
52	P3	v	no	650		x
53	P2	h	yes	650		x
54	P2	h	no	650		x
55	P1	h	yes	650		x

Tab. 3.5: Impact Hammer tests

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
56	P1	h	no	650		x
57	P2	h	yes	650	x	
58	P2	h	no	650	x	
59	P1	h	yes	650	x	
60	P1	h	no	650	x	
61	P7	v	yes	650	x	
62	P7	v	no	650	x	
63	P6	v	yes	650	x	
64	P6	v	no	650	x	
65	P5	v	yes	650	x	
66	P5	v	no	650	x	
67	P4	v	yes	650	x	
68	P4	v	no	650	x	
69	P3	v	yes	650	x	
70	P3	v	no	650	x	

Tab. 3.6: Shaker tests

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
1	P7	h	400	x	
2	P7	h	400	x	
3	P7	h	400		x
4	P7	h	400		x
5	P7	v	400		x
6	P7	v	400		x
7	P7	v	400	x	
8	P7	v	400	x	
9	P7	v	500	x	
10	P7	v	500	x	
11	P7	v	500		x
12	P7	v	500		x
13	P7	h	500		x
14	P7	h	500		x
15	P7	h	500	x	
16	P7	h	500	x	

Tab. 3.6: Shaker tests

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
17	P7	h	650	x	
18	P7	h	650	x	
19	P7	h	650		x
20	P7	h	650		x
21	P7	v	650		x
22	P7	v	650		x
23	P7	v	650	x	
24	P7	v	650	x	
25	P3	h	650	x	
26	P3	h	650	x	
27	P3	v	650	x	
28	P3	v	650	x	
29	P3	v	650		x
30	P3	v	650		x
31	P3	h	650		x
32	P3	h	650		x
33	P3	h	500		x
34	P3	h	500		x
35	P3	v	500		x
36	P3	v	500		x
37	P3	v	500	x	
38	P3	v	500	x	
39	P3	h	500	x	
40	P3	h	500	x	
41	P3	h	400	x	
42	P3	h	400	x	
43	P3	v	400	x	
44	P3	v	400	x	
45	P3	v	400		x
46	P3	v	400		x
47	P3	h	400		x
48	P3	h	400		x

Table 3.7 presents an overview over the QDeadalus tests. The tests were conducted during a preliminary testing series; Impact 1 and 2 were conducted on the 28th November 2013, Impact 3 and Shaker 4 to 7 on the 29th of November 2013 and Shaker tests 8 to 16 on the 6th of December

2013. The QDeadalus measurement system recorded data with a sampling frequency of 60Hz (maximum possible speed of the high-speed camera).

Tab. 3.7: Tests with QDeadalus measurements

Test	Excitation	Position	Orientation	P_0	Columns	
No.			vert/hor	[kN]	pinned	fixed
1	Impact Hammer	P2	h	280		x
2	Impact Hammer	P2	h	280		x
3	Impact Hammer	P2	h	260		x
4	Shaker	P7	h	280		x
5	Shaker	P7	h	280		x
6	Shaker	P7	h	210		x
7	Shaker	P7	h	210		x
8	Shaker	P7	h	320	x	
9	Shaker	P7	h	320	x	
10	Shaker	P7	h	390	x	
11	Shaker	P7	h	390	x	
12	Shaker	P7	h	490	x	
13	Shaker	P7	h	490	x	
14	Shaker	P7	h	590	x	
15	Shaker	P7	h	610	x	
16	Shaker	P7	h	610	x	

In order to combine test results conducted on identical specimens, the following six structural systems are defined:

- System 1: Column bottom connection fixed, P_0=400kN
- System 2: Column bottom connection pinned, P_0=400kN
- System 3: Column bottom connection fixed, P_0=500kN
- System 4: Column bottom connection pinned, P_0=500kN
- System 5: Column bottom connection fixed, P_0=650kN
- System 6: Column bottom connection pinned, P_0=650kN

All impact and shaker tests with acceleration, tilt and FBG sensors were conducted on these six systems. The QDeadalus measurements were conducted on slightly different systems and can therefore not be directly compared to the other tests.

Chapter 4

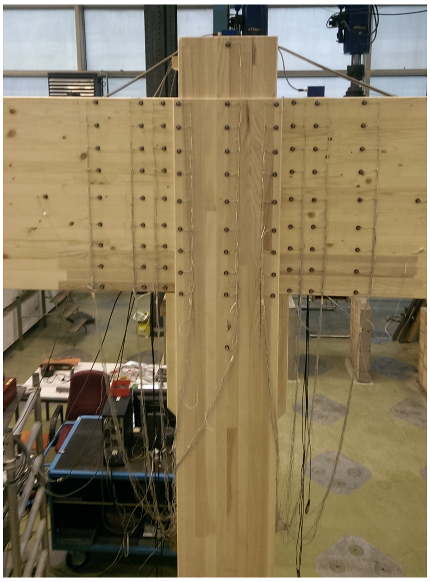
Experimental analysis

4.1 Pushover tests

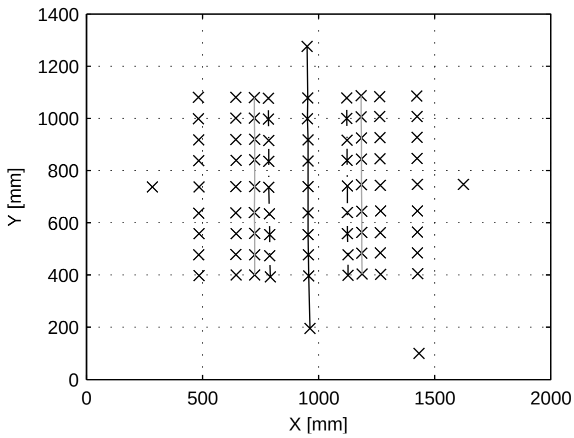
The implemented measurement system allows the estimation of several aspects of the post-tensioned timber connection. The focus of the current testing series was on the connection behaviour of the inner and outer column, specifically on the rotation capacity and the point of initial compression. The pushover-curve can be generated by extracting the displacements from the NDI-system or from the LVDTs attached to the beams.
Figure 4.1(a) illustrates the LEDs attached to the inner column, and figure 4.1(b) presents the coordinates of the measurement points. The continuous black line in figure 4.1(b) (x-coordinate of 1000 mm) indicates the central axis of the column. The displacement of the LEDs on this line can be used to calculate the total rotation of the connection. The two continuous grey lines in figure 4.1(b) indicate the first row of LEDs attached to the beams (x-coordinate of 750 mm and 1200 mm, respectively).
The coordinate system within the connection area is defined as follows; a negative x-coordinate corresponds to a movement to the left (according to figures 4.1(a) and 4.1(b)). A positive x-coordinate implicates a movement or displacement to the right.
The beam-column interface on the left side of the inner column (see figure 4.1(a)) is defined as the left connection, and the one on the right side is defined as the right connection.

Pushover curve

To generate a pushover curve, the horizontal force F applied to the frame is plotted against the horizontal displacement u (refer to figure 4.2). The force is calculated via the pressure measurement in the hydraulic system. The displacements were measured with the LEDs, positioned on the beam. In addition, the displacement from the upper LEDs was compared to the one obtained from the two LVDTs placed on top of the beams.



(a)



(b)

Fig. 4.1: 4.1(a): Picture of the LEDs on the inner column 4.1(b): Coordinates of the single LEDs and the columns axis (black line), as well as the first row of LEDs attached to the beams (grey lines)

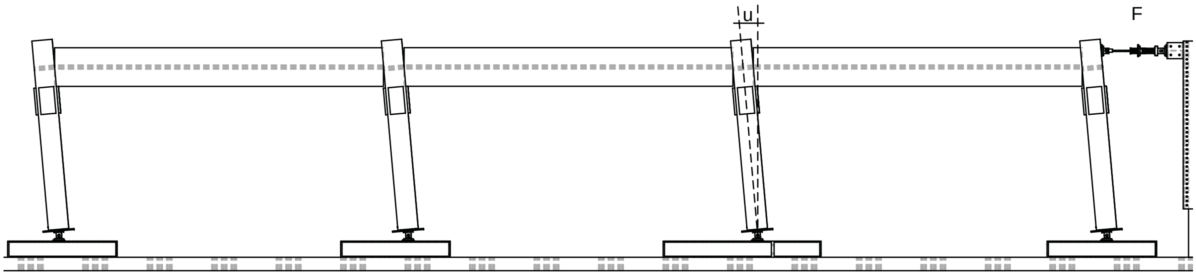


Fig. 4.2: Deformed frame under horizontal loading F with horizontal displacement u

Initial compression

The beams are pressed against the columns, as soon as a tendon force is applied. This leads to an initial compression in the interface, which has to be estimated. It is therefore essential, that the measuring equipment is already recording, before any load is applied to the tendon. Figure 4.3 presents the LEDs at the beam-column interface during the application of the tendon force. The grey shaded area corresponds to the initial compression, i.e., the left beam is being pressed into the column and moves to the right.

The initial compression is estimated with the relative displacement between the LEDs at the edge of the beam and the centre of the column, therefore eliminating the absolute displacement of the column, which can occur during the pre-stressing of the frame.

For safety reasons however, all measurements initiated at an initial tendon force of 100 kN. Therefore, the measured initial compression underestimates the real value.

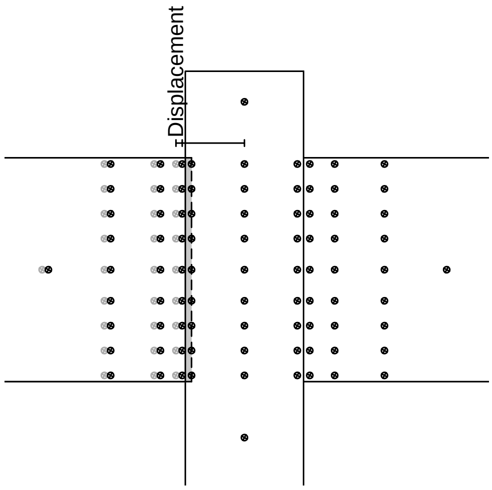


Fig. 4.3: Connection with LEDs during pre-stressing. The beam is being pressed into the column (as illustrated for the left connection)

Rotations of the connection

The rotations in the interface can be separated into rotations due to shear and due to the moment acting on the connection area. The LEDs are positioned on the interface as shown in Figure 4.4(a). If a horizontal load F is applied on the frame, a lateral displacement occurs, as shown in Figure 4.4(b) for a rigid body. The two resulting forces R acting on the interface lead to a shear deformation in the column as shown in Figure 4.4(c) and also due to the moment in the column as shown in Figure 4.4(d). The latter type of rotation is the same that could be observed during the test on the post-tensioned timber joint under gravity loads [28]. The total rotation of the interface is the sum of the rotation due to shear and due to the moment in the column:

$$\theta_{tot} = \theta_{GA} + \theta \tag{4.1}$$

The total deformation of the column can be estimated by using the inclinometers or with the LEDs. The inclination of the beam-column interface minus the elastic rotation of the column $\theta_{col,el}$ corresponds to the total rotation θ_{tot}. Both components are shown in Figure 4.4(e).
Moreover, it is possible to determine the single components of the rotation by using the LEDs. The rotation due to shear θ_{GA} can be estimated with the length of the diagonals D and D' as shown in Figure 4.4(c). The diagonal D was chosen, since it is not influenced by the compression perpendicular to the grain. The moment acting on the column will lead to the behaviour known from the tests on the post-tensioned timber connection, i.e., the beam will be pressed into the column, leading to a compressive zone and a gap opening (Figure 4.4(d)). The total rotations are shown in Figure 4.4(e) and include the rotation due to shear as well as the rotation due to the moment. The column itself will also rotate, due to the moment in the column.
The same observations are also valid for the outer column with only one beam-column interface.

However, the resulting force R is fixed to the middle of the column on the side where the anchorage is mounted as shown in Figure 4.4(f). The shear panel is smaller in the outer column as compared against the inner one, and the shear deformation will therefore not be as large.
Since the columns are wider than the beams (380 mm compared to 280 mm) the LEDs are not all in plane. The influence on the total rotation however, should be negligible, since it mainly depends on the rotation of the interface and the column. The influence on the shear rotations, on the other hand, may be significantly larger. The recorded values should therefore only be considered as approximations.

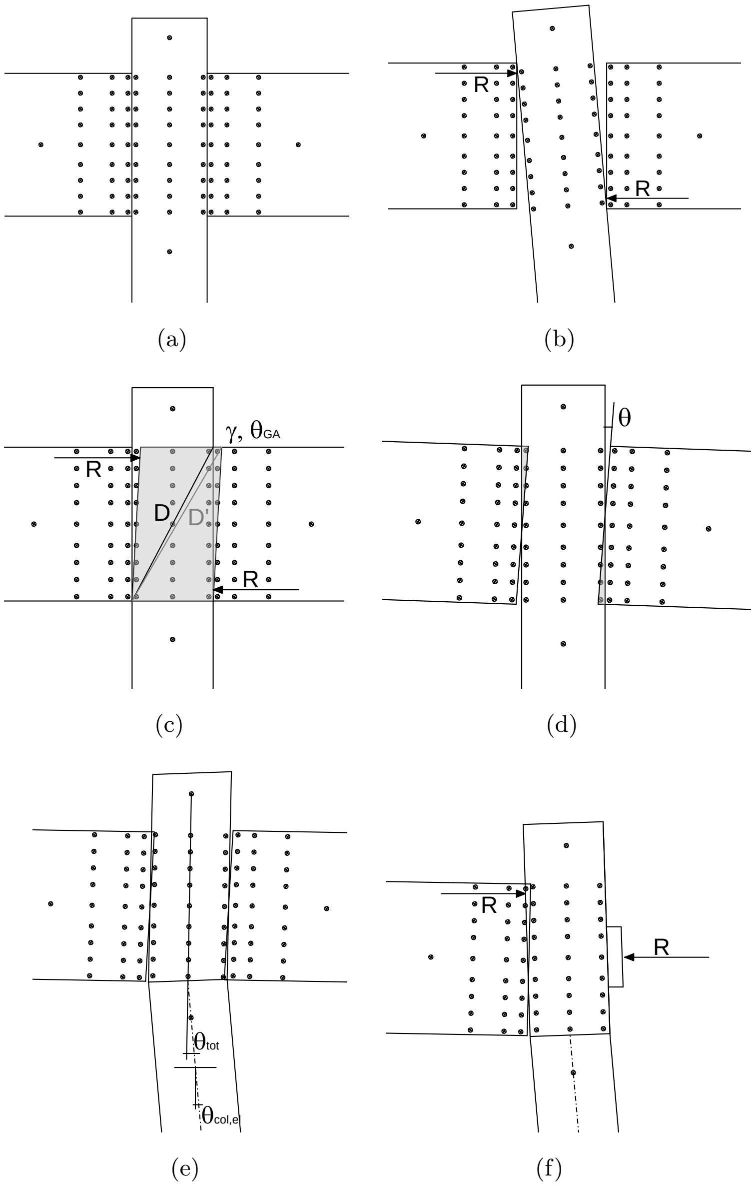


Fig. 4.4: 4.4(a): LEDs on the unloaded specimen 4.4(b): Rigid body motion and resulting forces R on the interface 4.4(c): Shear rotation θ_{GA} in the connection area 4.4(d): Rotation θ due to the moment in the beam-column interface 4.4(e): Total rotation θ_{tot} of the specimen due to shear, compression and elastic rotation of the column $\theta_{col,el}$ 4.4(f): Rotation of the outer column with resulting forces R in the connection area

Inclination

The inclination is measured with inclinometers at the top of each column. The inner column with two connection interfaces is expected to behave differently from the outer column with only one connection. The outer column should display a softer behaviour, therefore measuring a higher inclination compared to the inner column.

4.2 Dynamic tests

In the following section, firstly the general evaluation framework will be detailed and then applied to an example dataset to illustrate its functioning. The application to all datasets is documented in chapter 5.

4.2.1 General framework

To evaluate the dynamic test data, an automated evaluation procedure was programmed in Matlab. The procedure is based on the Software MACEC [29] and a modal analysis automation proposed by Reynders (2012) [30]. Figure 4.5 presents the three main steps of the evaluation: first a signal processing step, second the identification of linear time-invariant systems that reproduce the data as accurately as possible and third a modal analysis step of the identified systems, which delivers the modal characteristics (eigenfrequency, damping ratio and mode shape). This procedure is generally applicable to any type of excitation and sensor. The three main steps and their specific implementation will be detailed in the following subsections. For the evaluation the acquired data is divided into seven subsets, based on the 2 different excitation techniques (shaker and impact), and based on the three different sensor types (accelerometers, tiltmeters and FBGs). An additional (seventh) subset comprises the data acquired by the QDeadalus system.

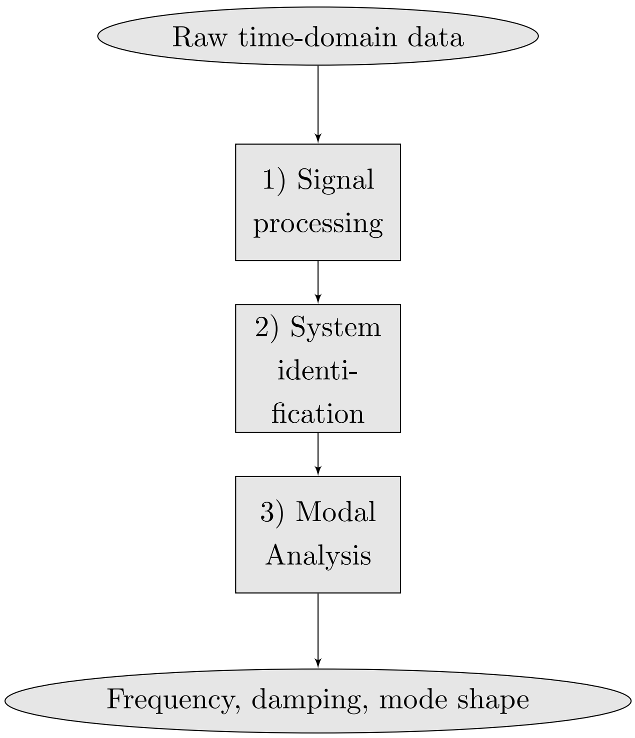


Fig. 4.5: Data processing: Basic flowchart

Signal processing

The following processing steps are applied to the raw data:

- Truncation of the data (if necessary)
- Deletion of malfunctioning channels (if applicable)
- Removal of mean and linear trends
- Removal of electricity peaks in the frequency domain (f=50Hz, 100Hz, 150Hz)
- Decimation to a frequency range of DC-400Hz (except for the QDeadalus measurements, where $f_s = 60\text{Hz} < 400\text{Hz}$)

System identification

Three different types of system identification methods are implemented (henceforth-implemented abbreviations of the methods in brackets):

- A nonparametric estimation of the frequency response function (nonpar)
- A poly-reference least squares complex frequency domain estimation (pLSCF)
- A stochastic or combined deterministic-stochastic subspace identification technique (SSI/CSI)

If an output-only identification is carried out, the stochastic variants of these methods are implemented. If the input to the system is known (e.g. the shaker acceleration or the impact force are measured), input-output variants of the methods are implemented, which are referred to as deterministic, or deterministic-stochastic (combined) variants of the methods.
For the testing series on the 2D frame, all impact hammer tests were evaluated with output-only identification methods. Although the impact force was measured, several issues occurred with the impact hammer amplifier, by thus hindering the acquisition of reasonable impact excitation data. Since the impact hammer produces a broadband frequency excitation, the error on the results is expected to be marginal. For the shaker tests, the measurement of the acceleration at the tip of the moving coil of the shaker is considered as input signal for the acceleration and tiltmeter sensors. Since the FBG sensors are acquired with a different DAQ, a time-synchronization procedure would be necessary. For simplicity reasons in the test conduction however, it was decided to try a synchronization during post-processing of the data. Due to the low amount of meaningful signal in the FGB data this, however, proved a difficult task. Therefore, the shaker-data of the FBG sensors was analysed with output-only techniques, taking into account that this might lead to erroneous results.
For all QDeadalus measurements an output-only identification is carried out since a time-synchronisation with the input signals was not possible, especially due to the low sampling frequency and additionally, due to the erroneous data of the acceleration signal from the shaker (first testing phase, which is only considered for the QDeadalus data). These errors were resolved for the later testing series, from which the acceleration, tiltmeter, and FBG data is taken.

The parametric models (pLSCF and SSI/CSI) are identified for a large number of model orders, since the correct model order is not known a priori. It is a common technique to over-specify the model order and to discard spurious numerical frequencies occurring at high model orders in a second processing step. The selected maximum model order varies with the excitation technique, sensor type and identification method (cf. Table 4.1).
The nonparametric estimation of the frequency response function (FRF) is carried out with the H1 method [31] for input-output data. Since this method relies on an averaging procedure, the data set is divided into several blocks of equal length, which include roughly 2000 data points for impact excitation data and 5000 data points for shaker excitation data. The same number of data points per block is implemented for the estimation of the FRF for the pLSCF method. For output-only data, the positive power spectral density is estimated (instead of the frequency response function with the H1 method). For the estimation of the positive power spectral density, the correlogram method is adopted and the number of time lags has to be specified. Herein, the number of time lags equals the multiple of 2, which is smaller than the data length.

Tab. 4.1: System orders for the 7 data subsets

Index	Excitation	Sensor type	System orders (pLSCF)	System orders (SSI/CSI)
1	Impact	Acceleration	14:14:140	2:2:80
2	Impact	Tilt	10:10:100	2:2:60
3	Impact	FBG	4:4:40	2:2:60
4	Shaker	Acceleration	2:2:60	2:2:60
5	Shaker	Tilt	2:2:50	2:2:50
6	Shaker	FBG	4:4:40	2:2:60
7	Impact&Shaker	QDeadalus	4:4:60	2:2:60

Modal Analysis

The goal of the modal analysis is to extract modal characteristics from the identified system models. Depending on the identified model, different modal analysis techniques are implemented:

- Complex mode indication function (nonpar method)
- Stabilization diagram (pLSCF and SSI/CSI method)

Complex mode indication function - peak picking The complex mode indication function (CMIF) presents the singular values of the estimated FRF. The peaks of the singular values indicate a structural mode and they are usually selected manually (hence the name peak picking). From the selected peaks, the modal characteristics can be derived. As the nonparametric identification techniques are known to yield low-quality damping ratio estimates, the damping ratios are excluded from the modal characteristics.
Herein, a semi-automated peak-picking method is implemented. The technique utilizes the MATLAB built-in function peakfinder, which identifies all peaks above a pre-defined threshold.

This threshold needs to be set manually. To avoid the selection of a large number of spurious peaks, only peaks with a modal phase collinearity (MPC) above 0.7 are retained (0.5 for FBG sensor data). An MPC value of zero means that the mode shape components are not at all collinear in the complex plane, whereas an MPC value of one means, that the components are perfectly collinear. Ensuring a high MPC value is based on the assumption that, if a structure is proportionally damped the mode shape components should form a straight line in the complex plane [30, 32]. Furthermore, the selection process should yield unique modes. Therefore, all modes with a modal assurance criterion (MAC) value above 0.95 are merged into a single mode by selecting the mode with the highest MPC value among the identical modes. The term mode generally refers to a set of modal characteristics (eigenfrequency, damping ratios and mode shapes), whereas in the context of nonparametric identification the term mode only refers to a set of eigenfrequency and corresponding mode shape. The MAC-value is known as modal assurance criterion and is implemented to identify whether two mode shapes are identical (MAC = 1) or different (MAC = 0) [33].
This semi-automated peak-picking method only requires the setting of an appropriate threshold for the Matlab peakfinder algorithm. To automatize the procedure further, thresholds were selected as follows:

- $1.0 \cdot \text{mean}(\text{SV}_1)$, for acceleration and tilt sensors
- $4.0 \cdot \text{mean}(\text{SV}_1)$, for FBG-impact data
- $5.0 \cdot \text{mean}(\text{SV}_1)$, for FBG-shaker data

The selected thresholds are higher for the FBG data, due to the higher noise content in the signal. SV_1 is the vector of the first singular values for different frequencies. Although, not all peaks are perfectly captured with these thresholds, it is assumed that it leads to good results in most cases. The presented technique allows a fast estimation of modal characteristics from the tested system.

Stabilization diagram The second modal analysis method is based on the stabilization diagram. This diagram is built by extracting the modal characteristics from every identified pLSCF or SSI/CSI model and plotting the resulting frequencies in a frequency versus model order diagram. The true frequencies of the system should form a straight vertical line in the stabilization diagram. The MACEC-software user can manually select the frequencies lying on a straight line. This manual selection process can be quite time-consuming, especially if performed for a large number of tests.
Therefore, a fully automated modal analysis procedure was developed by Reynders et al. [30]. This automation technique is adapted here and the reader may refer to the cited reference for more details. In the reference, the automation procedure is applied to models identified with the SSI and CSI methods. Herein, the method is additionally applied to stabilization diagrams generated via the pLSCF method. As the pLSCF method delivers clear stabilization diagrams, two modifications are made to the automation procedure. Firstly, the k-means clustering step to

separate clearly spurious modes from possibly physical modes based on soft validation criteria is left out. Secondly, the cut-off distance ($\tilde{d}$ - equation (17) in [30]) is iteratively increased until the data set comprises only unique modes or until the maximum number of modes in a mode group exceeds the number of model orders (i.e., the lowest possible number of clusters is reached). Due to the low number of spurious modes in the pLSCF method, keeping $\tilde{d}$ at its original value would distribute the same mode across several mode clusters. The uniqueness of the modes is determined via the MAC-value, which should be below 0.8 (clearly different mode shape).

It has to be noted that the above procedure relies heavily on the MAC-value, thereby requiring a sufficiently high sensor density. It is assumed that the sensor density is sufficiently high for the acceleration and tilt-sensors. For the FBG and QDeadalus measurements (four measured signals each), this may not be guaranteed. This should be kept in mind when comparing the results from the different sensor types.

A further small modification was implemented in the final step, where one representative mode is selected from each cluster (for the pLSCF and the SSI/CSI method). Instead of selecting the final mode based on the median of the damping ratio, the mode with the highest MPC value is selected.

Furthermore, an additional hard validation criterion was added for the modal analysis of stabilization diagrams stemming from the SSI method with covariance estimation. This method additionally estimates the covariance of the modal characteristics, based on the algorithm documented in [34–36]. The additional hard validation criterion concerns the standard deviation of the damping ratio, which should be below 20% (in addition to the already existing criterion, which requires the damping ratio to be below 20%).

Comparison of results from different identification methods and selection of final mode set for each data set

Prior to proceeding to the combination of the 10-12 impact tests and 8 shaker tests conducted on one type of the 2D post-tensioned timber frame structure, the results from the 3 methods from a single test undergo a final check and a comparison. All modes that have an MPC value below 0.7 (below 0.5 for FBG-data based modes) are discarded and modes identified with the same method, with a MAC-value above 0.95 are merged to a single mode (keeping the mode with the highest MPC value). The MPC-value threshold is lowered for the FBG sensors, since the number of sensors is quite limited and the signal to noise ratio is lower. Therefore, modes with MPC values above 0.7 are not present in the FBG dataset; however, the identified frequencies are in a reasonable range. To allow a comparison of FBG data to data from other sensor types the threshold was therefore lowered to 0.5, keeping in mind that the quality of these modes might be poor.

To align modes identified by the three different methods, a hierarchical clustering is applied to identify values of the same mode across the three methods. As input to the hierarchical cluster, a simplified distance measure based on the distance in eigenfrequency and the distance in MAC-value between mode i and mode j is implemented:

$$d_{i,j} = \frac{(f_i - f_j)}{\max(f_i, f_j)} + 1 - \text{MAC}(\phi_i, \phi_j) \tag{4.2}$$

The original distance between modes, as defined in [30] cannot be used since it implements the distance in eigenvalue, which relies on the damping ratio. The damping ratio, however, is not defined for the modes identified with the nonpar method.

As a cut-off distance for the hierarchical clustering to align identical modes, a value of 0.4 is selected. The cut-off distance of 0.4 roughly accounts for 0.2 error in the mode shape (MAC values between 0.8-1.0 are attributed to the same mode) and a 20% variation in frequency. Global mode indices are attributed to the identified mode sets. The results of this combination are presented in chapter 5 in the form of tabulated values for each test and sensor type.

Combination of results from different tests

In a next step, the results from the six data subsets (Impact-Acceleration, Impact-tilt, Impact-FBG, Shaker-Acceleration, Shaker-Tilt, Shaker-FBG) are combined for each tested specimen type (six main structure types - pinned, fixed bottom connection and 3 different post-tensioning levels). The goal of this combination is to analyse the influence of the sensor type and excitation technique on the results, and to determine a mean value and standard deviation of frequency and damping ratios for each mode, as well as a representative mode shape. This standard deviation is the standard deviation obtained from multiple tests and is not the same as the standard deviation estimated with the SSIcov method. The combination is conducted separately for each sensor type. This has the advantage that the MAC-value can be implemented for checking if modes are identical or not. From each test, the final tabulated values from the previous step are merged into two main datasets, the first dataset comprising all identified modes from the shaker tests, and the second all identified modes from the impact hammer tests, regardless of the implemented identification method. Both datasets are then combined, and a hierarchical clustering step is applied with a cut-off distance of 0.4 (equation 4.2; same reasoning as in the previous section). After the clustering step, the data is separated into several main mode clusters, keeping track of impact-based and shaker-based results. A mode is considered a main mode or a global mode if the cluster comprises at least one value for the mode from each excitation technique and at least three value for one of the two excitation techniques. This assumes that global modes of the structure should have been identified across multiple tests (> 2) and with both excitation techniques. For each global mode a bootstrapping procedure [37] is applied to the shaker-based frequency and damping values and to the impact-based frequency and damping values, thereby extending the dataset and allowing a visualization of the coefficient of variation (COV). The resulting distribution of the bootstrapped samples is presented in a mean-COV diagram for each global mode in chapter 5. Additionally, the mean value and COV of the actual data (not bootstrapped) for the three identification methods are calculated separately and indicated in the same diagram.

These calculations are carried out for the three sensor types and then plotted on the same page with identical axis scaling to visualize the influence of the sensor type.

Since the mode shape resolution is higher for the acceleration sensors, only the MAC-matrix of the global mode clusters obtained from acceleration sensors is plotted together with a selected mode shape. Impact-based and shaker-based mode shapes are not distinguished here. If all modes in the cluster are identical, the MAC-matrix should present only values of 1.0 (diagonal and off-diagonal elements). The most representative mode shape of the group is selected by analysing the off-diagonal elements of the MAC-matrix. The row with the highest sum of off-diagonal elements is deemed most representative of the cluster's mode shape. Furthermore, the mean value of the off-diagonal elements is considered as an indicator for how well the mode shape agrees within a cluster. If the mean value of the off-diagonal elements equals one, the mode shapes agree perfectly, indicating a high quality of the identified mode shape. This indicator is henceforth named $\text{MAC}_{\text{quality}}$.

4.2.2 Application of the framework

In the following section, an application of the described framework to a single data set will be illustrated. The data set is the acceleration data from impact hammer test Nr.11 (cf. Table 3.5).

Signal processing

Figure 4.6(a) presents the processed time-domain signal of a single axis of an accelerometer. The presented signal is truncated to 0.5 seconds of data prior to the impact hammer hit and 15 seconds of data after the hit, to assure that the entire decay of the signal is retained for the analysis. The mean value and linear trends are removed, together with the electricity-induced peaks. The signal was decimated by a factor of five leading to a new sampling rate of $f_\text{s} = 2'000/5 = 400\text{Hz}$ and a Nyquist frequency of $f_\text{Nyq} = 200\text{Hz}$. The processed signal consists of $N = 6'201$ data points.

The number of channels was reduced to 14 signals to speed up the data analysis, thereby, maintaining the signals with the highest signal to noise ratio and discarding malfunctioning channels.

Figure 4.6(b) presents the spectrogram of the signal. The spectrogram illustrates the frequency content in the signal with respect to time; a clear horizontal frequency line can be noted around 8Hz, most probably corresponding to the fundamental mode of the structure. The spectrogram additionally allows identifying for how long a frequency is present in the signal. The frequency at 8Hz is present roughly until 14 seconds after the hit. In the first 2 seconds, further frequencies are dominantly present in the signal (around 60Hz, 90Hz, and 175Hz). Those at 60 and 90Hz decay much faster, whereas the one at 175Hz remains in the signal for the entire recorded time. The spectrogram additionally presents frequency lines at 50,100 and 150Hz. These are remains of the electricity frequencies, which could not be completely removed from the signal.

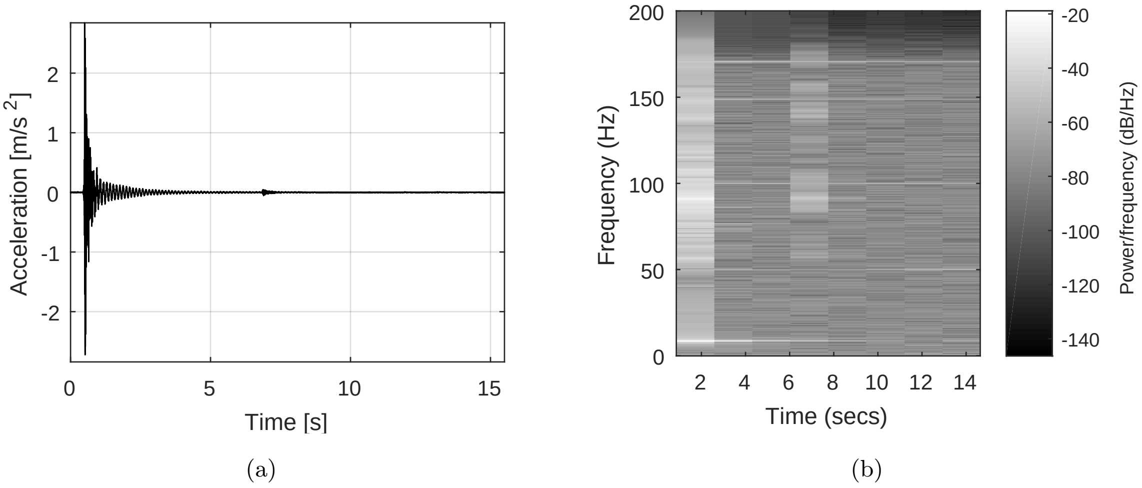


Fig. 4.6: 4.6(a): Time-domain response of 1 axis of 1 accelerometer 4.6(b): Spectrogram of the same signal

Nonparametric identification and modal analysis

First, a nonparametric model, via the estimation of the positive power spectral density with the correlogram method, is identified. The number of time lags is chosen as 4096 (2^{12}, $< N = 6021$). From this model, the singular values of the complex mode indication function are plotted (cf. figure 4.7(a)). The black stars correspond to the peaks identified with the peakfinder algorithm, whereas the vertical black lines present the selected modes. The modes satisfy the two conditions, that their MPC > 0.7 and their MAC-value with respect to all other modes < 0.95 (mode uniqueness). Figure 4.7(b) additionally displays the matrix of the MAC-values. The mean value of the off-diagonal elements is nearly zero, indicating that the final selection of modes includes only unique modes and that the modes are orthogonal to each other.

Table 4.2 displays the frequency, MPC-values, and the mean phase deviations (MPD) of the selected modes. The mean phase deviation is the mean of the deviation of the mode shape components from a straight line fit in the complex plane. The fitted straight line corresponds to the mean phase. The MPD is a second measure to determine mode shape complexity [30]. If the MPD equals zero, the mode shape components figure a perfect line in the complex plane. The selected modes present high MPC values and low MPD values, indicating a good quality of the identified modes (especially for mode 1 and 2).

Tab. 4.2: Selected modes - nonparametric

Mode Nr.	Frequency [Hz]	MPC [-]	MPD[°]
1	8.59	0.99	1.45
2	91.1	0.95	5.78
3	160	0.87	15.3

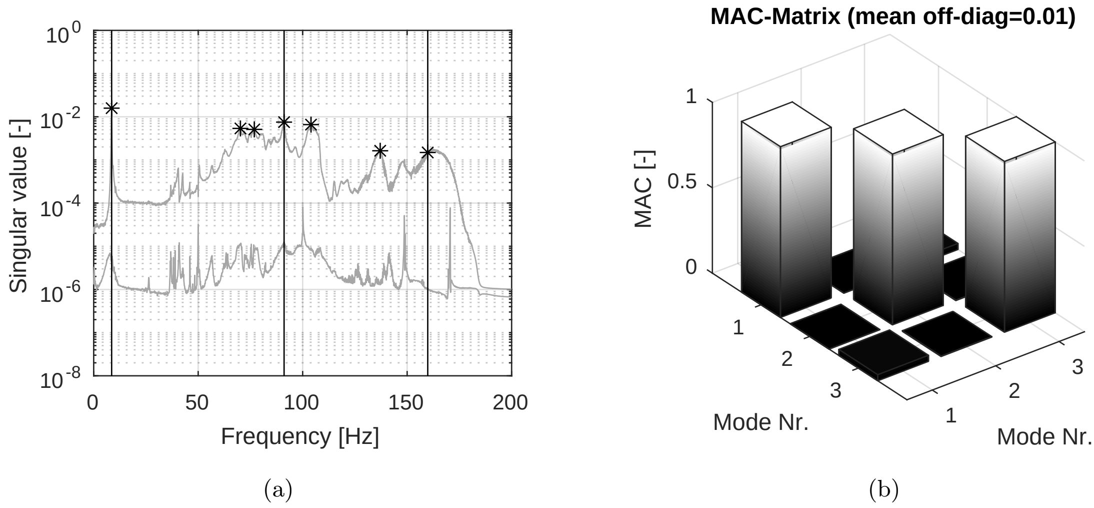
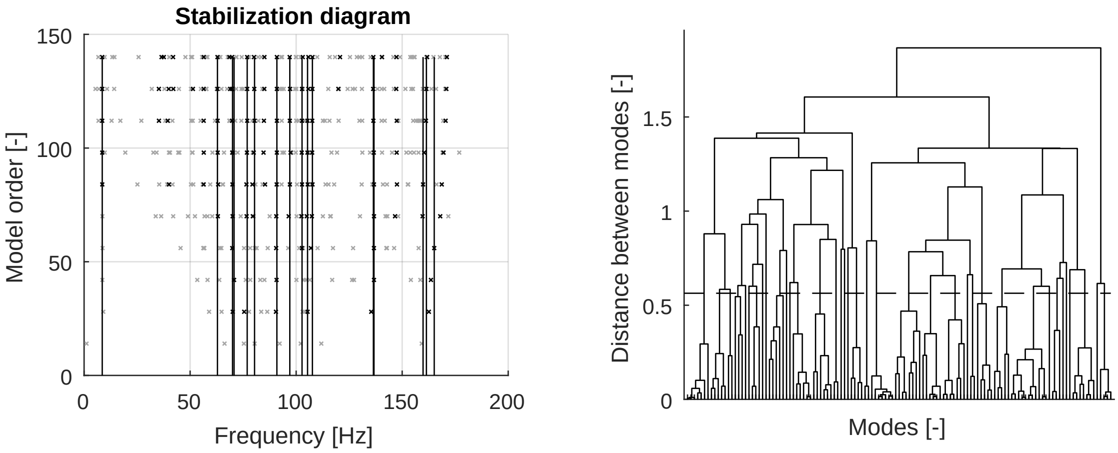


Fig. 4.7: 4.7(a): Complex mode indication function (stars: peaks selected by the peakfinder algorithm, vertical black lines: selected modes that satisfy MPC > 0.7 4.7(b): MAC-Matrix of the selected modes (nonparametric method)

pLSCF identification and modal analysis

In a second identification step, a poly-reference least squares complex frequency domain model is estimated. This algorithm is commercially known as the Polymax method and further details can be found in [38]. A right matrix fraction description model (RMFD) is fitted to the nonparametric FRF estimation performed in the previous step (nonparametric model identification). The same number of time lags is chosen and the RMFD is fitted for polynomial orders ranging from 1 to 10. These correspond to system orders ranging from 14:14:140 (the system order equals the polynomial order times the number of reference channels, whereas here all 14 output channels are chosen as reference channels). For each model order, the corresponding modes are extracted and plotted in a stabilization diagram (cf. figure 4.8(a)). To clear the stabilization diagram, the hard validation criteria, according to [30], are applied. The remaining procedure is analogue to the algorithm described in [30]: the remaining modes are distributed into groups with identical modes via a hierarchical clustering procedure, and then the clustered mode groups with a low number of elements are discarded via a 2-means clustering algorithm. For the current dataset, the initial value of $\tilde{d} = 0.56$ leads to 37 clusters (mode groups), with a maximum of 11 elements per cluster. This number is higher than the number of different model orders; therefore, the number of clusters is iteratively increased to 57. With 57 clusters, the maximum number of elements per cluster equals eight, which is now lower than the number of model orders. No further iteration on $\tilde{d}$ is performed, since that would lead to an increase in modes per cluster. Figure 4.8(b) illustrates the final clustering of the modes in a dendogram with the initial cut-off distance $\tilde{d}$.

Figure 4.9(a) illustrates the results of the k-means clustering approach that separates the mode cluster groups into groups with physical and spurious modes. It is assumed that physical modes are present at a large number of model orders. Modes with more than two elements are retained



(a) (b)

Fig. 4.8: 4.8(a): pLSCF - Stabilization diagram (grey: all modes, black: remaining modes after the hard validation criteria are applied, continuous lines: selected modes) 4.8(b): pLSCF - Dendogram: displaying the mode grouping in the hierarchical clustering step and the cut-off distance (dashed horizontal line)

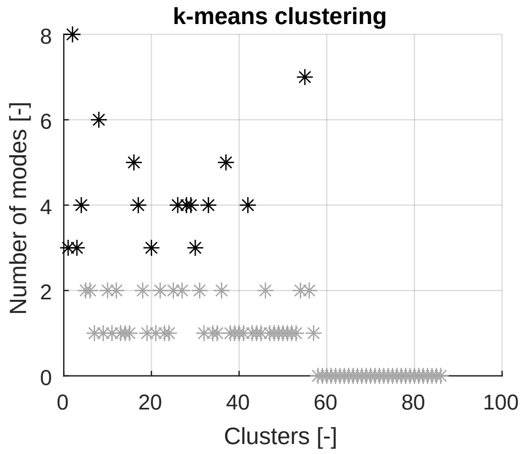
in the set. Table 4.3 displays the final selection of modes, where within each cluster the mode with the highest MPC value is selected. Furthermore, the MAC-matrix of the selected modes is displayed in figure 4.9(b). From the table and the MAC-matrix, it is obvious that at least three modes are not unique and that some modes have low MPC values. This issue will be resolved in the following processing step.

SSI identification and modal analysis

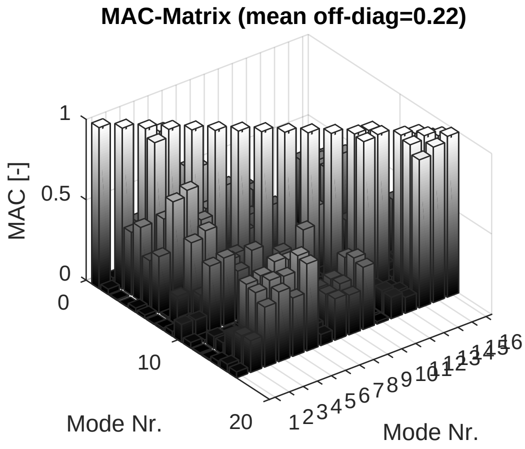
As third identification method, the stochastic subspace method with covariance estimation of the modal parameters is implemented (cf. [34, 35] for details on the algorithm). The number of block rows in the block Hankel matrix is chosen as 20 and the model orders range from 2 to 80 in steps of 2. In this way, 40 different models are estimated. For each model order, the corresponding modes are extracted and plotted in a stabilization diagram (cf. figure 4.10(a)). To clear the stabilization diagram, the algorithm of [30] is applied (with soft and hard validation criteria). The clearing of the stabilization diagram is again followed by the hierarchical clustering procedure, and then the 2-means clustering algorithm.

For the current dataset the cut-off distance for the hierarchical clustering equals $\tilde{d} = 0.22$, leading to 151 clusters (mode groups), with a maximum number of elements per cluster of 31. This is the final number of clusters, since 31 is below the maximum number of model orders of 40 and the iteration on $\tilde{d}$ is only performed for the pLSCF method (fewer spurious modes). Figure 4.10(b) illustrates the final clustering of the modes in a dendogram with the final (and initial) cut-off distance $\tilde{d}$.

Figure 4.11(a) illustrates the results of the k-means clustering approach. Modes with more than 11 elements are retained in the set. Table 4.4 displays the final selection of modes, where within each cluster the mode with the highest MPC value is selected. Furthermore, the MAC-matrix



(a)



(b)

Fig. 4.9: 4.9(a): Result of the k-means clustering: black stars: clusters with a high number of elements, grey stars: clusters with a low number of elements, which are discarded (pLSCF); 4.9(b): MAC-matrix of the identified modes (pLSCF)

of the selected modes is displayed in figure 4.11(b). From the MAC-matrix, it seems that mode three and four are not unique, although their frequencies are slightly different. This issue will be checked in the following processing step.

Combination of results from different identification methods

As described in the previous section, the 'raw modes' identified from the three methods are submitted to a final clearing step (discard modes with MPC < 0.7 (0.5 for FBG data) and merge modes with MAC > 0.95). Then a hierarchical clustering with a cut-off distance of 0.4 is implemented to determine the global numbering of the modes stemming from the three identification methods. Table 4.5 displays the result of this procedure, by aligning the same mode identified by different methods. Additionally, the two times standard deviation bounds are indicated for the frequency and damping estimates from the SSIcov method. This final overview table for all tests conducted on the same structural system can be found in chapter 5.

Combination of results from different tests

The previous example focused on the evaluation of acceleration data from a single test. In the last step of the evaluation algorithm, the final modes from all data sets acquired on a structural system are merged to obtain the final modes of the system. The herein presented data set (Impact Nr. 11) stems from dynamic tests on the structural system Nr. 2 (pinned bottom connection, post-tension force of 400kN). The combined results of all tests on the structural system Nr. 2 can be found in chapter 5 section 5.2.3.

Tab. 4.3: Selected modes - pLSCF

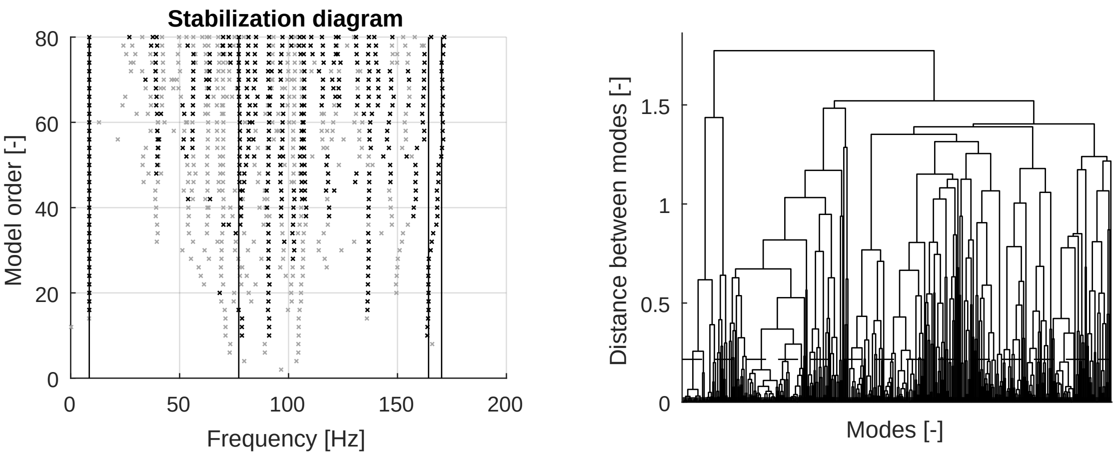
Mode Nr.	Frequency [Hz]	Damping [%]	MPC [-]	MPD [°]
1	8.56	1.36	1.0	0.47
2	62.9	1.16	0.39	28.4
3	70.0	1.22	0.32	29.6
4	70.7	1.54	0.53	22.6
5	76.9	1.49	0.61	22.4
6	80.4	1.44	0.88	13.6
7	90.9	1.18	0.84	10.3
8	97.0	0.56	0.74	20.2
9	102.8	0.83	0.51	24.3
10	105.4	0.42	0.83	12.9
11	107.7	0.67	0.61	18.4
12	136.4	1.37	0.60	23.3
13	136.7	1.16	0.60	24.1
14	159.9	1.70	0.89	14.3
15	161.4	2.27	0.89	14.5
16	165.1	1.13	0.82	15.5

Tab. 4.4: Selected modes - SSIcov

Mode Nr.	Frequency [Hz]	Damping [%]	MPC [-]	MPD [°]
1	8.54	1.56	1.0	0.63
2	77.2	1.58	0.95	7.28
3	164.3	3.54	0.93	10.3
4	170.3	2.46	0.89	11.1

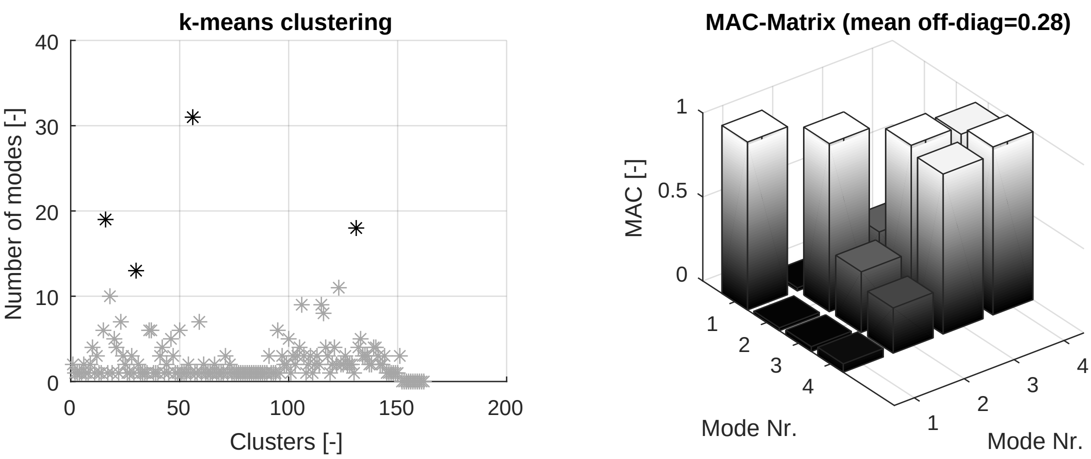
Tab. 4.5: Selected modes - 3 methods combined

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.99	8.56	1.36	1.0	-0.13	8.54±0.01	1.56±0.27	1.00	-0.46
2	-	-	-	-	-	-	77.2±0.48	1.58±2.04	0.95	-0.46
3	-	-	80.4	1.44	0.85	1.39	-	-	-	-
4	91.1	0.95	90.9	1.78	-	-0.04	-	-	-	-
5	-	-	97.0	0.56	0.82	-7.97	-	-	-	-
6	-	-	105.4	0.42	0.96	-10.7	-	-	-	1.52
7	162.2	0.85	159.9	1.70	0.89	-3.28	164.3±1.49	3.54±0.99	0.93	-2.34



(a) (b)

Fig. 4.10: 4.10(a): SSIcov - Stabilization diagram (grey: all modes, black: modes after soft and hard validation criteria were applied, continuous lines: selected modes) 4.10(b): SSIcov - Dendogram: displaying the mode grouping in the hierarchical clustering step and the cut-off distance (dashed horizontal line)



(a) (b)

Fig. 4.11: 4.11(a): Result of the k-means clustering: black stars: clusters with a high number of elements, grey stars: clusters with a low number of elements, which are discarded (SSIcov) 4.11(b): MAC-matrix of the identified modes (SSIcov)

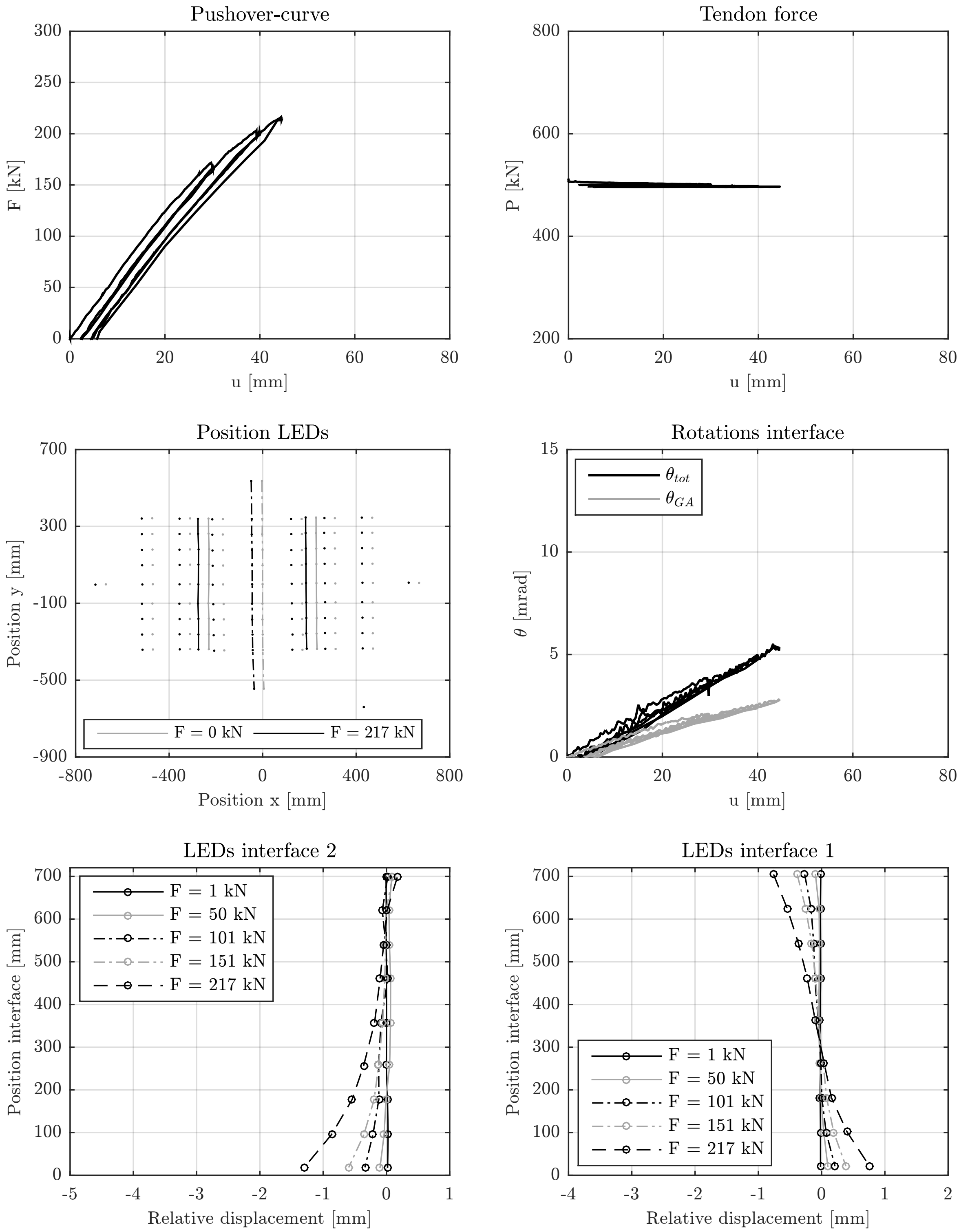
Chapter 5

Test Results

5.1 Pushover tests

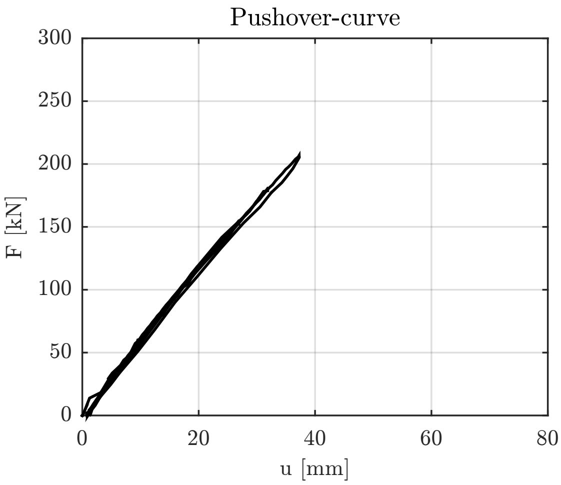
5.1.1 Pushover 1

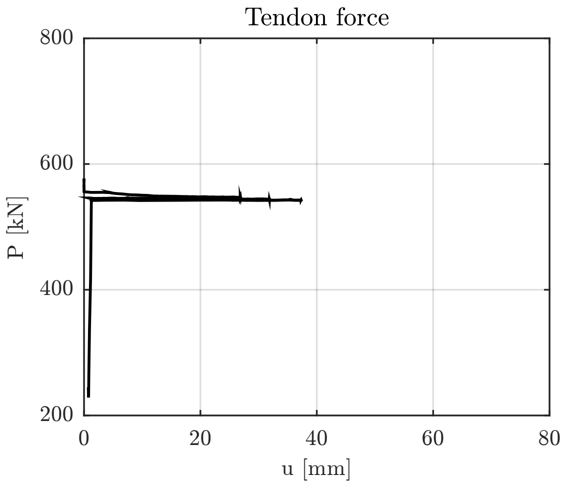
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
1	500	x			220		x

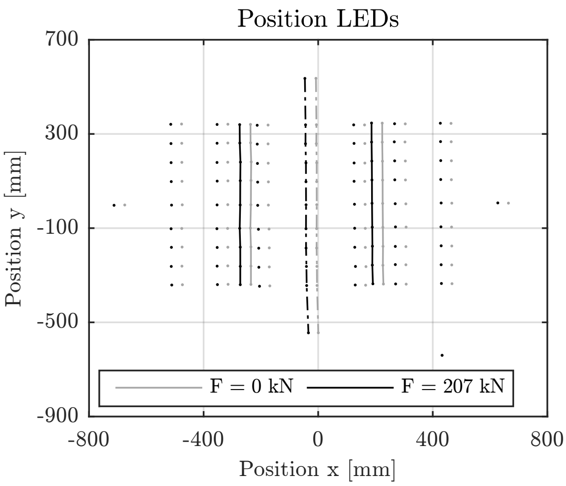


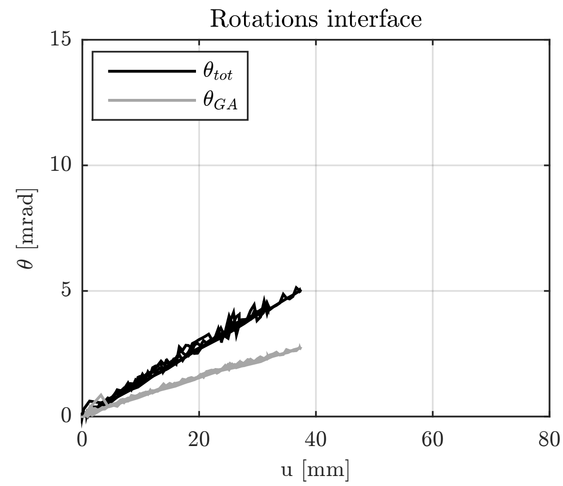
5.1.2 Pushover 2

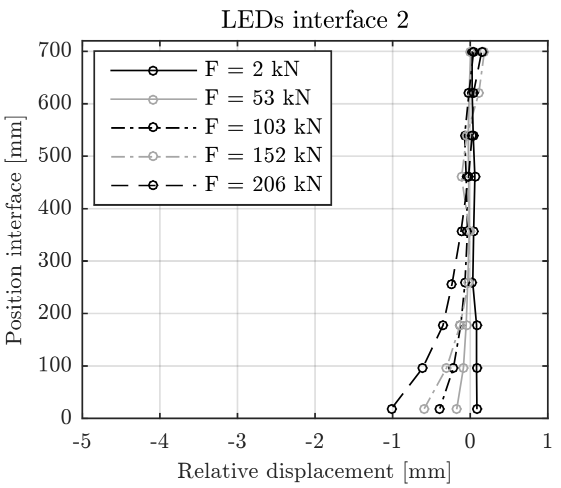
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
2	550	x			210		x

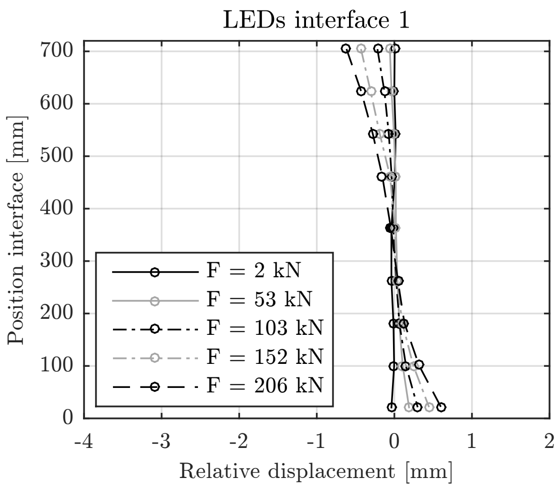






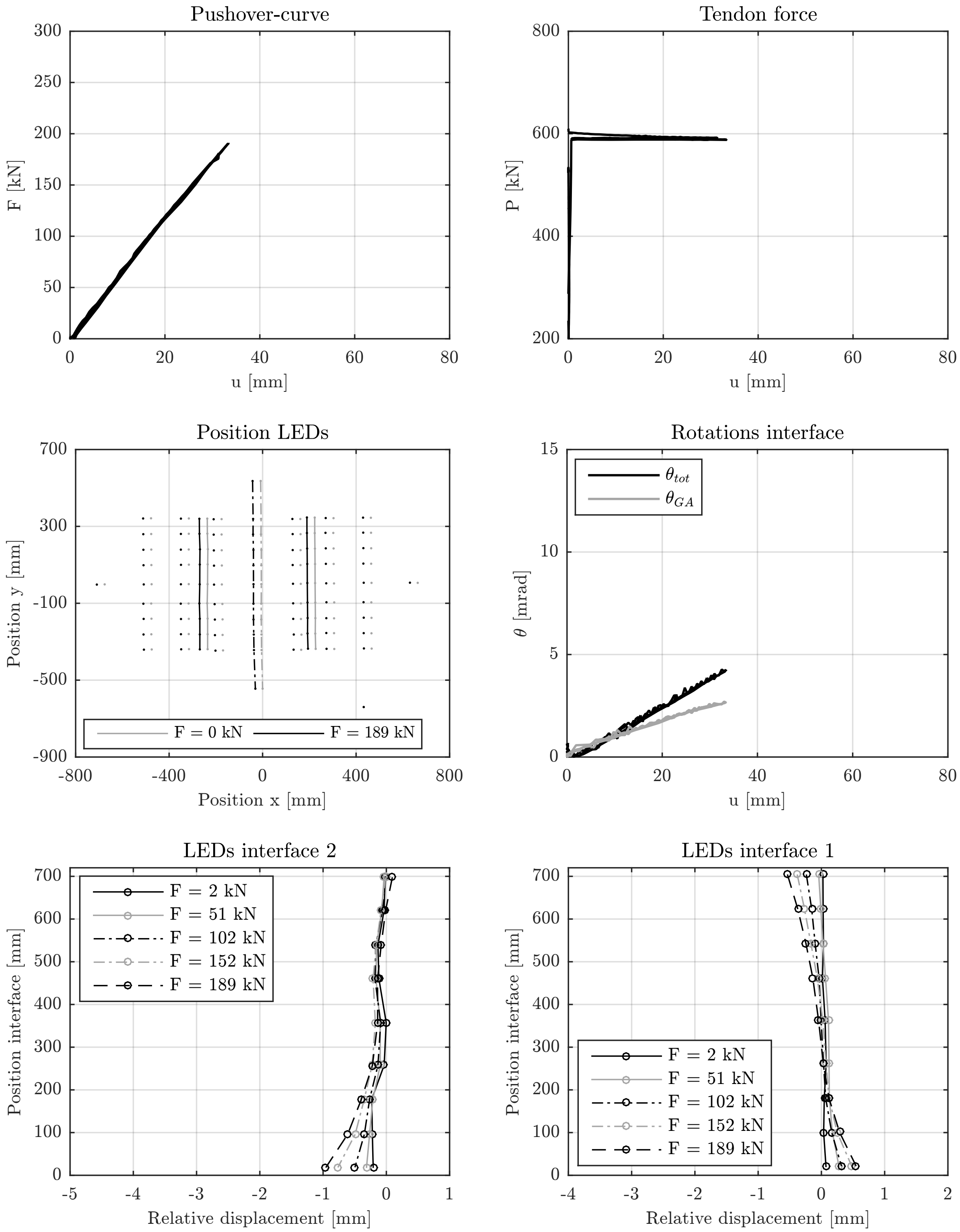






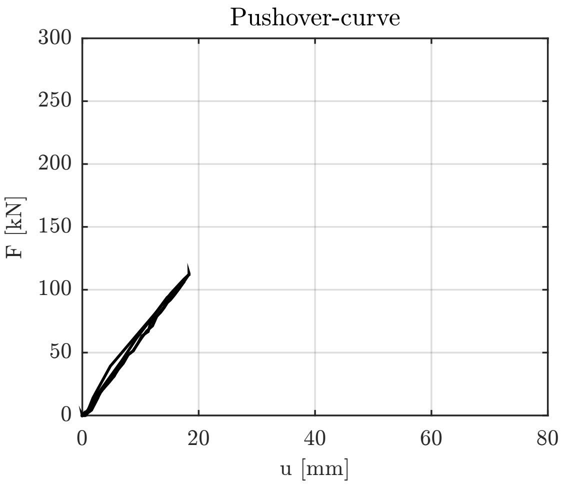
5.1.3 Pushover 3

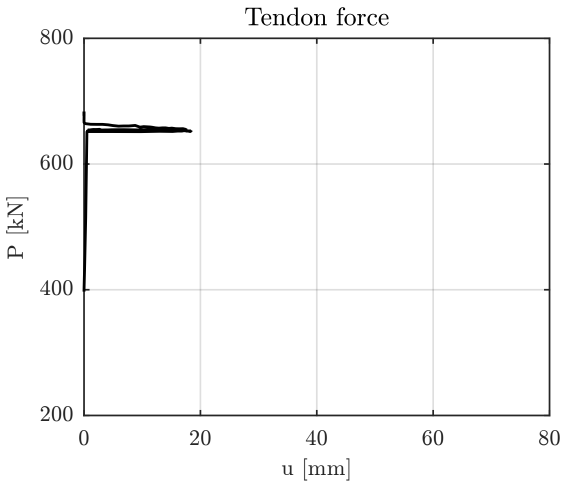
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
3	600	x			190		x

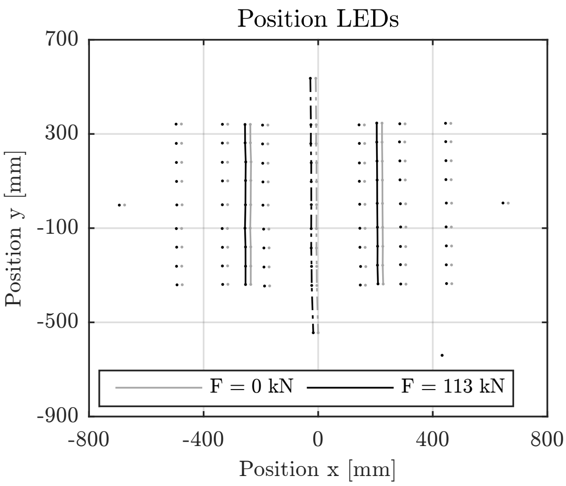


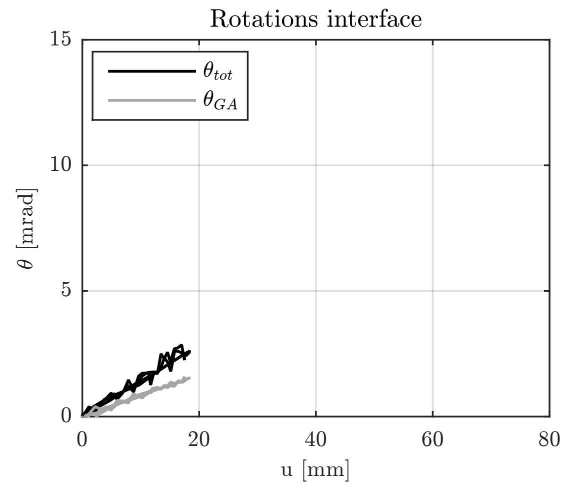
5.1.4 Pushover 4

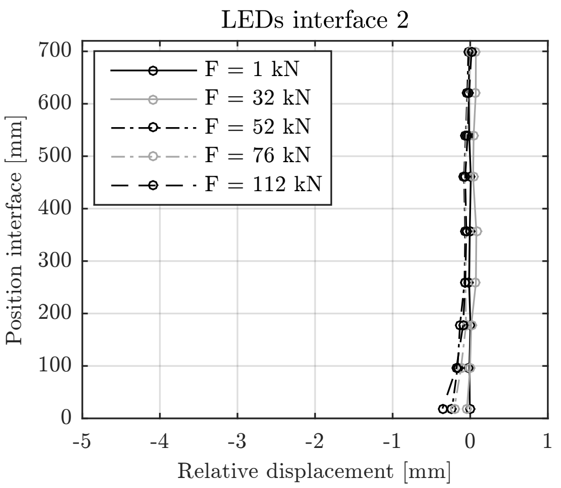
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
4	650	x			110		x

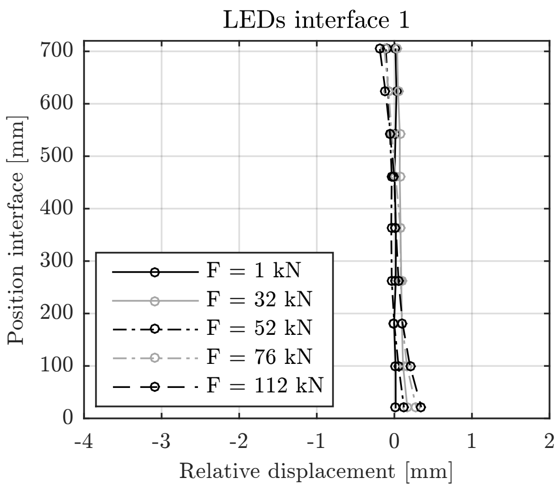






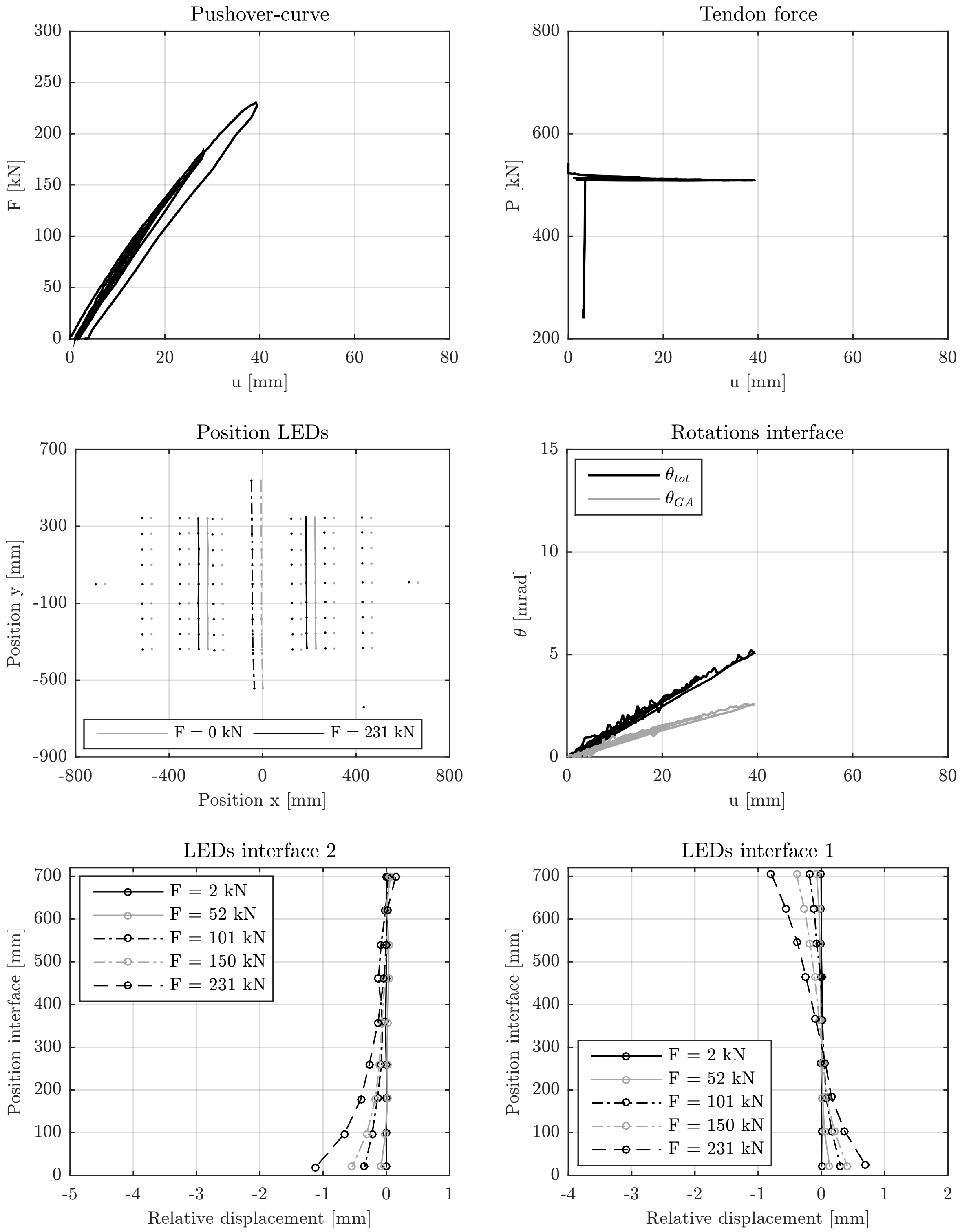






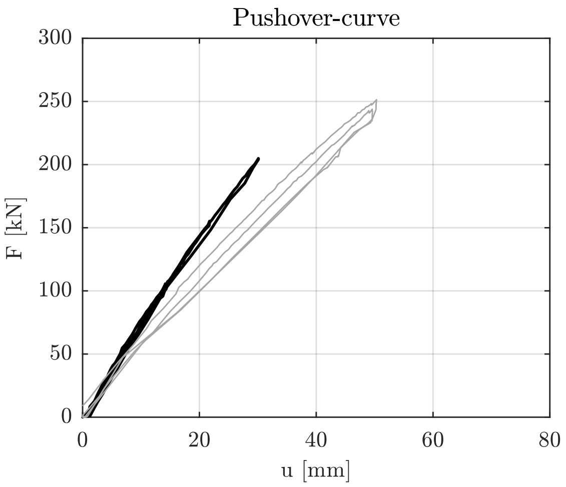
5.1.5 Pushover 5

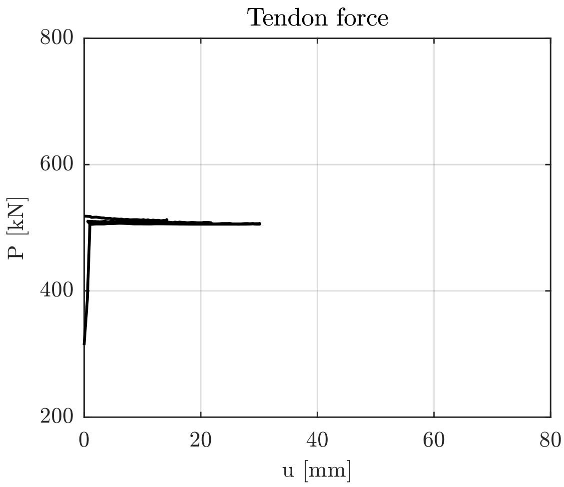
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
5	515		x		230		x

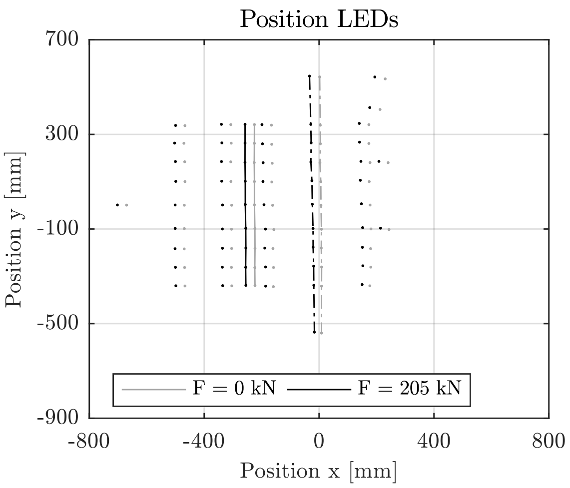


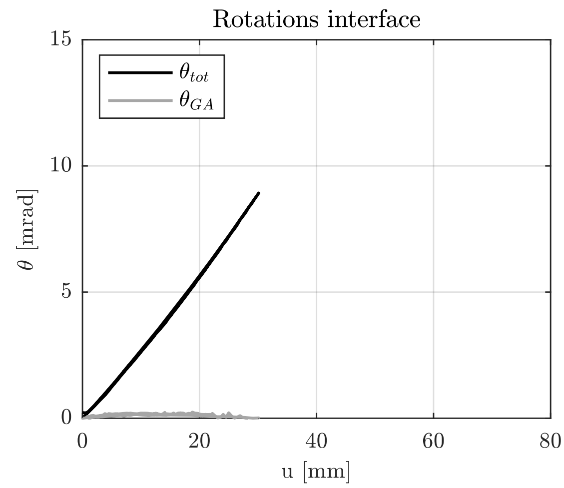
5.1.6 Pushover 6

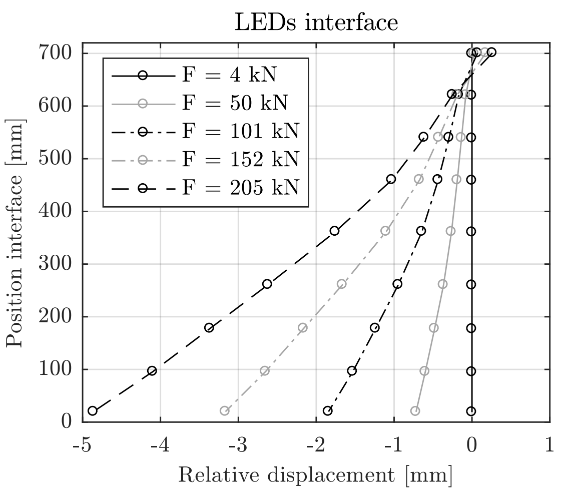
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
6	510		x		205	x	





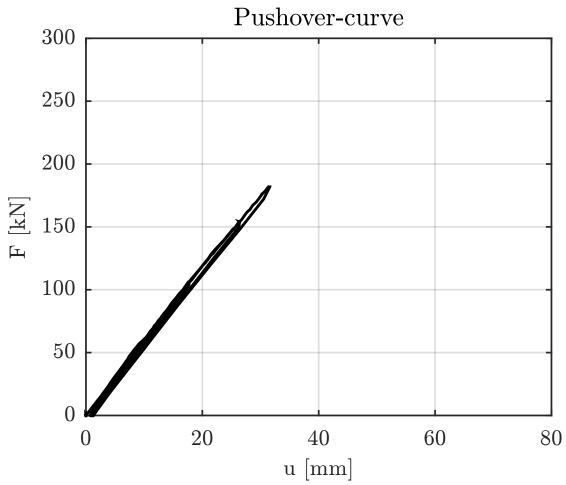


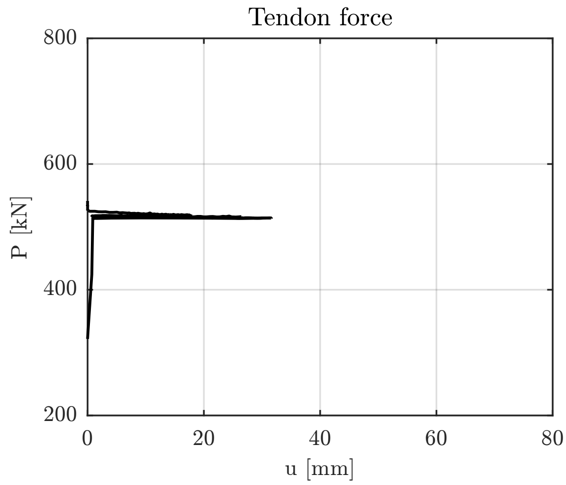


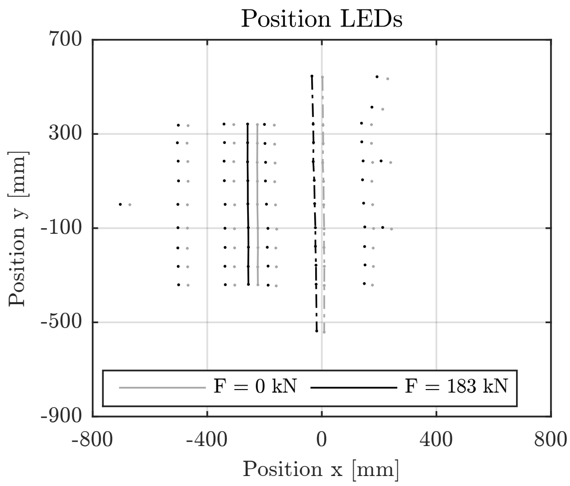


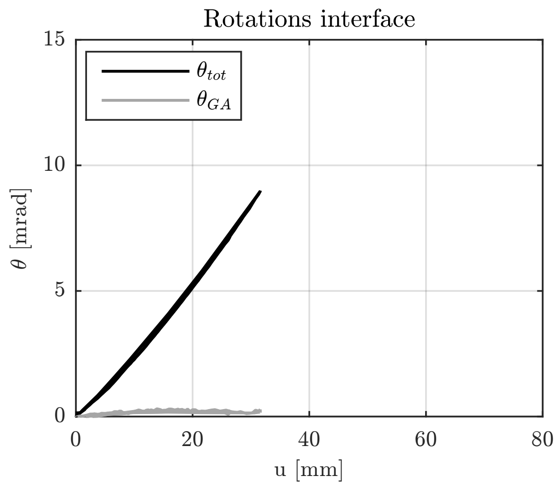
5.1.7 Pushover 7

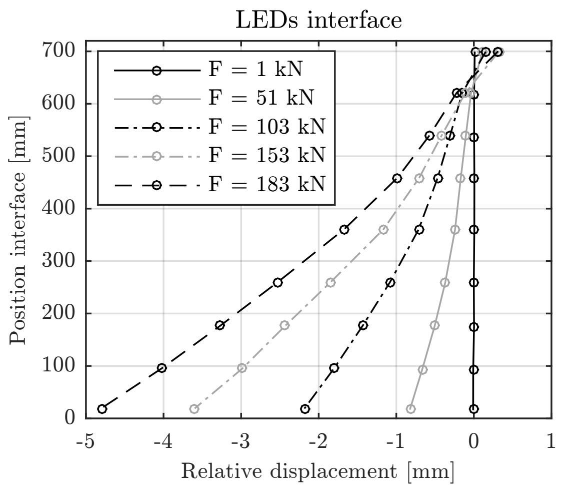
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
7	520	x			180	x	





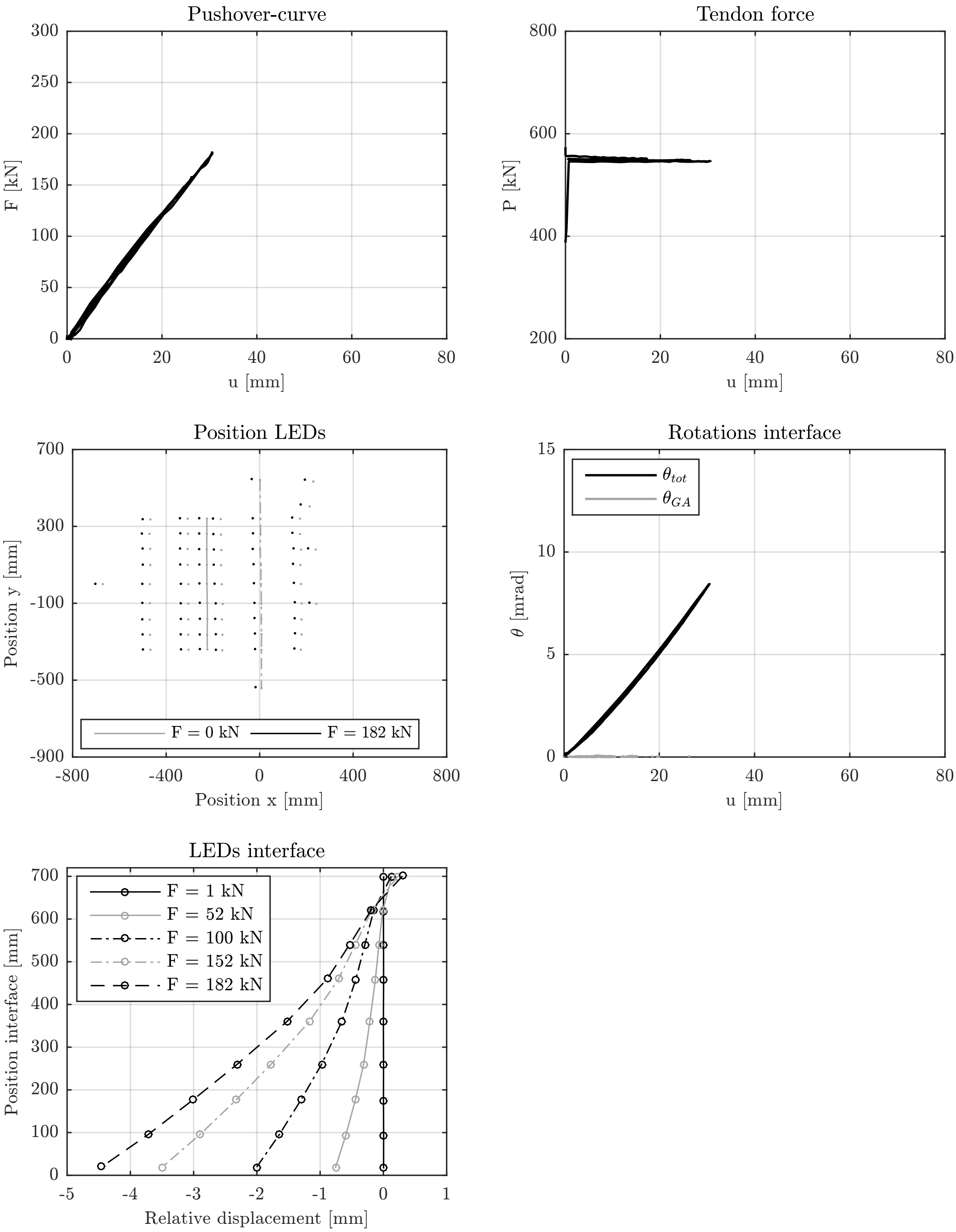






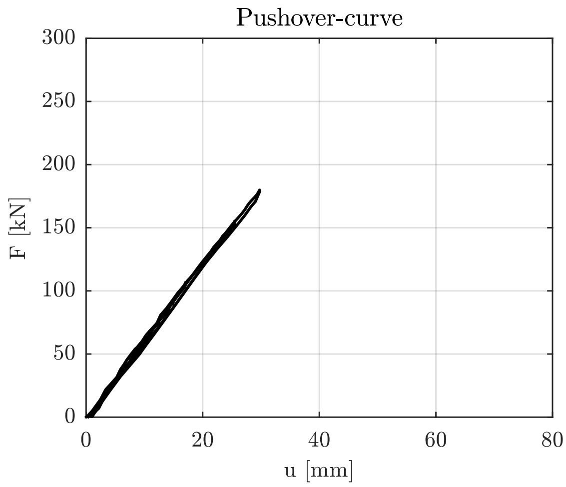
5.1.8 Pushover 8

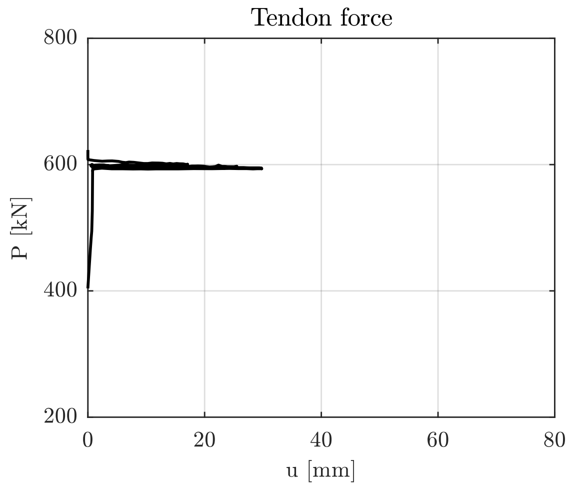
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
8	550	x			180	x	

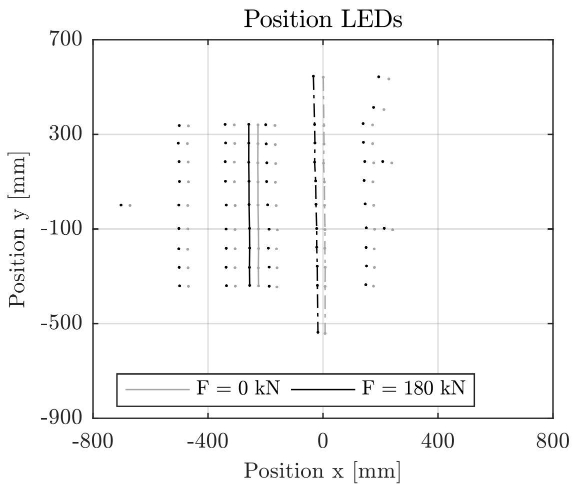


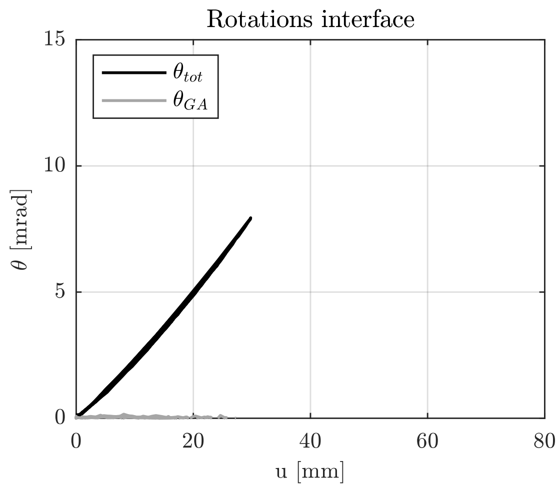
5.1.9 Pushover 9

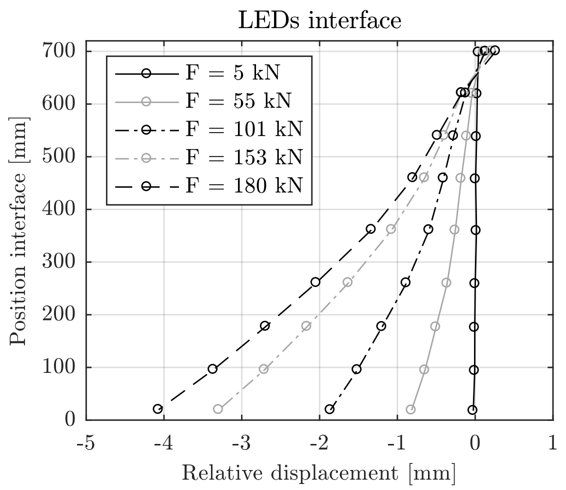
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
9	600	x			180	x	





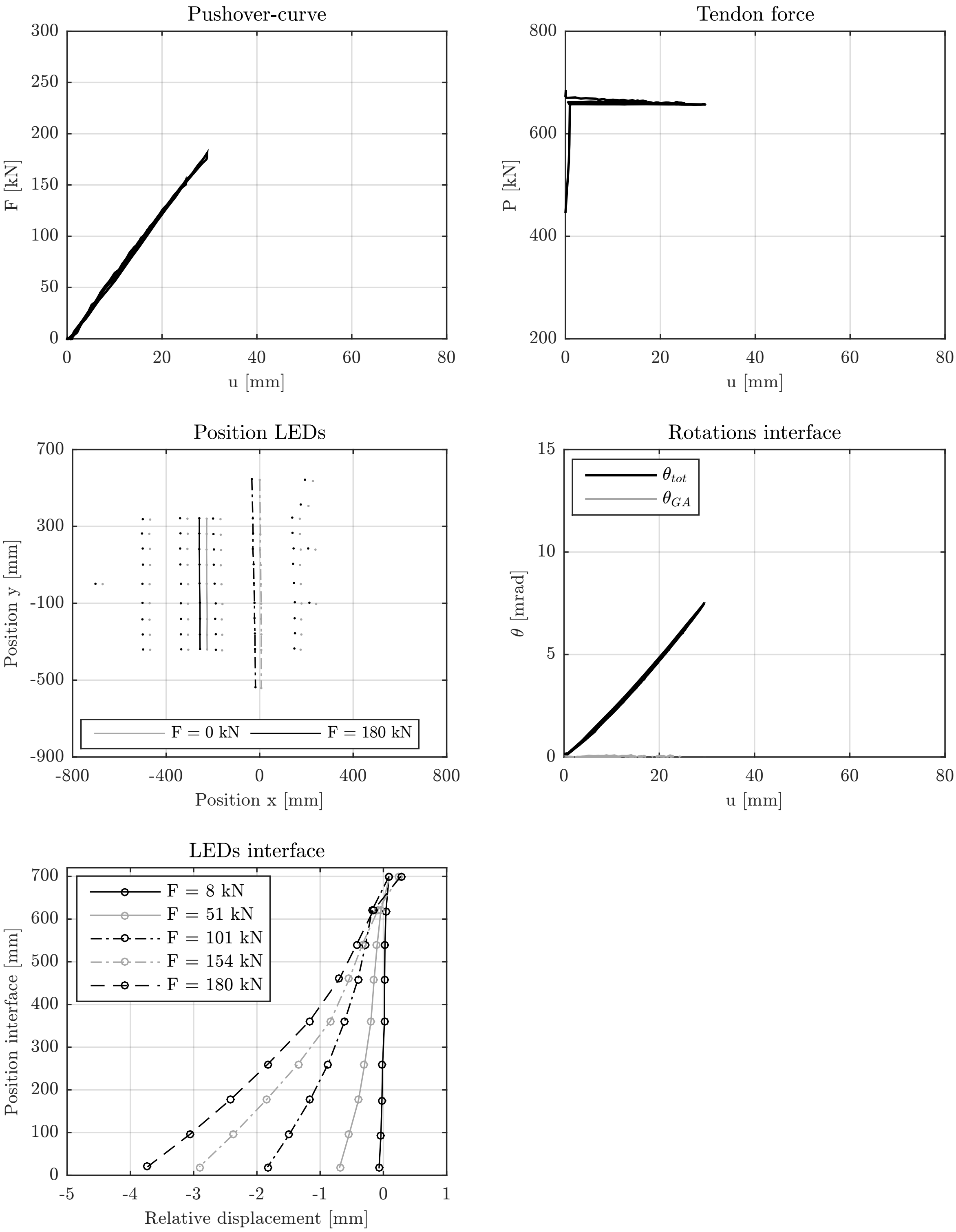






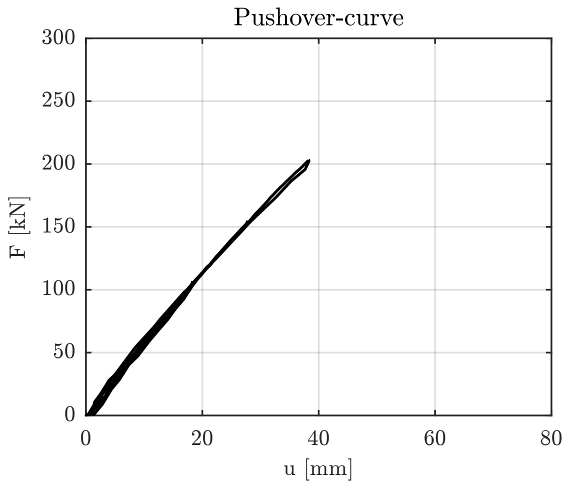
5.1.10 Pushover 10

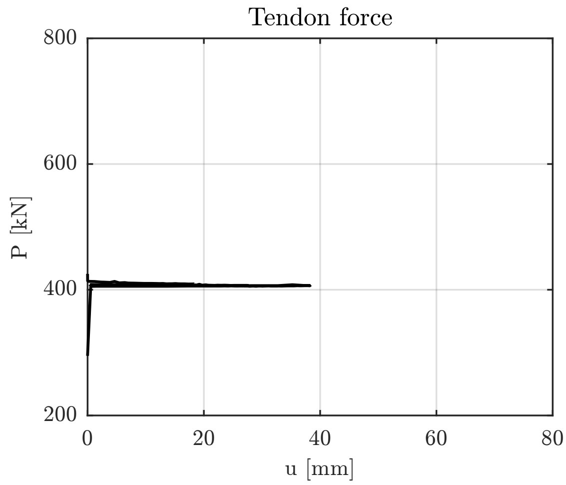
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
10	660	x			180	x	

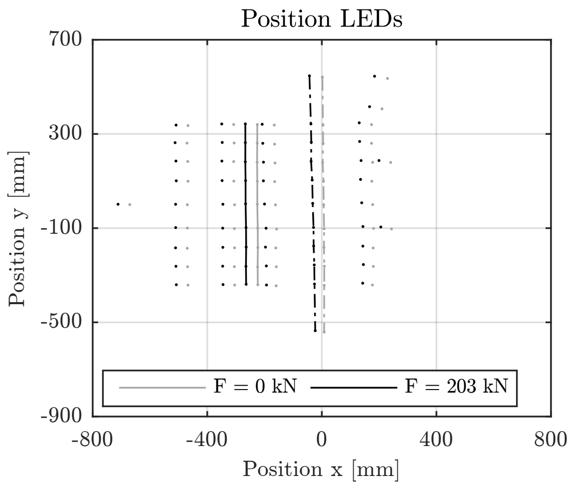


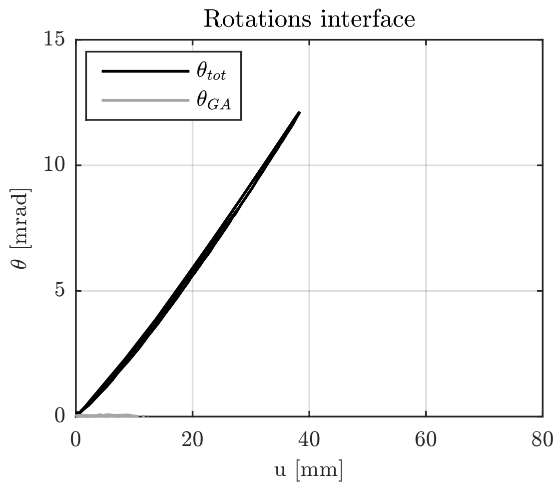
5.1.11 Pushover 11

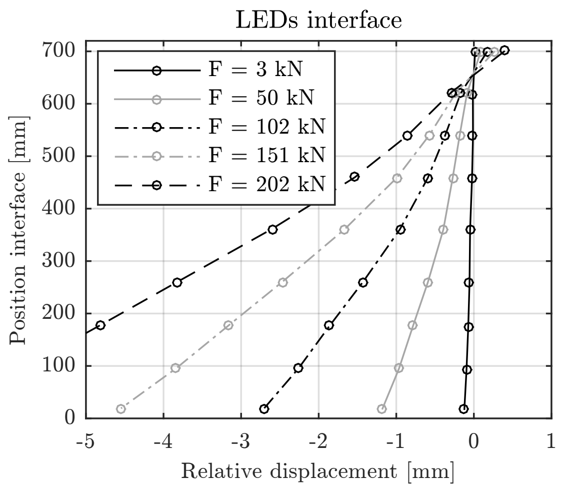
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
11	410	x			200	x	





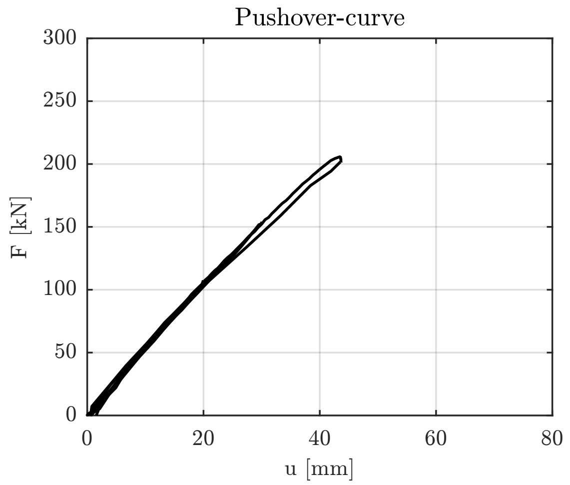


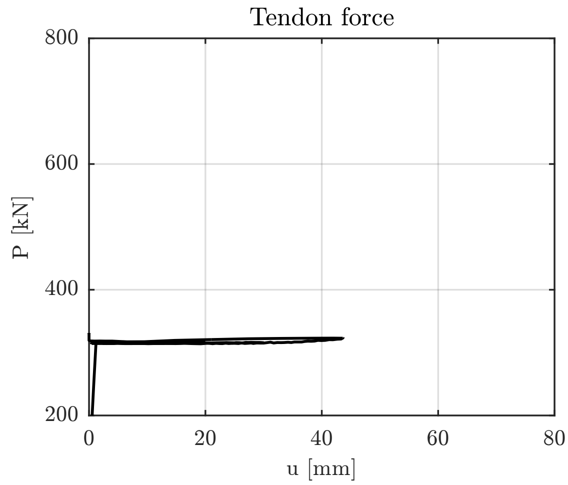


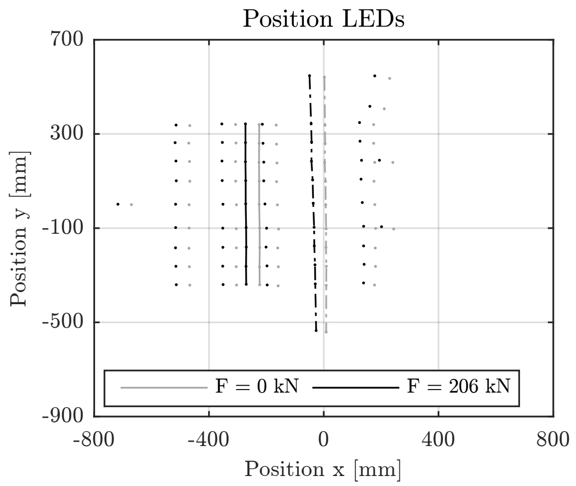


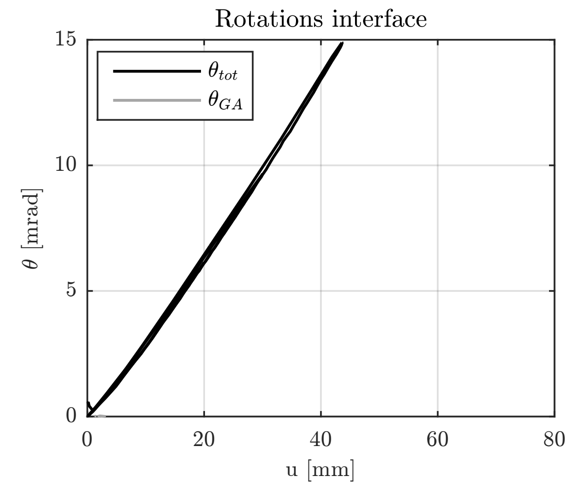
5.1.12 Pushover 12

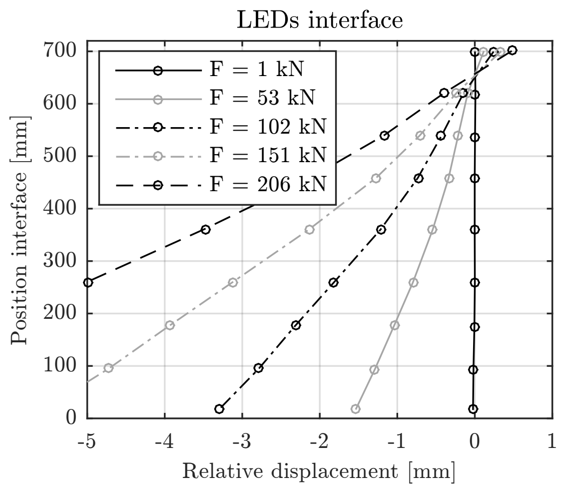
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
12	320	x			205	x	





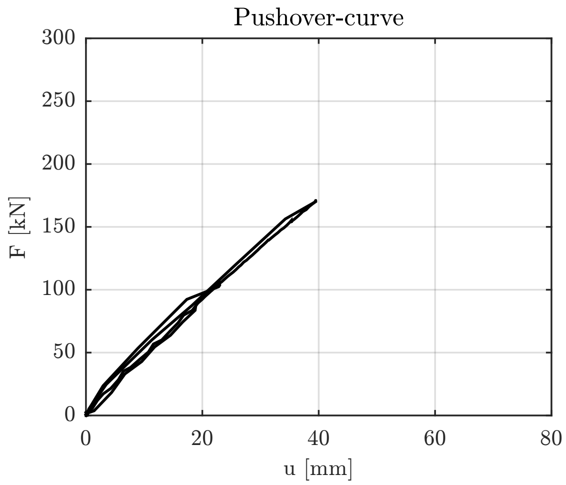


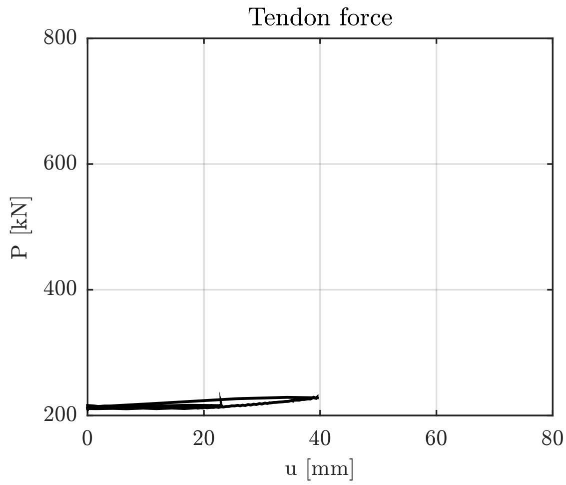


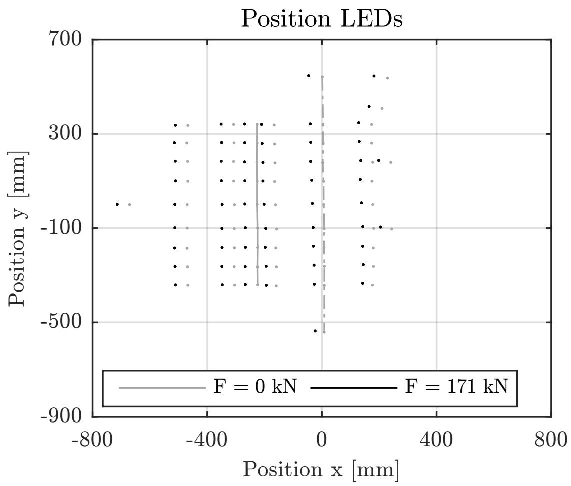


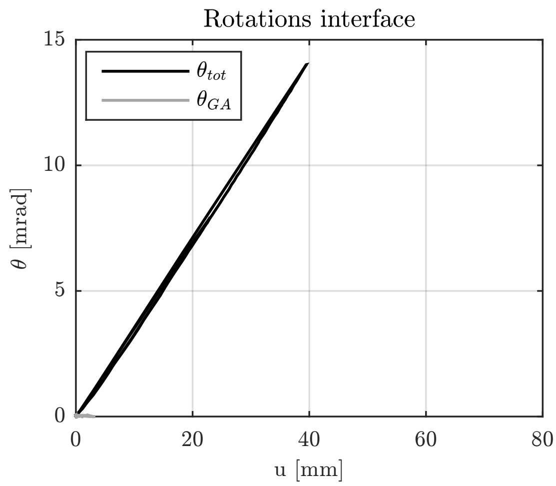
5.1.13 Pushover 13

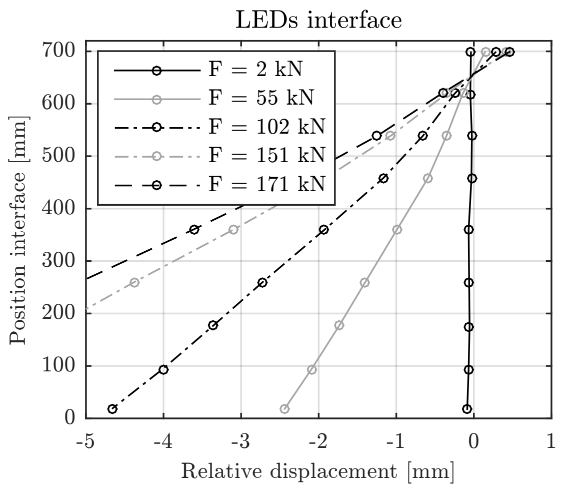
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
13	215	x			170	x	





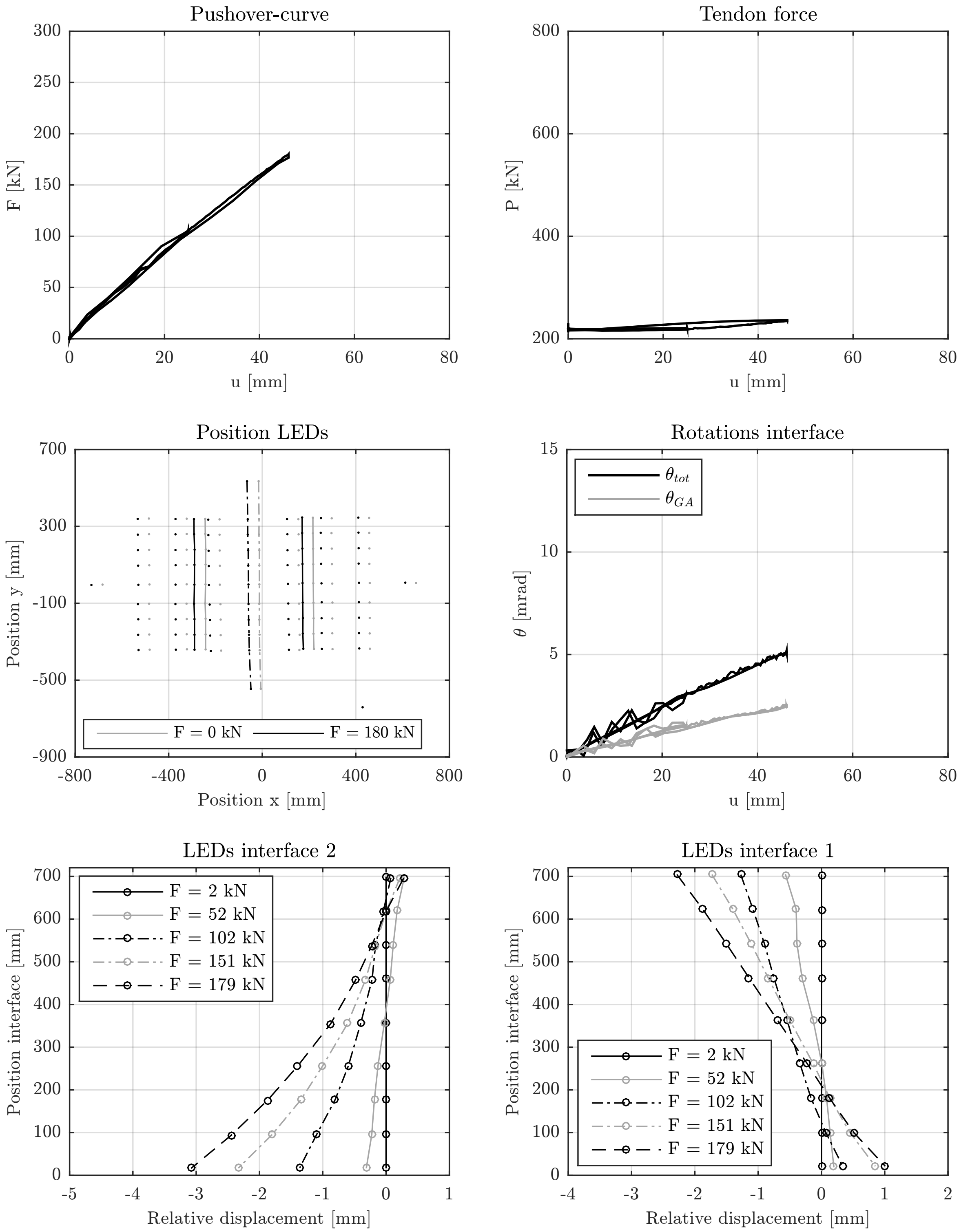






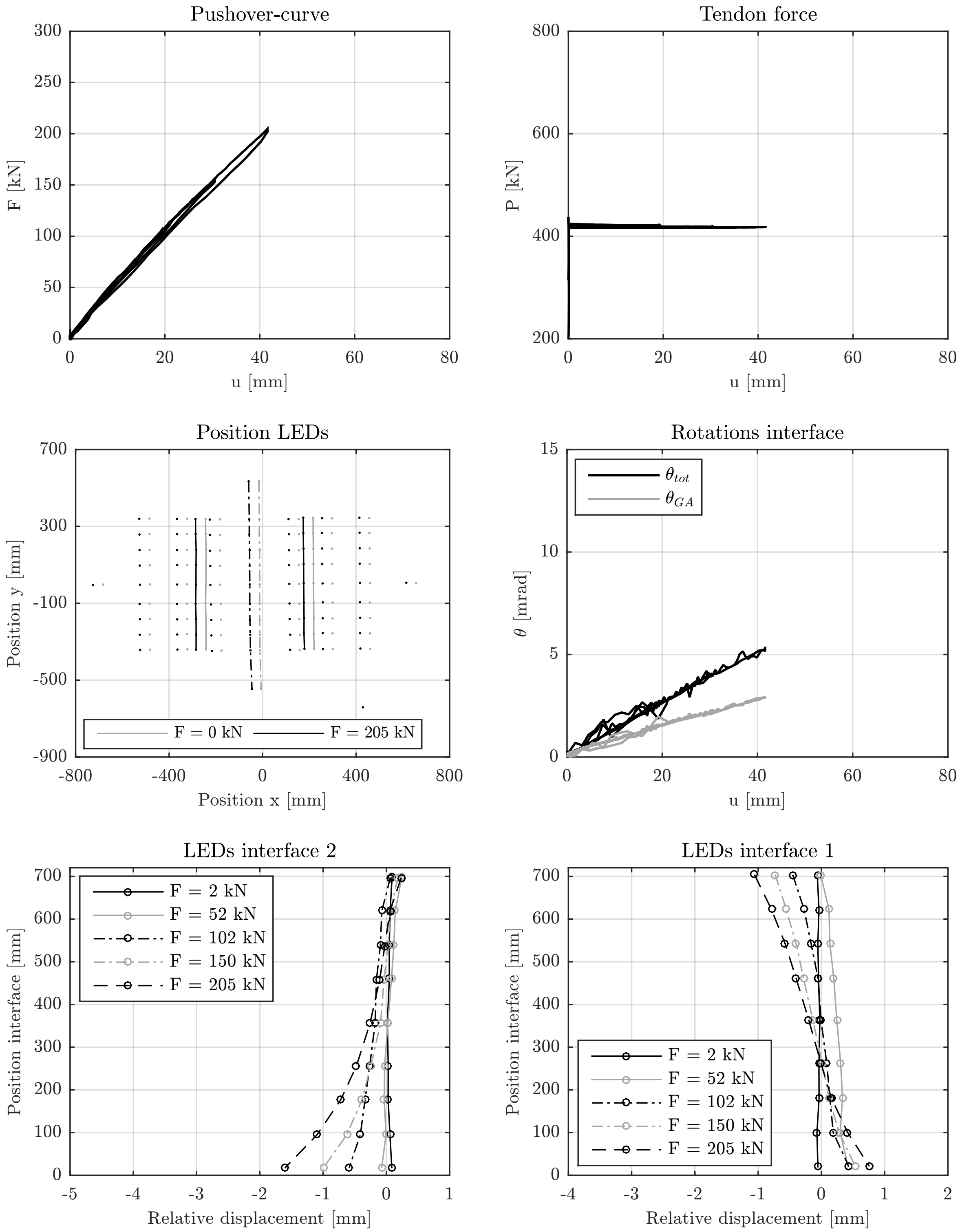
5.1.14 Pushover 14

Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
14	220	x			180		x



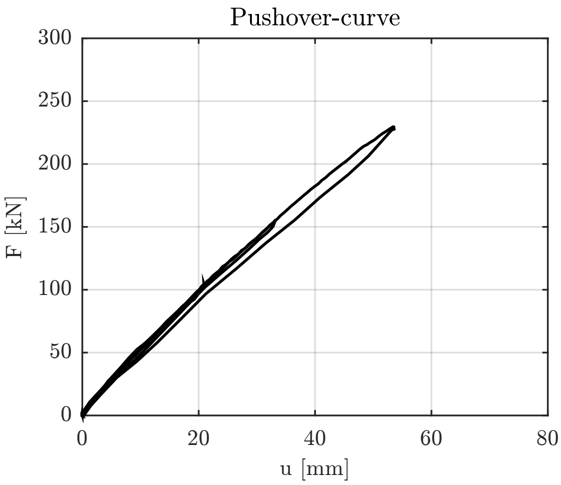
5.1.15 Pushover 15

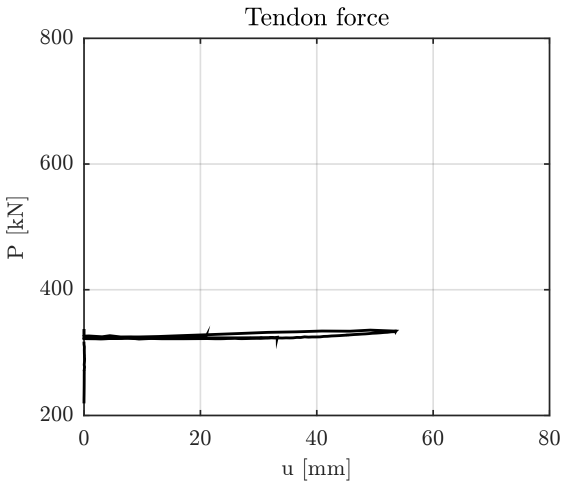
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
15	420	x			205		x

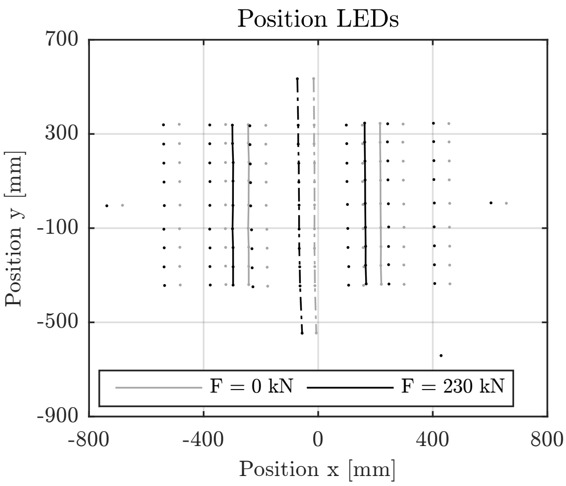


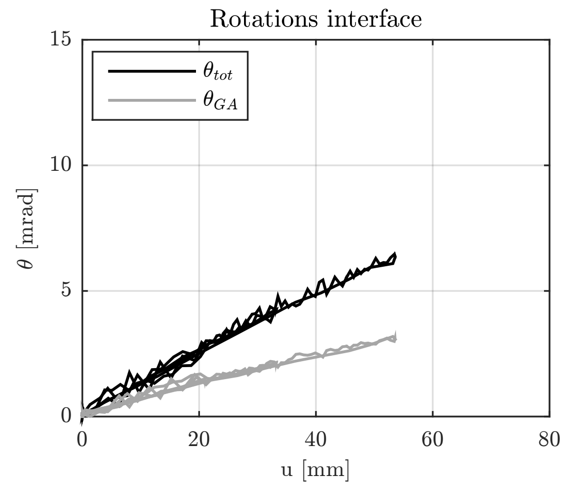
5.1.16 Pushover 16

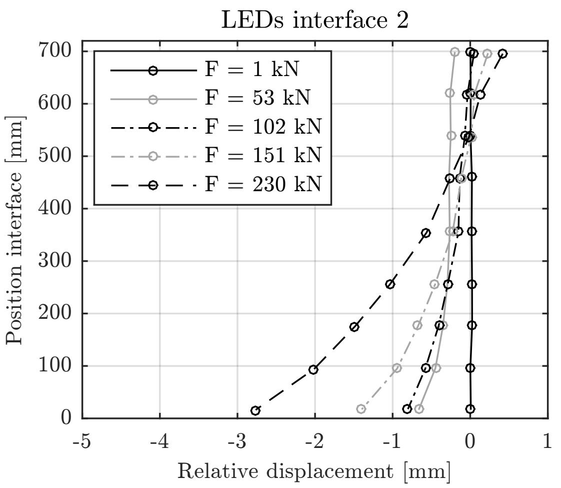
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
16	325	x			230		x

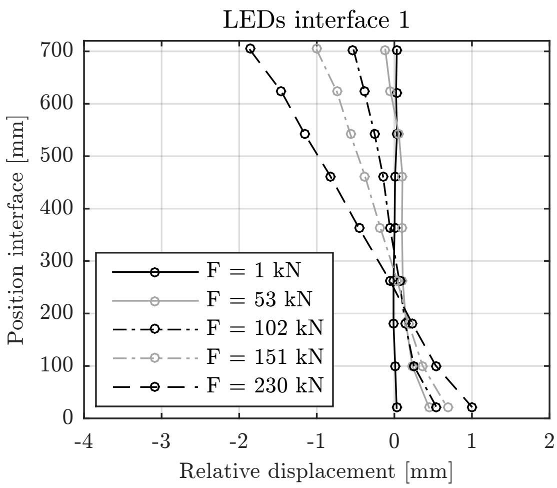






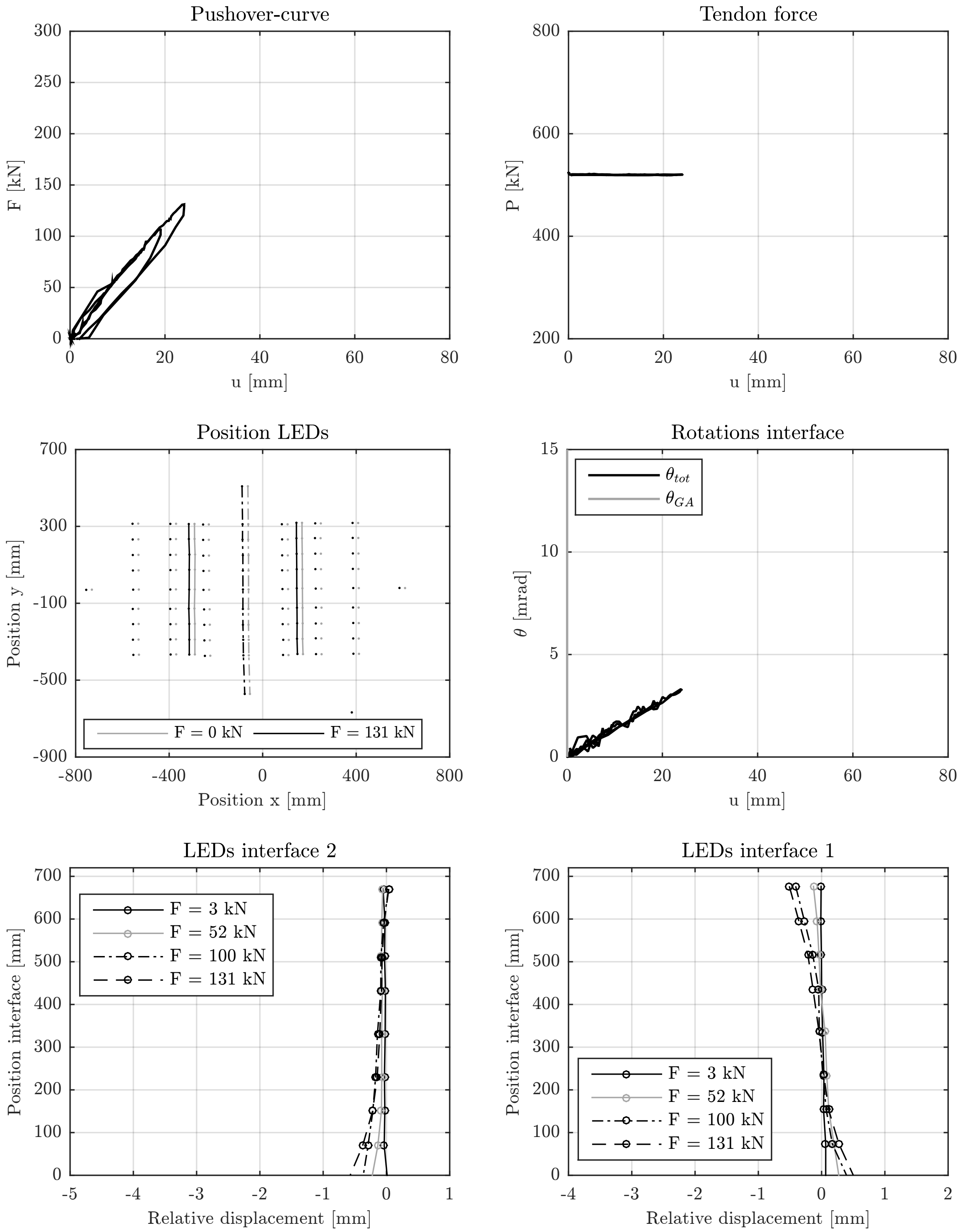






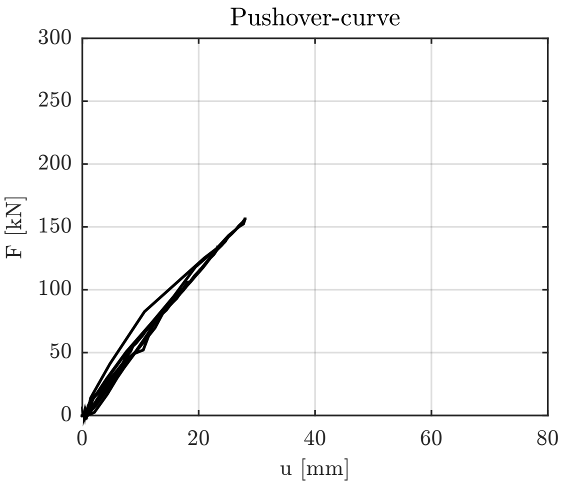
5.1.17 Pushover 17

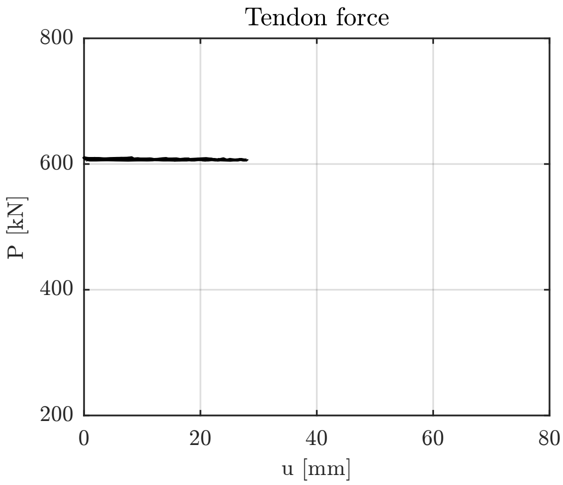
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
17	520	x		x	130		x

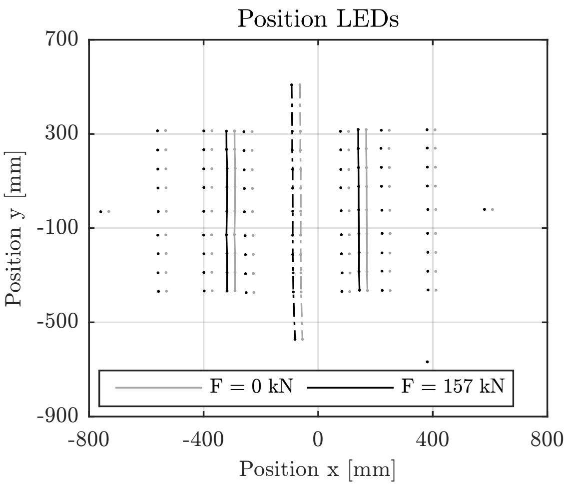


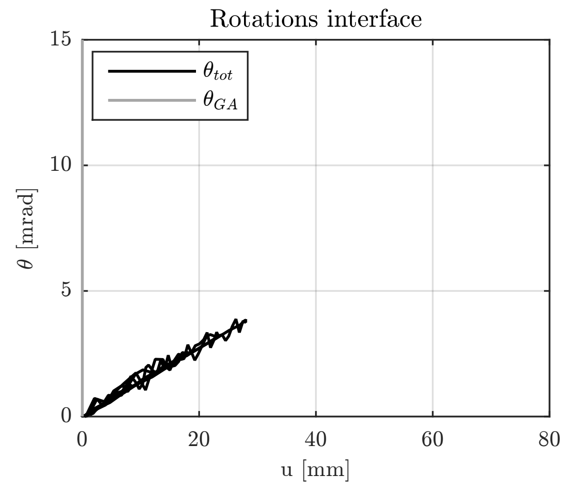
5.1.18 Pushover 18

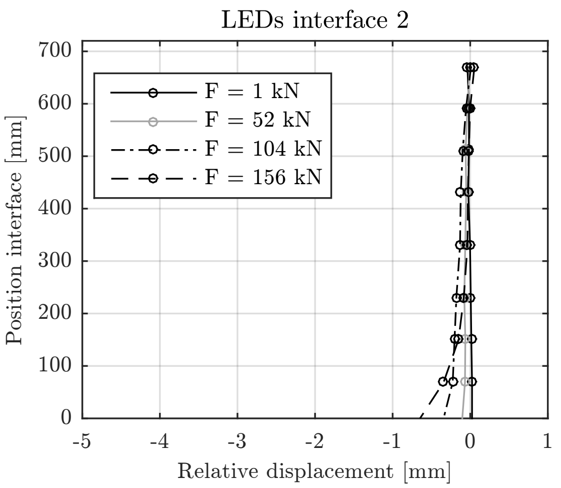
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
18	610	x		x	155		x

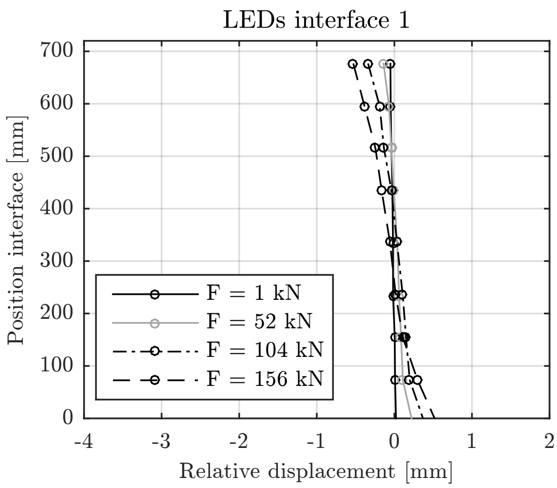






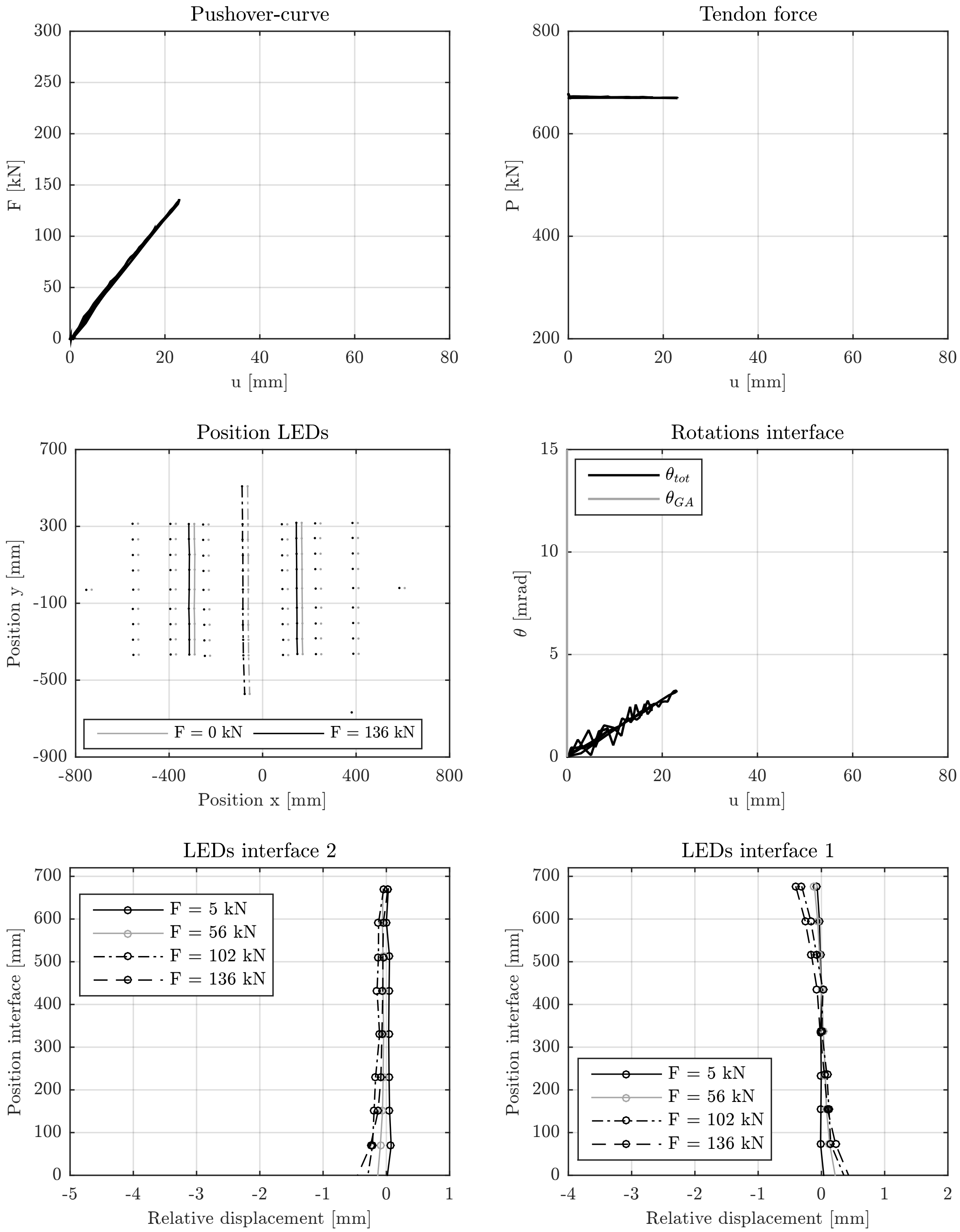






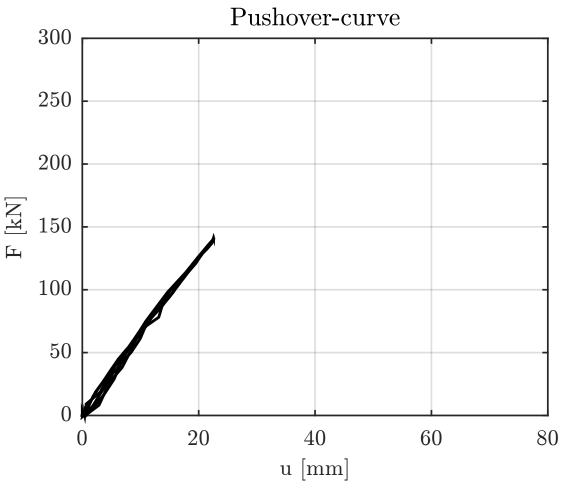
5.1.19 Pushover 19

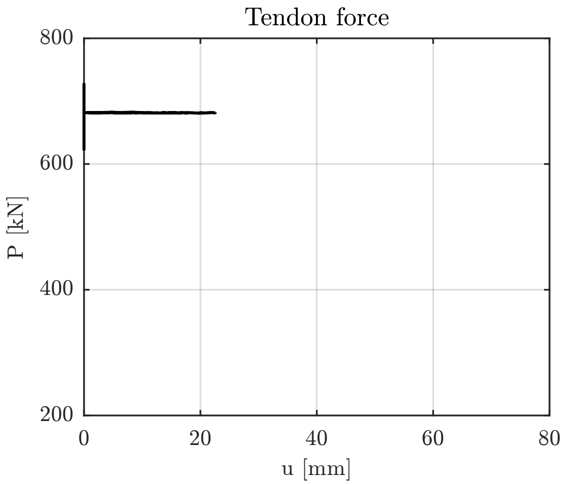
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
19	675	x		x	135		x

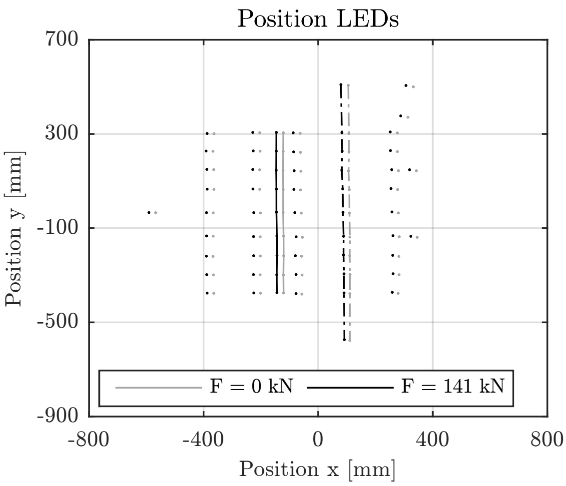


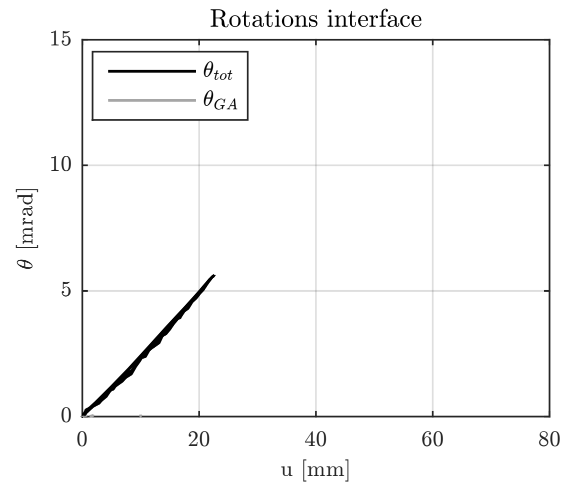
5.1.20 Pushover 20

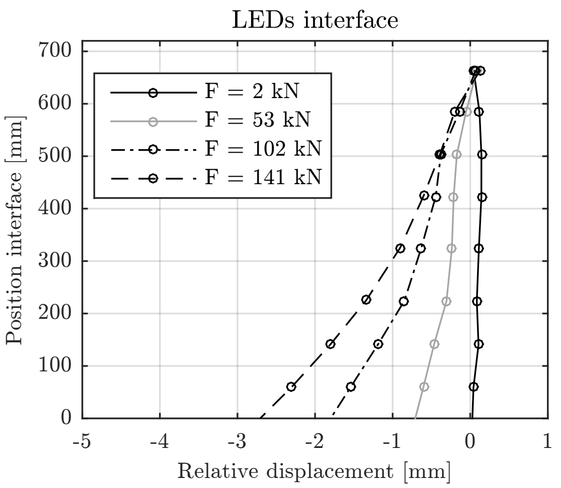
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
20	680	x		x	140	x	





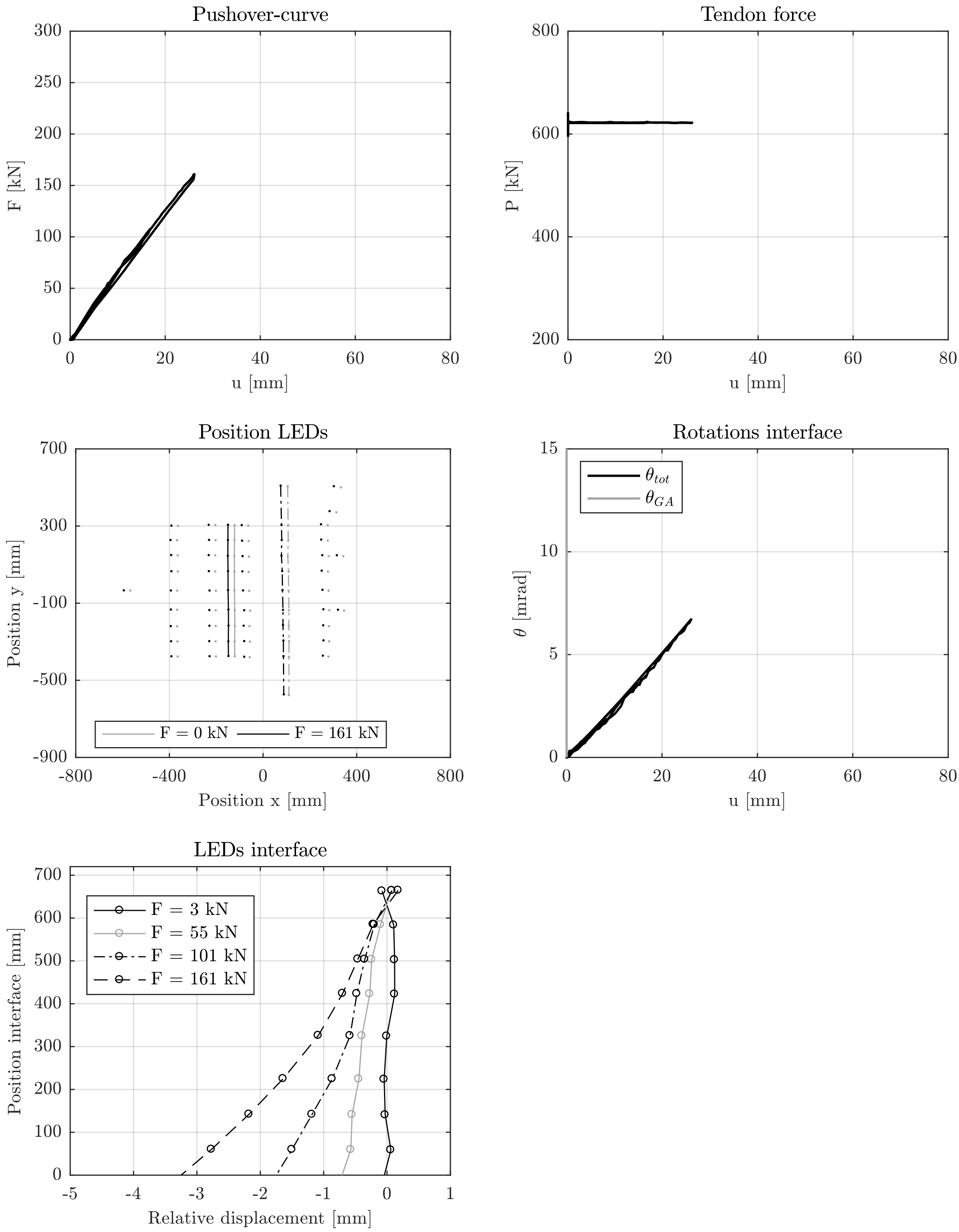






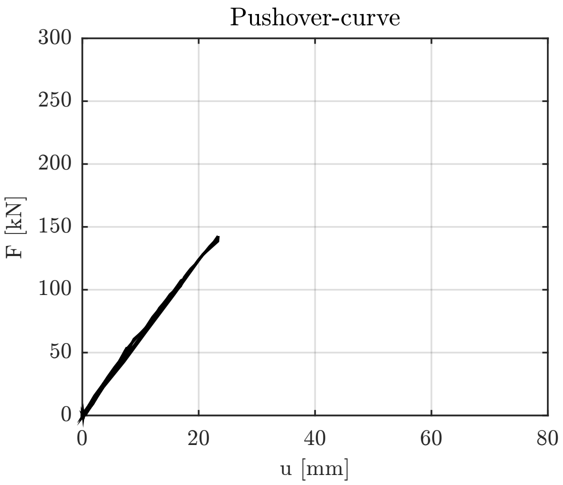
5.1.21 Pushover 21

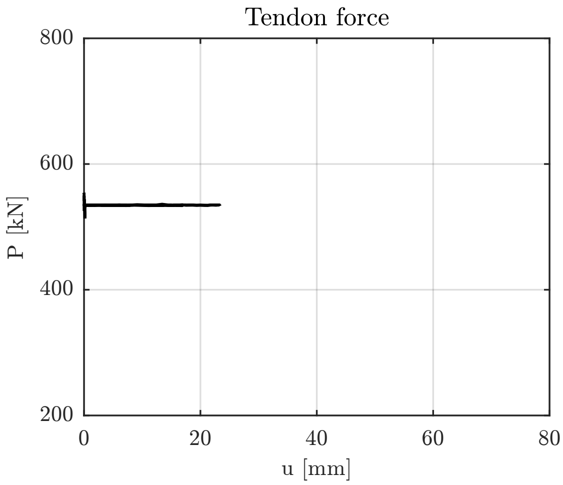
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
21	620	x		x	160	x	

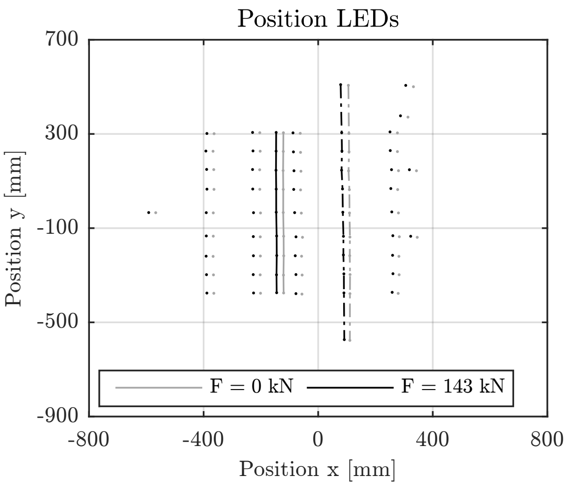


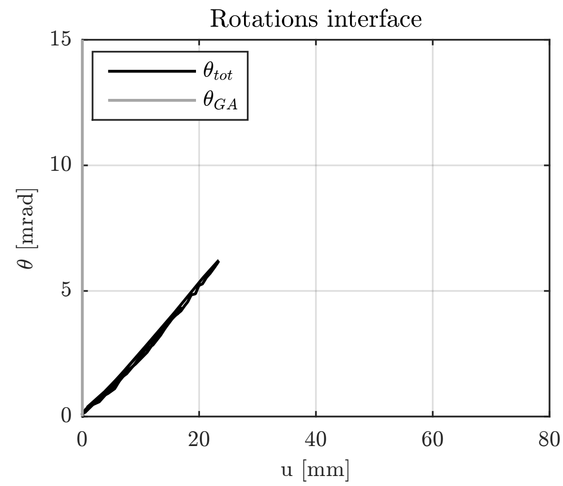
5.1.22 Pushover 22

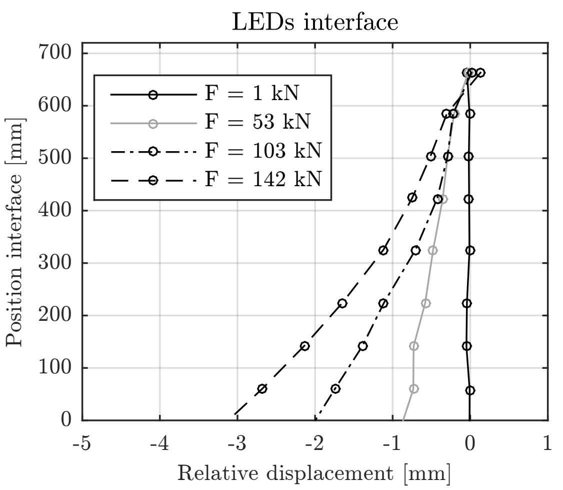
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
22	535	x		x	140	x	





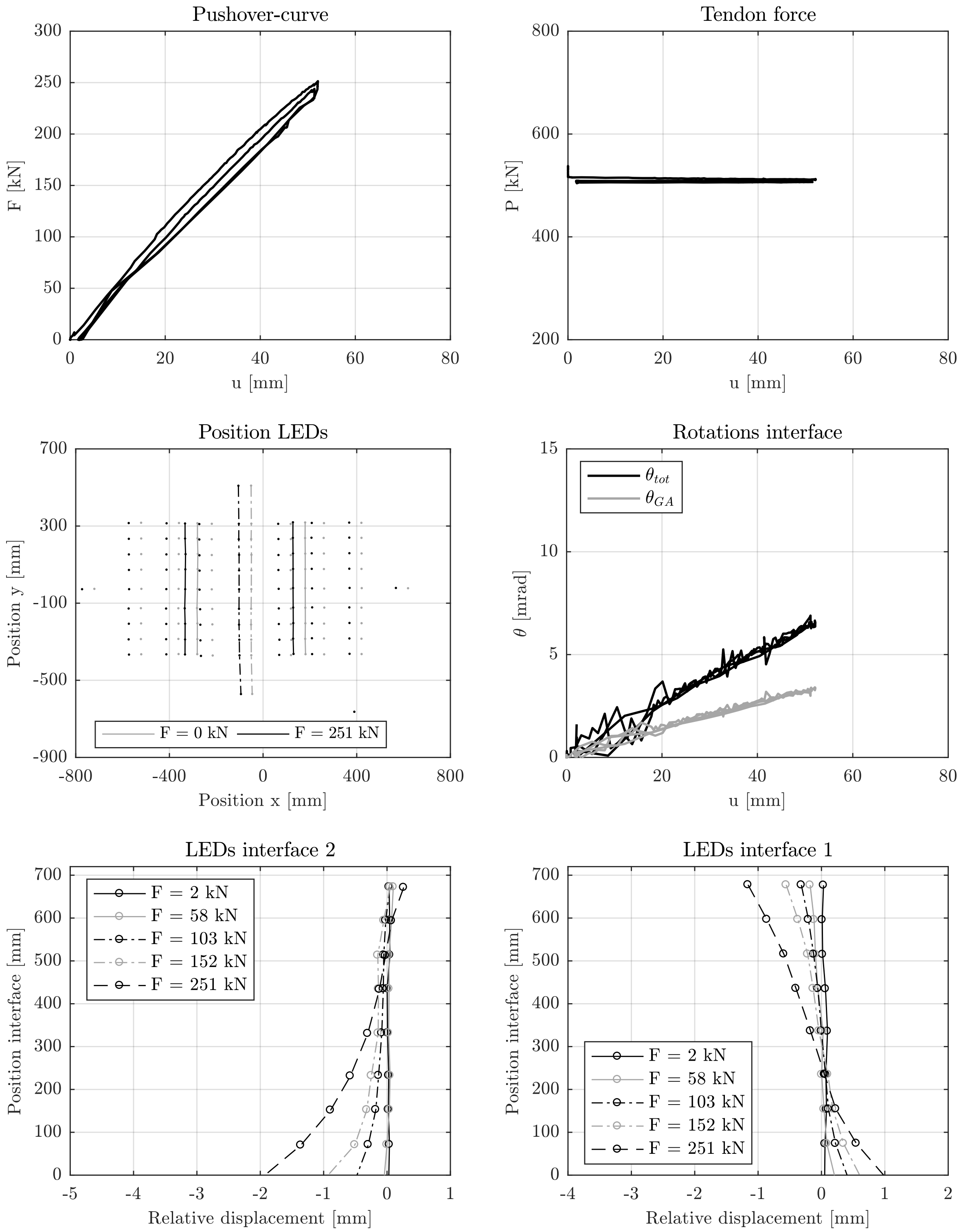






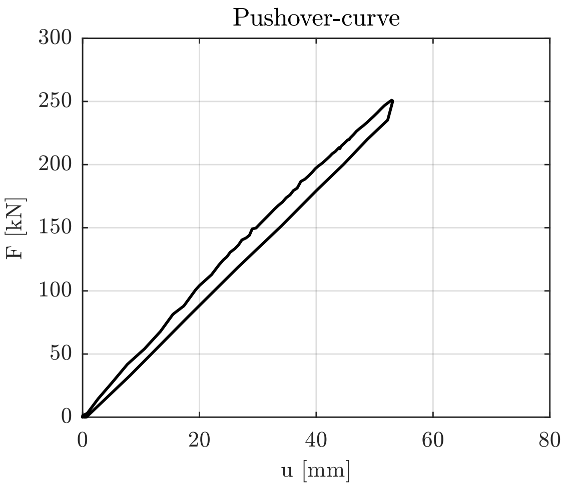
5.1.23 Pushover 23

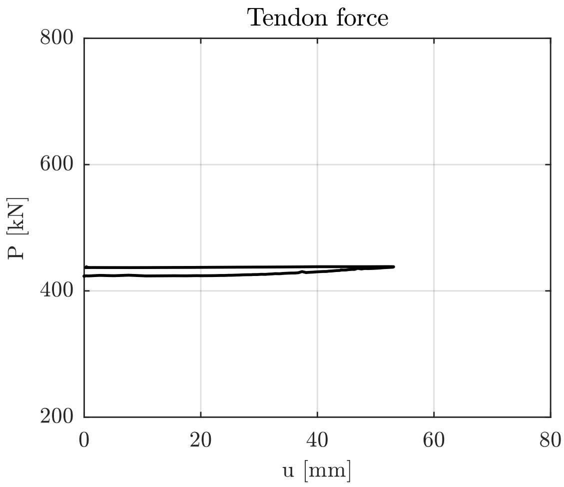
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
23	510	x			250		x

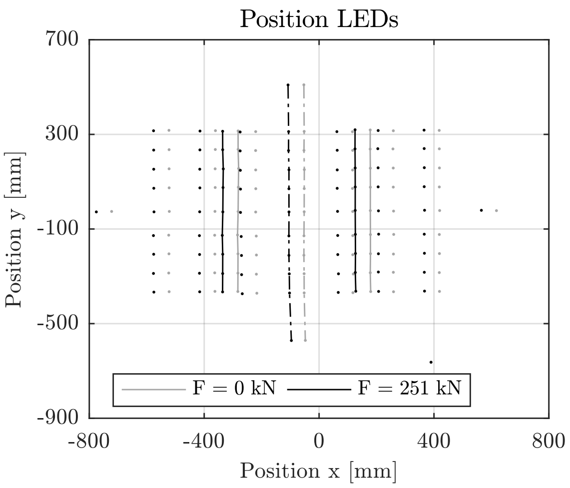


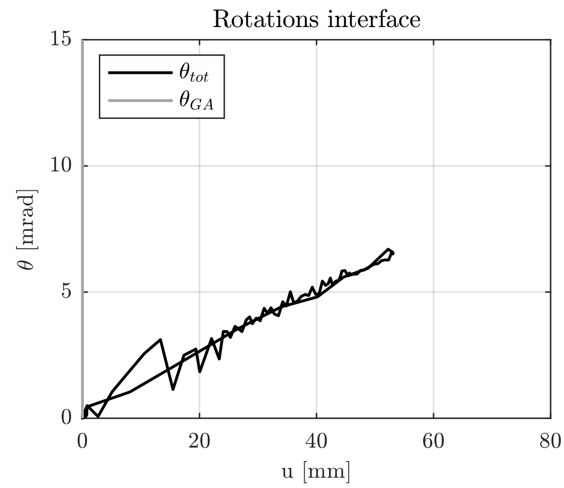
5.1.24 Pushover 24

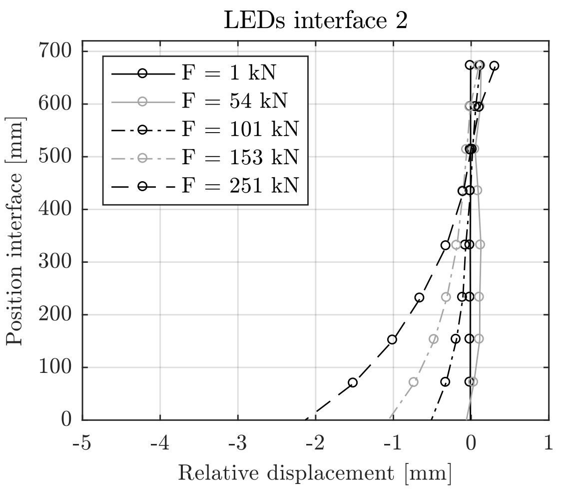
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
24	420	x			250		x

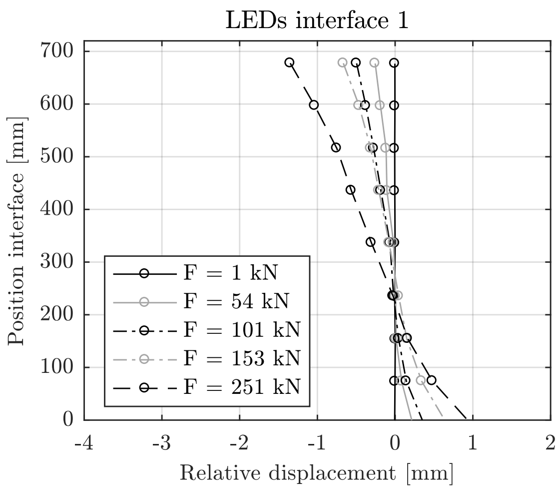






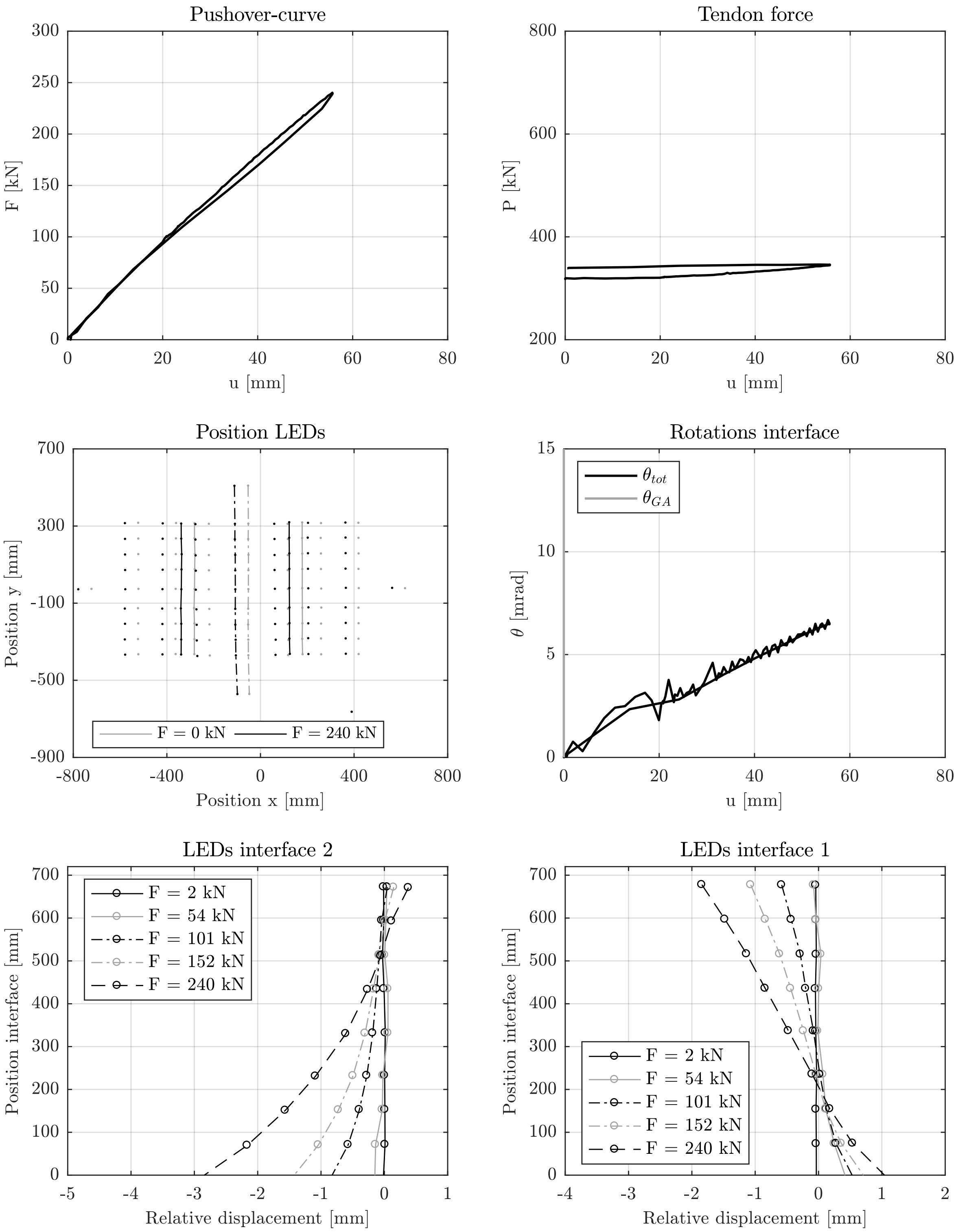






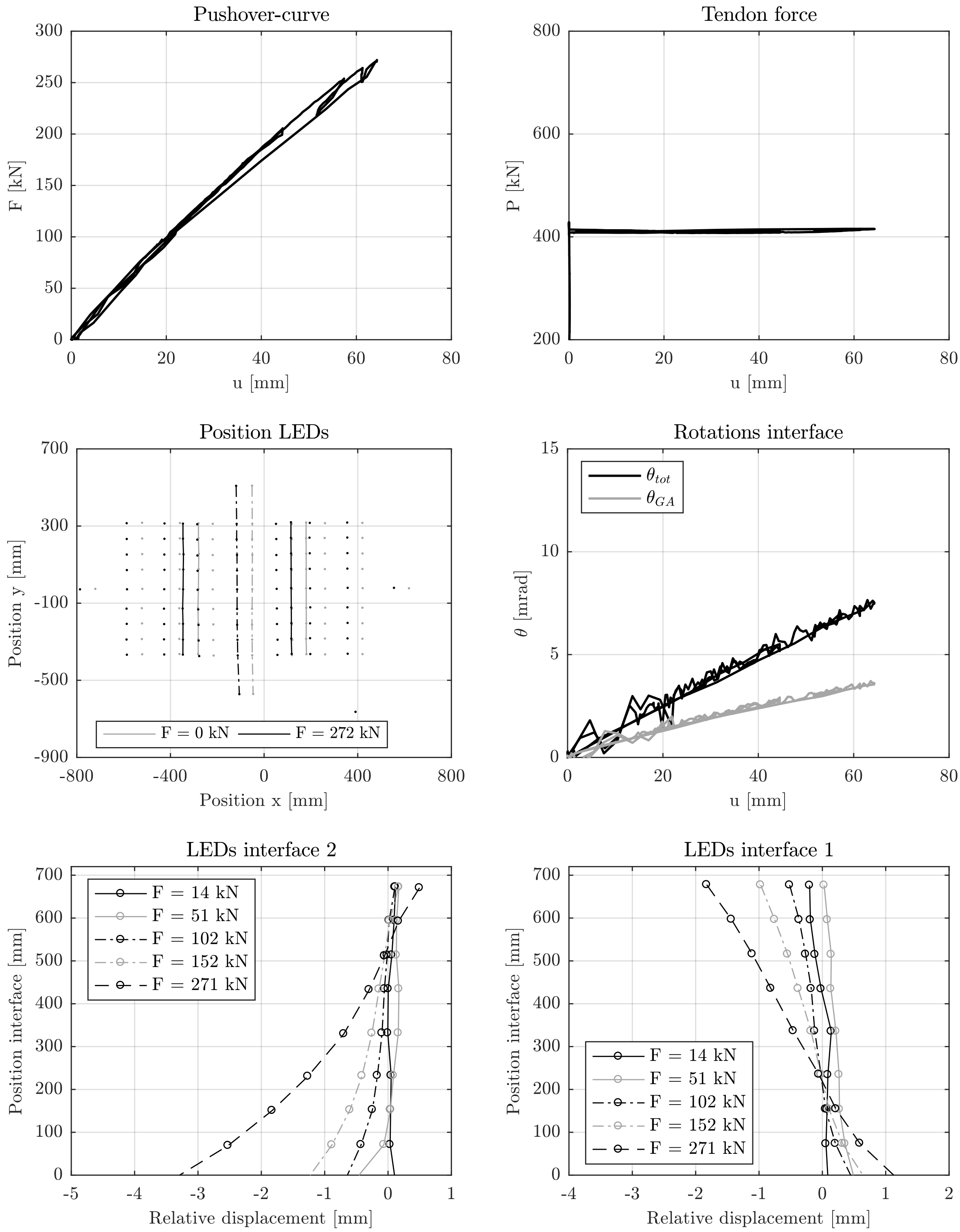
5.1.25 Pushover 25

Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
25	320	x			240		x



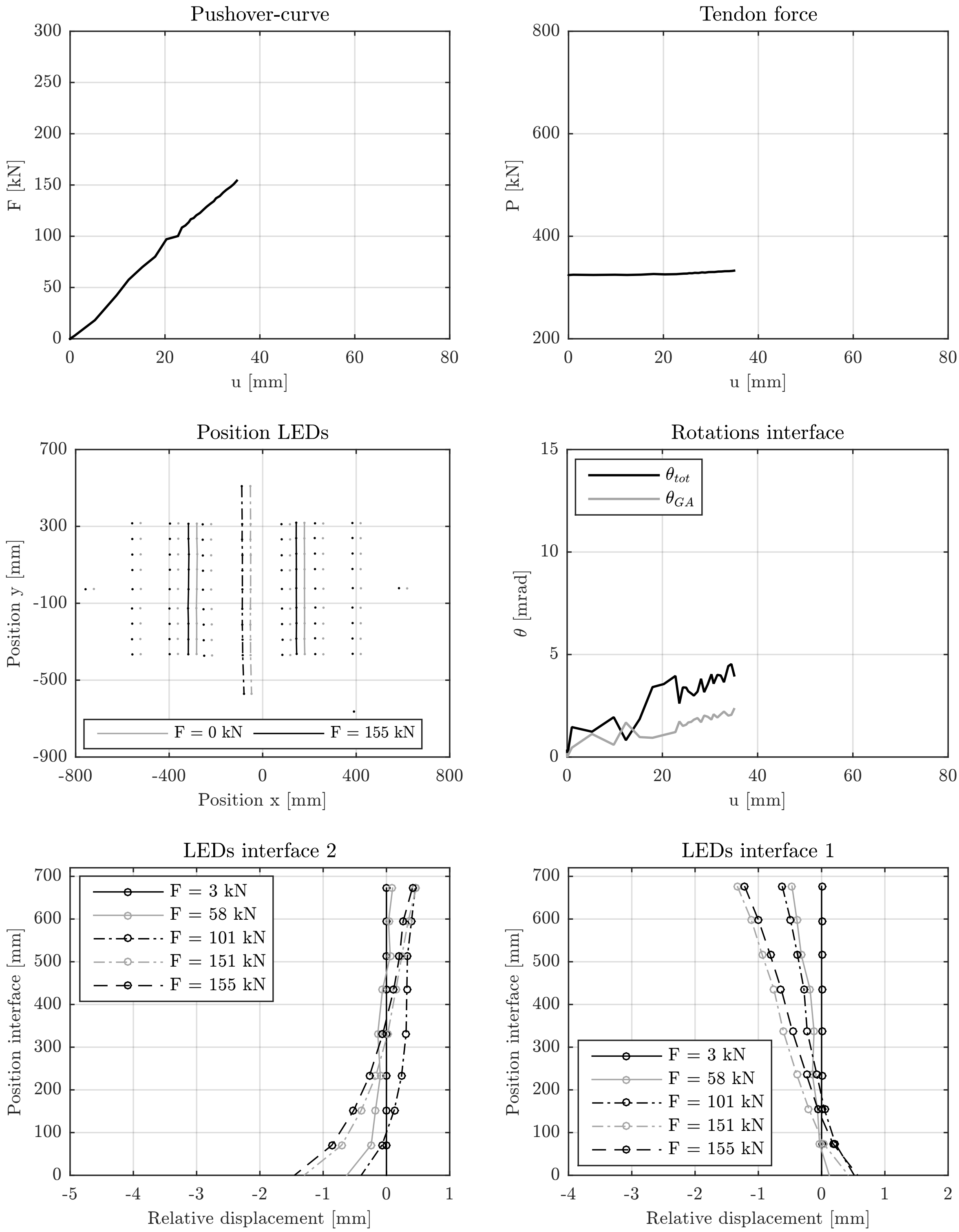
5.1.26 Pushover 26

Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
26	410	x			270		x



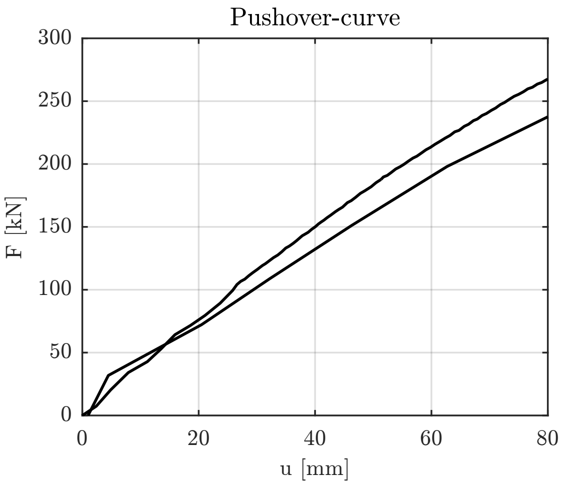
5.1.27 Pushover 27

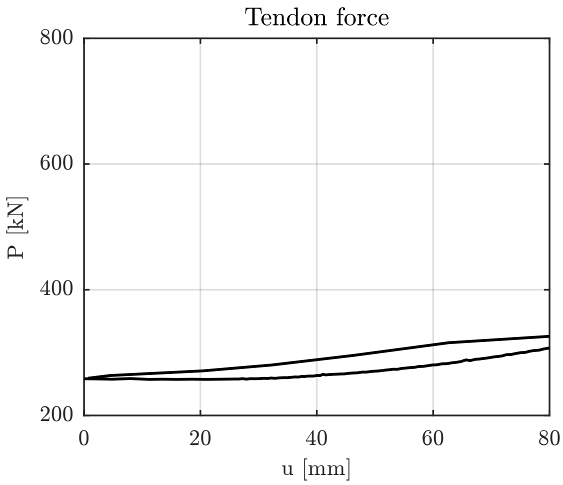
Test No.	P_0 [kN]	Columns pinned	Columns fixed	Gravity load 10 kN	F_{max} [kN]	Position NDI Col.1	Position NDI Col.2
27	325	x			-		x

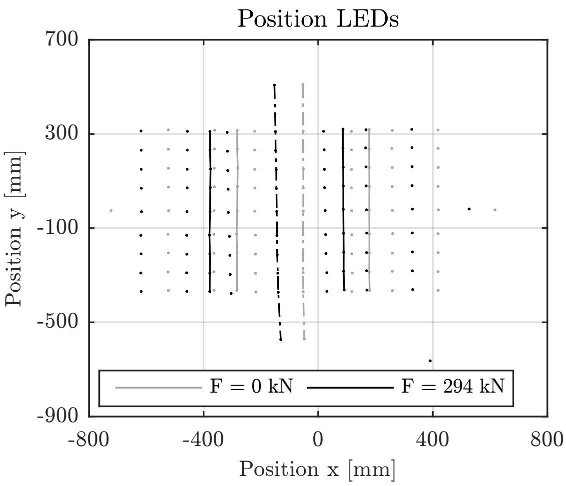


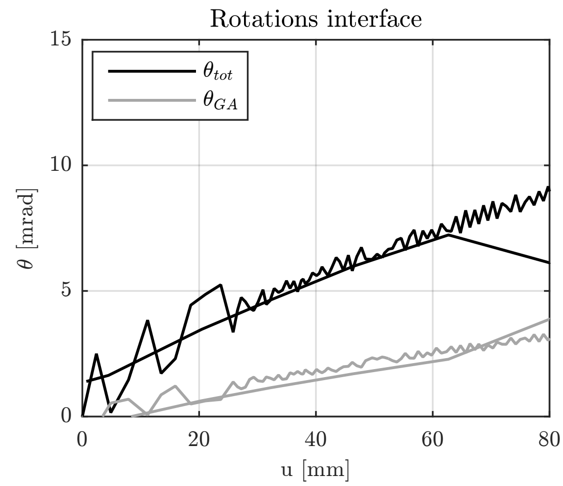
5.1.28 Pushover 28

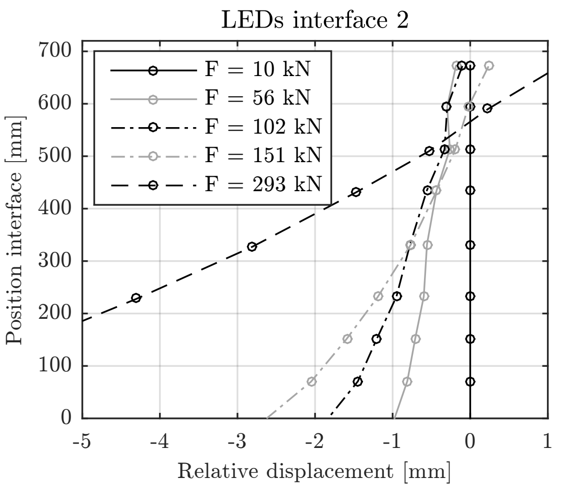
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
28	260	x			295		x

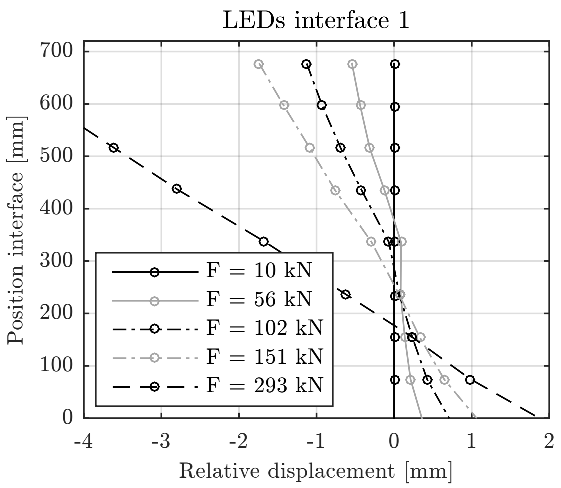






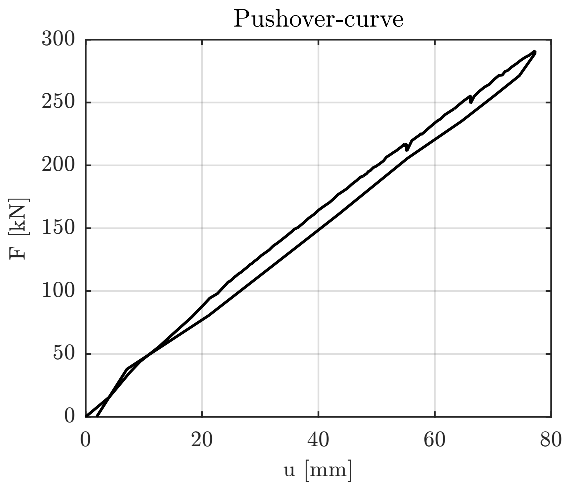


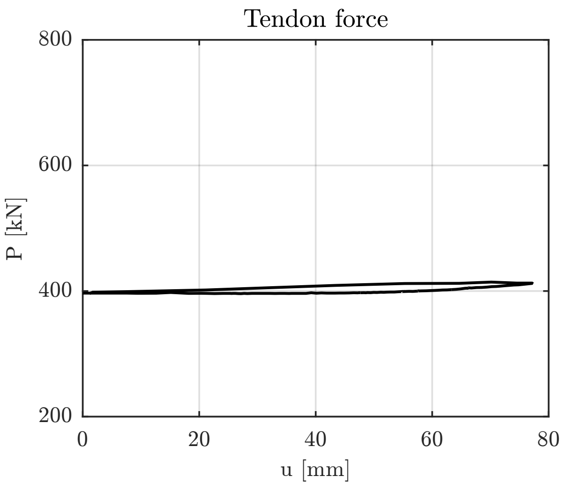


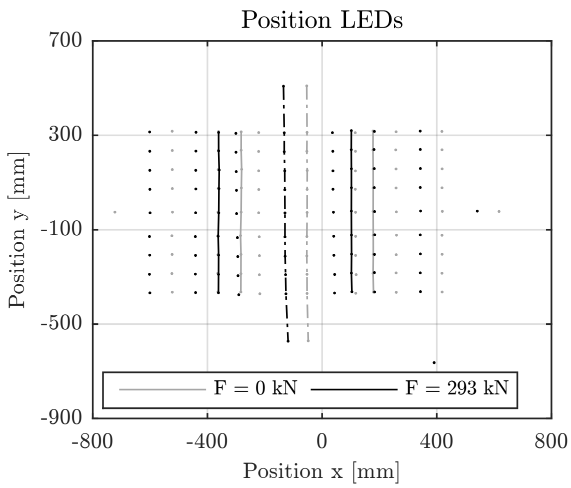


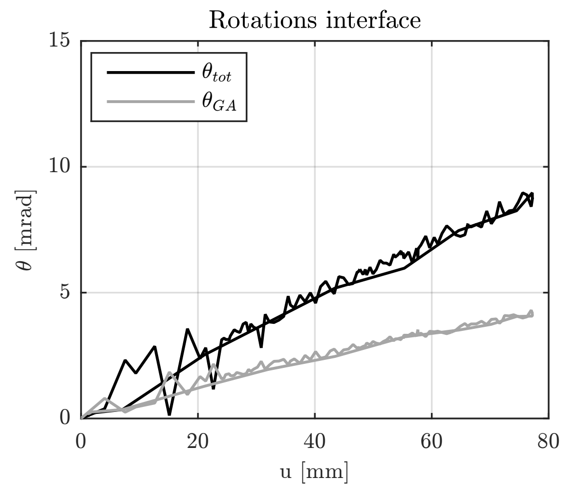
5.1.29 Pushover 29

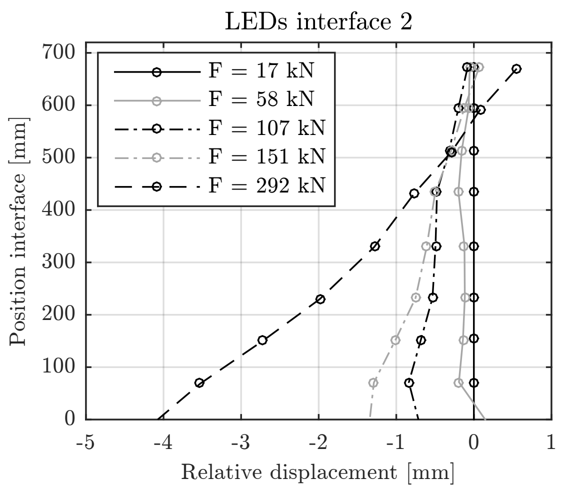
Test	P_0	Columns		Gravity load	F_{max}	Position NDI	
No.	[kN]	pinned	fixed	10 kN	[kN]	Col.1	Col.2
29	400	x			295		x

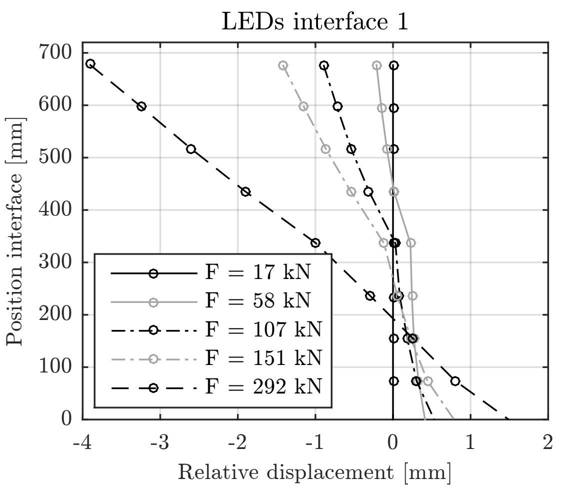












5.2 Dynamic tests

5.2.1 Impact Hammer - single test results

Impact 1

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
1	P3 (midspan of middle beam)	v	yes	400		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	37.79	0.81	37.40	2.13	0.96	-1.83	37.65±2.71	5.64±7.57	0.98	1.33
2	-	-	40.53	1.25	0.77	-16.95	40.37±0.29	1.32±1.76	0.86	-9.12
3	-	-	41.75	1.14	0.93	-1.23	41.71±0.32	1.61±1.24	0.97	2.67
4	-	-	64.77	1.36	0.93	2.03	-	-	-	-
5	-	-	68.06	0.82	0.95	-2.76	-	-	-	-
6	-	-	97.16	0.67	0.82	-2.14	-	-	-	-
7	103.13	0.74	103.40	1.28	0.79	-1.86	-	-	-	-
8	-	-	106.77	1.45	0.83	1.22	-	-	-	-
9	-	-	-	-	-	-	133.82±2.44	2.15±1.43	0.78	6.62

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.47	0.98	-	-	-	-	9.59±0.11	2.14±1.47	0.98	3.26
2	37.89	0.91	40.37	1.41	0.90	1.19	40.51±0.77	1.22±1.05	0.92	-0.48
3	-	-	-	-	-	-	41.67±0.66	1.52±2.47	0.95	0.13
4	-	-	-	-	-	-	64.45±1.74	2.29±2.36	0.93	-3.63
5	-	-	-	-	-	-	73.90±3.90	4.09±5.16	0.96	0.78
6	93.95	0.85	93.29	1.24	0.86	-6.92	91.12±10.83	1.90±11.09	0.92	1.14
7	-	-	-	-	-	-	106.24±9.82	2.33±9.47	0.75	6.53
8	-	-	-	-	-	-	132.46±0.94	2.13±1.30	0.97	-1.18
9	-	-	-	-	-	-	142.47±2.78	1.78±0.65	0.86	-7.38

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.02	0.87	-	-	-	-	-	-	-	-
2	14.63	0.78	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	38.23±6.46	7.54±16.38	0.89	-4.48
4	41.52	1.00	-	-	-	-	40.97±0.24	0.33±1.01	0.86	-1.74
5	-	-	-	-	-	-	73.88±9.49	2.04±16.41	0.84	5.62
6	-	-	-	-	-	-	104.34±19.86	3.01±28.33	0.83	-3.42
7	-	-	-	-	-	-	134.99±15.34	5.35±9.74	0.58	1.12
8	135.46	0.88	-	-	-	-	141.42±4.60	9.86±4.41	0.97	-1.67

Impact 2

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
2	P3 (midspan of middle beam)	v	no	400		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	37.79	0.77	37.49	2.91	0.93	-1.33	38.04±0.71	4.53±3.69	0.95	-0.18
2	-	-	40.54	1.22	0.78	-15.39	40.29±0.67	1.30±1.21	0.89	-6.04
3	-	-	41.74	1.20	0.94	0.88	41.72±0.63	1.31±1.15	0.99	0.30
4	-	-	64.79	1.28	0.92	-2.69	-	-	-	-
5	-	-	68.17	0.90	0.91	-3.45	-	-	-	-
6	-	-	74.88	1.20	0.87	6.13	-	-	-	-
7	103.42	0.73	103.51	1.72	0.87	-2.20	-	-	-	-
8	-	-	106.18	0.84	0.78	0.42	-	-	-	-
9	-	-	113.83	0.08	0.88	-0.20	-	-	-	-

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.28	0.95	-	-	-	-	-	-	-	-
2	37.79	0.89	-	-	-	-	37.99±1.71	5.71±2.76	0.78	-9.06
3	40.72	0.74	40.35	1.43	0.93	4.56	40.65±0.43	1.28±0.83	0.96	7.60
4	-	-	-	-	-	-	41.63±0.40	1.35±2.77	0.93	1.99
5	-	-	-	-	-	-	64.35±0.60	3.47±2.64	0.90	0.71
6	-	-	-	-	-	-	74.13±1.42	3.77±1.74	0.96	1.90
7	79.69	0.81	-	-	-	-	-	-	-	-
8	91.31	0.85	93.34	1.32	0.85	-7.29	93.57±0.36	1.65±0.46	0.84	-7.19
9	-	-	-	-	-	-	105.44±2.75	1.93±3.91	0.86	6.16
10	-	-	-	-	-	-	123.72±0.92	2.34±0.53	0.75	-5.26
11	-	-	-	-	-	-	132.59±6.60	2.36±2.83	0.98	-1.95
12	-	-	-	-	-	-	142.54±1.50	1.80±1.07	0.77	-3.66
13	154.49	0.83	-	-	-	-	156.53±0.36	1.11±0.16	0.99	-0.28

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.02	0.89	-	-	-	-	-	-	-	-
2	14.61	0.81	-	-	-	-	14.83±1.33	6.94±8.90	0.92	-4.34
3	-	-	-	-	-	-	39.21±3.14	5.03±9.66	0.98	0.07
4	41.71	0.93	-	-	-	-	41.16±0.26	1.22±1.05	0.88	0.35

Impact 3

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	Columns fixed
3	P5 (top of middle column)	v	yes	400		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	41.41	0.83	41.23	1.31	0.99	-0.24	40.97±0.22	1.76±0.86	0.98	0.30
2	44.34	0.95	-	-	-	-	44.07±1.93	3.09±5.77	0.96	0.35
3	-	-	64.17	0.83	0.87	-2.38	-	-	-	-
4	-	-	72.28	1.85	0.80	0.44	72.60±0.40	3.21±3.80	0.92	-0.82
5	-	-	-	-	-	-	78.82±1.91	1.95±4.31	0.72	-11.13
6	-	-	-	-	-	-	86.10±1.51	3.16±0.78	0.78	-4.97
7	93.85	0.97	93.56	1.31	0.94	-0.30	93.16±0.91	2.68±0.94	0.84	-6.34
8	-	-	-	-	-	-	95.27±5.97	0.85±7.73	0.93	5.44
9	-	-	104.42	1.05	0.80	-3.95	103.59±1.97	2.96±1.14	0.77	-4.27
10	-	-	-	-	-	-	120.35±4.90	2.43±2.59	0.92	-2.12
11	-	-	-	-	-	-	129.44±22.09	4.75±12.78	0.83	-0.18
12	-	-	133.36	1.66	0.76	-2.57	-	-	-	-
13	-	-	144.82	1.58	0.80	0.85	144.64±2.30	1.64±1.91	0.90	-1.76
14	156.84	0.79	156.94	0.81	0.87	-8.31	156.85±1.13	1.35±1.56	0.90	4.30
15	-	-	-	-	-	-	161.84±5.13	0.74±3.63	0.74	4.00

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	9.70±1.37	1.84±6.95	0.98	-1.97
2	-	-	-	-	-	-	41.02±1.65	2.16±6.19	0.96	-3.87
3	-	-	-	-	-	-	71.41±1.59	3.79±3.53	0.85	3.05
4	91.31	0.99	93.46	0.68	0.98	1.65	93.37±2.43	2.13±1.67	0.99	-0.24
5	-	-	-	-	-	-	105.97±1.30	2.11±0.77	0.92	3.58
6	-	-	-	-	-	-	134.16±2.45	2.84±1.73	0.93	-6.69
7	-	-	-	-	-	-	143.43±4.10	1.68±0.82	0.84	-7.89
8	157.03	0.75	157.06	0.71	0.87	5.19	156.35±3.68	1.50±2.37	0.98	0.89

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	8.98±1.33	17.77±17.47	0.68	-9.39
2	-	-	-	-	-	-	41.34±9.80	6.04±29.50	0.70	2.38
3	-	-	-	-	-	-	59.10±16.12	5.05±31.08	0.50	18.74
4	72.02	0.84	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	91.88±6.39	1.05±6.02	0.97	-2.88
6	-	-	-	-	-	-	108.69±14.08	3.99±16.92	0.65	-2.19
7	-	-	-	-	-	-	137.67±7.64	5.74±6.92	0.51	-7.32
8	-	-	-	-	-	-	139.69±8.93	8.44±4.61	0.97	-2.76
9	-	-	-	-	-	-	140.53±8.90	7.46±3.38	0.99	-0.53
10	-	-	-	-	-	-	141.40±9.05	8.90±3.05	0.90	7.78

Impact 4

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
4	P5 (top of middle column)	v	no	400		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	9.62±0.15	3.47±3.98	1.00	0.94
2	41.50	0.81	41.24	1.65	0.97	1.86	41.01±0.16	1.76±1.78	0.96	0.81
3	44.34	0.94	43.85	1.12	0.86	2.59	43.86±0.58	2.61±1.46	0.95	0.28
4	-	-	64.14	0.75	0.85	-1.12	-	-	-	-
5	-	-	72.45	1.55	0.75	-0.66	72.08±4.42	3.57±9.03	0.86	2.36
6	-	-	-	-	-	-	78.81±3.99	2.25±2.33	0.70	-9.98
7	93.85	0.97	93.61	1.41	0.97	-2.18	93.71±1.55	1.86±1.41	0.92	-2.95
8	-	-	-	-	-	-	95.70±0.68	0.75±0.68	0.87	-1.44
9	-	-	101.96	1.07	0.85	-4.48	104.01±2.28	1.78±2.38	0.88	-2.21
10	-	-	-	-	-	-	124.33±5.08	1.48±4.83	0.78	10.74
11	-	-	133.27	1.58	0.73	-2.20	-	-	-	-
12	-	-	-	-	-	-	144.75±2.86	1.82±2.01	0.89	3.56
13	157.03	0.81	156.90	0.80	0.86	-8.17	155.83±1.59	1.93±0.57	0.88	-6.45

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.28	0.97	-	-	-	-	9.63±0.13	3.38±1.23	0.99	-3.61
2	68.65	0.71	-	-	-	-	69.01±0.43	0.13±0.77	0.76	-5.23
3	-	-	-	-	-	-	71.30±7.59	2.60±15.58	0.79	-12.12
4	93.95	0.98	94.54	0.09	0.70	-4.05	92.83±1.07	2.81±2.08	0.99	-0.14
5	-	-	-	-	-	-	104.95±2.01	2.61±3.08	0.93	0.89
6	156.93	0.82	-	-	-	-	156.56±0.53	1.51±0.32	0.98	-0.31

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	74.51±10.21	3.93±18.80	0.56	-17.98
2	-	-	-	-	-	-	91.38±6.05	3.23±4.31	0.88	-2.08

Impact 5

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
5	P7 (midspan of exterior beam)	v	yes	400		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	9.59±1.09	4.65±7.54	0.95	-1.27
2	-	-	38.31	1.93	0.98	-0.74	40.29±1.44	1.38±6.26	0.74	10.20
3	40.43	0.72	40.36	1.84	0.91	2.32	40.18±0.79	4.06±2.00	0.78	-4.78
4	-	-	60.47	0.48	0.90	-6.30	-	-	-	-
5	-	-	-	-	-	-	70.89±3.26	3.48±3.13	0.77	0.33
6	79.59	0.90	-	-	-	-	-	-	-	-
7	-	-	83.11	1.40	0.87	-1.94	85.04±2.86	2.57±6.56	0.97	0.13
8	-	-	93.35	1.40	0.96	-2.62	93.46±0.95	1.95±1.41	0.81	0.92
9	-	-	95.38	0.53	0.82	-3.14	95.47±1.11	1.11±1.83	0.97	-0.42
10	-	-	105.26	1.00	0.81	-1.65	105.35±1.48	1.58±0.76	0.95	0.63
11	-	-	-	-	-	-	115.39±1.81	1.19±1.30	0.83	1.14
12	-	-	125.41	1.14	0.89	2.70	124.98±2.20	1.74±2.27	0.98	0.75
13	-	-	-	-	-	-	142.56±2.39	1.47±0.88	0.85	7.16
14	-	-	-	-	-	-	156.56±0.57	1.79±0.31	0.84	-8.09

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.38	0.99	-	-	-	-	9.61±0.15	3.15±1.97	0.99	-1.92
2	-	-	39.33	4.01	0.80	4.93	36.06±28.92	6.03±20.36	0.75	2.45
3	47.27	0.74	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	83.35±2.13	2.35±0.76	0.97	1.20
5	93.95	0.87	-	-	-	-	-	-	-	-
6	107.42	0.92	-	-	-	-	105.83±2.06	1.31±3.48	0.99	-1.61
7	-	-	-	-	-	-	156.37±0.85	1.47±0.61	0.96	2.86

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	39.59	0.94	-	-	-	-	39.15±3.06	7.33±9.20	0.98	3.12
2	-	-	-	-	-	-	137.59±11.43	10.44±12.46	0.98	0.35
3	-	-	-	-	-	-	138.09±4.47	4.47±3.70	0.60	-11.83

Impact 6

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
6	P7 (midspan of exterior beam)	v	no	400		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	1.46	1.00	-	-	-	-	-	-	-	-
2	-	-	37.25	3.54	0.83	-7.14	37.58±1.99	7.32±11.51	0.93	-2.68
3	-	-	-	-	-	-	40.34±7.71	1.32±23.23	0.77	4.11
4	-	-	40.69	1.36	0.85	3.21	-	-	-	-
5	-	-	60.53	0.57	0.93	2.27	60.72±0.83	0.67±3.50	0.97	-0.04
6	-	-	65.24	0.17	0.83	4.98	-	-	-	-
7	-	-	-	-	-	-	70.69±2.21	4.23±3.40	0.74	5.06
8	72.07	0.79	-	-	-	-	71.79±0.71	0.62±1.13	0.96	2.53
9	79.88	0.88	-	-	-	-	-	-	-	-
10	-	-	83.60	1.69	0.94	-1.92	83.65±0.27	2.18±0.62	0.99	-0.66
11	-	-	93.27	1.56	0.95	-2.43	93.70±1.28	2.49±1.70	0.75	-5.20
12	-	-	95.31	0.77	0.80	-0.40	95.35±1.92	1.53±2.81	0.84	7.60
13	-	-	-	-	-	-	103.62±5.68	2.42±2.78	0.86	7.45
14	-	-	-	-	-	-	107.67±4.86	1.42±4.22	0.70	0.91
15	-	-	-	-	-	-	131.01±3.30	1.89±2.31	0.96	1.25
16	-	-	-	-	-	-	156.16±0.60	1.90±0.30	0.82	-8.25

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.38	0.87	-	-	-	-	-	-	-	-
2	40.33	0.73	39.53	3.76	0.74	7.94	-	-	-	-
3	70.80	0.84	-	-	-	-	-	-	-	-
4	83.79	0.76	-	-	-	-	84.01±1.80	1.76±1.05	1.00	-0.57
5	93.95	0.73	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	156.35±0.76	1.51±0.38	0.98	1.32

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	5.70	0.94	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	7.93±0.92	9.82±14.98	0.87	-2.25
3	40.20	0.91	-	-	-	-	39.82±2.10	6.34±4.64	0.97	0.09

Impact 7

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
7	P2 (exterior column (top))	h	yes	400		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.67	0.98	9.61	2.07	0.80	0.43	9.57±0.02	1.72±0.19	1.00	0.34
2	40.82	0.94	40.60	1.18	0.95	-0.49	-	-	-	-
3	-	-	72.30	1.68	0.74	1.64	-	-	-	-
4	-	-	90.63	1.71	0.77	0.99	-	-	-	-
5	-	-	96.23	0.59	0.73	4.75	-	-	-	-
6	-	-	105.28	0.30	0.86	-1.54	-	-	-	-

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	10.64	0.99	9.61	1.90	0.99	-3.80	9.59±0.05	2.13±0.73	0.99	-3.97
2	90.92	0.99	91.02	2.60	1.00	-1.39	90.57±1.76	2.92±3.03	0.99	-1.21
3	-	-	155.09	1.00	0.86	9.26	156.23±0.87	1.42±0.52	0.99	2.18

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	34.99	0.93	-	-	-	-	-	-	-	-
2	95.34	0.87	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	135.33±5.48	3.82±2.90	0.89	-4.85

Impact 8

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
8	P2 (exterior column (top))	h	no	400		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.67	0.98	9.64	1.77	0.90	3.34	9.58±0.02	1.78±0.26	1.00	0.27
2	40.82	0.92	40.68	0.95	0.96	-0.26	-	-	-	-
3	-	-	-	-	-	-	72.56±1.45	2.56±0.75	0.97	1.81
4	-	-	-	-	-	-	78.47±0.73	1.40±2.07	0.92	2.89
5	-	-	-	-	-	-	91.27±1.29	1.32±1.11	0.94	-0.12
6	-	-	-	-	-	-	95.30±3.85	1.36±1.41	0.79	-14.70
7	-	-	96.88	0.85	0.87	-8.88	-	-	-	-
8	-	-	-	-	-	-	101.73±1.08	1.43±2.22	0.77	8.11
9	-	-	105.09	0.15	0.72	-3.05	-	-	-	-
10	-	-	-	-	-	-	120.47±2.56	2.20±2.22	0.89	-0.54
11	-	-	135.86	0.40	0.82	1.28	-	-	-	-
12	-	-	-	-	-	-	156.41±3.23	1.48±0.76	0.91	11.33
13	-	-	167.64	0.33	0.76	3.40	-	-	-	-
14	-	-	-	-	-	-	174.85±3.21	1.50±0.94	0.96	-1.10

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.08	0.99	9.61	1.80	0.98	-4.94	9.61±0.06	2.19±0.78	0.99	-3.86
2	91.11	0.99	91.33	2.47	1.00	-0.40	90.87±50.61	2.13±18.56	1.00	0.81
3	-	-	155.16	0.55	0.78	16.02	154.97±2.42	1.92±0.68	0.97	-0.28

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	7.53	0.98	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	9.83±3.23	5.32±23.68	0.58	15.60
3	-	-	-	-	-	-	37.33±8.42	5.21±24.23	0.95	5.28
4	-	-	-	-	-	-	41.96±11.79	3.53±26.05	0.89	-4.38
5	-	-	-	-	-	-	60.77±18.95	10.13±38.37	0.77	-1.13
6	-	-	-	-	-	-	78.26±24.75	4.90±25.47	0.56	-12.63
7	-	-	-	-	-	-	96.00±4.30	3.02±5.79	0.97	4.29
8	-	-	-	-	-	-	122.29±7.88	1.82±5.74	0.50	-13.12
9	-	-	-	-	-	-	126.77±19.64	3.27±11.54	0.54	3.13
10	-	-	-	-	-	-	138.81±7.10	5.48±4.83	0.80	0.80
11	-	-	-	-	-	-	139.28±7.53	8.11±3.09	0.83	-6.95
12	-	-	-	-	-	-	142.34±21.89	9.15±6.38	0.87	2.82

Impact 9

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
9	P1 (exterior column (mid-height))	h	yes	400		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.67	1.00	-	-	-	-	9.60±0.07	1.81±0.41	1.00	0.24
2	-	-	26.63	13.51	0.97	0.56	-	-	-	-
3	40.92	0.92	-	-	-	-	40.53±0.73	0.74±1.73	0.99	0.16
4	-	-	72.23	2.19	0.75	8.98	72.38±1.05	2.98±1.37	0.90	5.15
5	-	-	78.55	1.62	0.92	0.28	78.35±0.68	1.64±0.72	0.98	-0.00
6	-	-	-	-	-	-	90.25±1.80	1.94±2.29	0.82	-1.85
7	103.91	0.86	104.19	1.08	0.82	-0.39	103.35±1.21	1.45±0.66	0.93	-1.14
8	-	-	114.72	0.38	0.78	1.68	114.82±13.92	0.42±15.42	0.71	-0.80
9	-	-	-	-	-	-	121.44±1.34	1.70±1.14	0.75	3.84
10	-	-	-	-	-	-	135.32±7.44	1.32±4.04	0.72	8.30
11	-	-	146.14	0.91	0.81	6.03	144.93±0.60	1.54±0.41	0.95	-0.63
12	-	-	170.85	1.53	0.96	-0.69	170.89±1.08	1.96±0.50	0.98	-0.18

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	10.64	0.99	9.63	1.91	0.99	-4.89	9.63±0.37	2.25±1.29	0.99	-4.04
2	12.11	0.89	-	-	-	-	-	-	-	-
3	79.98	0.80	77.71	1.42	0.94	1.56	-	-	-	-
4	90.53	0.96	91.72	0.81	0.99	-1.11	-	-	-	-
5	-	-	-	-	-	-	167.06±6.25	3.54±2.03	0.94	1.87

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	73.47±1.94	0.66±2.55	0.81	-10.25
2	-	-	-	-	-	-	77.18±11.55	4.32±9.42	0.74	-0.90
3	77.76	0.88	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	85.88±8.61	3.48±10.39	0.59	5.94
5	-	-	-	-	-	-	136.47±5.18	6.45±9.25	0.99	-0.92
6	-	-	-	-	-	-	144.58±8.23	8.34±5.66	0.88	6.72
7	-	-	-	-	-	-	141.26±4.71	7.02±1.90	0.98	-2.15
8	-	-	-	-	-	-	142.55±14.17	8.99±6.78	1.00	-0.63
9	-	-	-	-	-	-	143.65±3.04	8.42±1.62	0.89	4.17

Impact 10

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
10	P1 (exterior column (mid-height))	h	no	400		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.67	0.99	-	-	-	-	9.60±0.04	2.04±0.31	1.00	0.50
2	41.02	0.89	-	-	-	-	40.73±1.06	1.24±2.24	0.99	0.48
3	-	-	72.26	1.97	0.84	-10.24	72.48±1.11	2.88±1.35	0.89	6.89
4	-	-	-	-	-	-	78.49±1.21	1.79±0.92	0.98	-1.00
5	85.94	0.90	77.81	1.87	0.80	1.94	-	-	-	-
6	90.04	0.92	90.52	0.60	0.78	2.11	89.79±2.87	1.74±2.12	0.85	-1.58
7	-	-	-	-	-	-	101.84±1.32	1.78±0.81	0.81	5.24
8	103.91	0.88	103.67	0.40	0.78	5.00	103.30±0.38	1.18±0.49	0.92	-0.02
9	-	-	-	-	-	-	121.65±1.20	2.04±1.05	0.83	3.09
10	-	-	-	-	-	-	146.09±6.01	1.45±4.99	0.86	2.12
11	-	-	-	-	-	-	157.18±1.43	1.17±1.46	0.74	2.62
12	162.60	0.83	168.31	1.32	0.94	-0.82	170.46±0.85	1.98±0.71	0.98	-0.64

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	10.94	0.99	9.64	2.11	0.99	-3.74	9.63±0.10	2.21±0.72	0.99	-3.87
2	80.86	0.85	77.24	2.44	0.86	2.66	-	-	-	-
3	90.04	0.98	91.61	0.68	0.97	4.03	-	-	-	-
4	-	-	-	-	-	-	121.70±1.63	2.05±3.68	0.93	-7.25
5	-	-	-	-	-	-	169.02±8.49	3.67±3.97	0.97	2.12

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	19.94	0.89	-	-	-	-	-	-	-	-
2	76.70	0.83	-	-	-	-	74.66±5.17	1.97±4.26	0.67	1.50
3	-	-	-	-	-	-	81.76±25.10	6.33±26.13	0.89	-2.76

Impact 11

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
11	P1 (exterior column (mid-height))	h	yes	400	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.99	8.56	1.36	1.00	-0.13	8.54±0.01	1.56±0.27	1.00	-0.46
2	-	-	-	-	-	-	77.16±0.48	1.58±2.04	0.95	-0.46
3	-	-	80.39	1.44	0.88	1.39	-	-	-	-
4	91.11	0.95	90.91	1.18	0.84	-0.04	-	-	-	-
5	-	-	97.01	0.56	0.74	-7.97	-	-	-	-
6	-	-	105.38	0.42	0.83	-10.67	-	-	-	-
7	162.21	0.85	159.85	1.70	0.89	-3.28	164.28±1.49	3.54±0.99	0.93	-2.34

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.99	8.55	1.43	0.99	-3.01	8.61±0.84	2.05±13.58	0.99	-2.89
2	-	-	-	-	-	-	80.27±7.87	6.30±18.65	0.93	1.57
3	91.11	0.98	90.89	1.32	0.99	-1.45	90.72±1.47	1.58±3.05	0.99	0.74
4	-	-	163.25	0.42	0.95	-4.00	169.94±5.56	3.61±7.70	0.95	-1.30

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	71.87±2.66	0.88±4.46	0.55	4.88
2	-	-	-	-	-	-	135.26±6.23	4.82±6.76	0.95	3.70

Impact 12

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
12	P1 (exterior column (mid-height))	h	no	400	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	1.00	-	-	-	-	8.54±0.02	1.56±0.40	1.00	-0.52
2	-	-	-	-	-	-	77.13±0.49	1.54±0.47	0.97	-1.22
3	83.89	0.86	81.13	1.75	0.95	2.11	-	-	-	-
4	91.02	0.94	90.92	1.16	0.86	0.22	90.75±0.96	1.33±0.53	0.96	0.82
5	-	-	96.89	0.73	0.81	-1.91	-	-	-	-
6	-	-	105.88	0.68	0.89	5.35	-	-	-	-
7	-	-	107.78	0.72	0.72	6.14	107.55±1.65	0.79±0.63	0.92	1.25
8	-	-	138.98	1.25	0.71	9.48	138.93±0.58	1.27±0.67	0.84	7.46
9	158.69	0.88	157.82	1.78	0.92	-1.95	162.57±0.74	4.26±1.60	0.92	-1.89

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.99	8.55	1.40	0.99	-3.24	8.55±0.03	1.93±0.64	0.99	-2.89
2	90.53	0.87	90.75	1.33	0.99	0.88	91.01±0.69	1.53±1.06	0.99	-3.08
3	-	-	-	-	-	-	139.09±0.92	1.46±0.89	0.98	-1.26
4	-	-	-	-	-	-	170.35±4.94	3.38±1.42	0.92	-2.87

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	74.87±22.60	2.52±27.23	0.76	0.82
2	91.27	0.88	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	113.38±11.01	1.70±6.80	0.70	-8.87
4	-	-	-	-	-	-	142.31±16.19	9.03±8.51	0.73	0.95

Impact 13

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	Columns fixed
13	P2 (exterior column (top))	h	yes	400	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.99	8.57	1.72	0.72	45.81	8.53±0.01	1.62±0.22	1.00	-0.51
2	-	-	-	-	-	-	39.83±1.28	2.81±3.16	0.79	1.66
3	-	-	-	-	-	-	69.86±1.27	1.99±1.57	0.88	-1.25
4	90.92	0.71	90.75	1.11	0.86	1.42	90.84±0.60	1.16±0.57	0.96	1.13
5	-	-	-	-	-	-	92.60±0.47	0.86±0.46	0.85	3.47
6	96.78	0.70	96.63	0.98	0.86	-6.97	96.65±0.33	1.33±0.33	0.99	-2.15
7	-	-	103.66	0.82	0.74	3.03	-	-	-	-
8	-	-	106.65	0.60	0.75	-2.09	-	-	-	-
9	125.29	0.76	124.88	1.48	0.84	-0.29	124.98±0.49	2.26±0.15	0.97	0.90
10	-	-	-	-	-	-	140.91±0.62	0.67±0.53	0.99	-0.23

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.99	8.54	1.54	0.99	-3.67	8.55±0.15	1.91±2.17	0.99	-2.90
2	-	-	-	-	-	-	70.47±6.12	1.48±4.31	0.96	-3.35
3	90.82	0.99	90.37	2.14	0.98	-6.02	90.27±2.93	1.50±3.27	0.99	-2.93
4	-	-	125.52	0.94	0.80	-10.21	-	-	-	-
5	-	-	-	-	-	-	139.96±0.59	1.46±0.50	0.96	8.75
6	-	-	154.13	1.16	0.87	8.29	155.69±4.02	1.40±1.29	0.98	0.15

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	53.40±11.17	5.01±19.97	0.51	-11.54
2	-	-	-	-	-	-	68.07±9.77	3.13±11.91	0.60	1.75
3	-	-	-	-	-	-	71.29±8.68	1.41±11.47	0.82	-5.58
4	71.98	0.82	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	93.77±5.88	3.02±8.16	0.54	-3.01
6	-	-	-	-	-	-	106.92±22.13	3.92±11.25	0.79	-7.11
7	-	-	-	-	-	-	127.03±70.00	5.71±21.47	0.53	0.60
8	-	-	-	-	-	-	134.85±8.73	4.02±5.42	0.91	-3.96
9	-	-	-	-	-	-	135.17±4.05	6.38±3.51	0.55	6.29
10	-	-	-	-	-	-	139.09±10.32	8.97±9.20	0.88	2.78
11	-	-	-	-	-	-	141.04±12.27	7.90±3.57	0.80	3.52

Impact 14

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	Columns fixed
14	P2 (exterior column (top))	h	no	400	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.98	8.51	1.85	0.96	-12.04	8.54±0.02	1.56±0.26	1.00	-0.53
2	40.63	0.78	-	-	-	-	40.39±0.75	1.33±1.21	0.94	0.83
3	-	-	69.73	0.94	0.80	-0.24	-	-	-	-
4	90.92	0.71	90.82	1.07	0.86	2.59	90.94±0.48	1.19±0.58	0.97	0.67
5	96.78	0.73	96.70	1.01	0.91	-4.79	96.70±0.27	1.35±0.67	0.99	-1.07
6	-	-	104.72	0.60	0.70	4.73	-	-	-	-
7	125.39	0.76	125.38	1.26	0.85	2.98	-	-	-	-
8	-	-	-	-	-	-	141.00±0.80	0.79±0.96	0.98	0.02

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.99	8.55	1.46	0.99	-3.56	8.53±0.19	1.45±10.09	0.99	-2.89
2	90.92	0.99	90.62	2.20	1.00	0.73	90.69±1.33	1.70±1.42	0.99	-0.45
3	-	-	126.09	1.01	0.91	-6.46	125.31±0.78	2.38±0.46	1.00	1.09

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.54	0.82	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	32.41±15.15	9.28±37.21	0.53	-12.04
3	-	-	-	-	-	-	72.18±3.91	0.15±5.96	0.53	-12.80
4	-	-	-	-	-	-	94.14±14.94	2.37±11.68	0.62	7.40
5	-	-	-	-	-	-	140.62±15.73	7.61±7.28	0.87	3.55
6	-	-	-	-	-	-	134.96±5.33	4.86±4.36	0.65	7.91
7	-	-	-	-	-	-	144.58±5.53	8.40±3.56	0.93	-7.98
8	-	-	-	-	-	-	139.93±8.34	7.92±4.59	0.99	-0.25

Impact 15

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
15	P7 (midspan of exterior beam)	v	yes	400	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	1.37	1.00	-	-	-	-	-	-	-	-
2	36.91	0.87	-	-	-	-	-	-	-	-
3	48.24	0.99	48.78	3.05	0.99	0.93	48.45±0.69	4.15±0.57	0.99	1.52
4	67.58	0.91	-	-	-	-	-	-	-	-
5	73.24	0.86	-	-	-	-	-	-	-	-
6	-	-	83.19	1.23	0.74	-1.40	-	-	-	-
7	92.77	0.89	92.55	0.73	0.91	-3.26	-	-	-	-
8	-	-	96.97	0.69	0.74	7.74	-	-	-	-
9	103.71	0.91	103.55	0.79	0.96	-0.40	-	-	-	-
10	121.19	0.93	120.28	1.16	0.96	0.51	-	-	-	-
11	141.11	0.87	140.79	0.58	0.84	1.06	-	-	-	-

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.40	0.97	-	-	-	-	8.51±0.15	3.53±4.42	0.99	4.49
2	-	-	-	-	-	-	36.16±0.76	2.27±1.33	0.97	-3.75
3	48.24	0.99	47.68	3.27	0.96	-1.59	47.65±1.91	3.85±7.38	1.00	-0.01
4	-	-	-	-	-	-	82.46±0.58	1.80±1.86	0.97	2.77
5	92.68	0.87	92.43	0.40	0.74	-1.92	92.95±0.54	0.96±0.56	0.95	1.25
6	-	-	-	-	-	-	120.47±1.63	2.04±2.02	0.99	0.26
7	-	-	-	-	-	-	138.97±1.46	1.79±0.63	0.98	2.07
8	-	-	-	-	-	-	155.49±0.78	1.31±0.27	0.98	2.22

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	5.66	1.00	-	-	-	-	-	-	-	-
2	6.27	0.95	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	8.00±0.20	2.30±7.25	0.65	-9.78
4	-	-	-	-	-	-	47.51±2.73	3.91±6.55	1.00	-0.32

Impact 16

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
16	P7 (midspan of exterior beam)	v	no	400	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f\pm2\sigma$ [Hz]	$\xi\pm2\sigma$ [Hz]	MPC [-]	MP [°]
1	1.37	1.00	-	-	-	-	-	-	-	-
2	37.60	0.96	36.86	1.11	0.99	0.60	36.52±0.91	2.15±1.91	0.94	-1.37
3	47.17	0.99	-	-	-	-	48.83±1.23	3.87±1.38	0.99	1.55
4	67.58	0.95	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	82.54±0.85	2.89±0.60	0.81	1.78
6	92.87	0.92	92.63	0.67	0.92	-3.38	92.64±0.31	0.92±0.95	0.98	-0.57
7	-	-	-	-	-	-	96.74±0.55	0.57±0.54	0.95	1.05
8	103.71	0.91	103.52	0.90	0.95	-0.75	103.61±1.24	1.30±1.55	0.97	-0.80
9	121.39	0.90	120.33	1.12	0.94	1.11	121.18±1.46	1.28±0.97	0.98	0.95
10	140.92	0.86	140.94	0.78	0.85	1.43	140.86±1.47	0.80±0.49	0.98	0.59

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f\pm2\sigma$ [Hz]	$\xi\pm2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	47.86	3.33	0.97	-1.88	48.74±4.70	3.10±5.52	0.99	-1.17
2	-	-	-	-	-	-	67.97±2.89	4.35±3.21	0.90	-7.55
3	-	-	-	-	-	-	82.55±5.25	2.22±12.42	0.98	-2.41
4	92.68	0.78	92.52	0.54	0.78	-1.10	-	-	-	-
5	-	-	-	-	-	-	120.41±1.33	1.53±2.92	1.00	-1.08
6	-	-	-	-	-	-	139.62±3.42	1.43±0.74	0.96	4.72
7	-	-	-	-	-	-	155.40±2.72	1.32±0.19	0.97	4.04

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f\pm2\sigma$ [Hz]	$\xi\pm2\sigma$ [Hz]	MPC [-]	MP [°]
1	7.93	0.77	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	47.37±1.13	4.81±2.95	1.00	-0.63

Impact 17

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
17	P6 (quarterspan of exterior beam)	v	yes	400	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	36.91	0.87	-	-	-	-	36.11±1.85	2.62±3.92	0.97	-1.72
2	-	-	48.97	2.96	0.97	-2.63	48.57±0.74	3.74±2.58	0.99	0.26
3	-	-	-	-	-	-	56.37±0.63	1.34±1.03	0.96	1.18
4	68.07	0.75	65.22	2.32	0.96	-0.73	68.35±2.45	2.89±1.28	0.96	-0.50
5	-	-	-	-	-	-	81.60±1.55	1.38±2.46	0.87	-4.45
6	-	-	90.95	0.74	0.85	-14.76	-	-	-	-
7	92.77	0.81	92.63	0.63	0.93	-0.31	92.59±0.56	0.78±0.33	0.99	-0.01
8	-	-	96.48	0.87	0.88	7.88	96.58±1.19	1.11±0.48	0.98	-0.29
9	103.71	0.85	102.95	1.05	0.93	-1.42	103.05±3.23	1.10±1.75	0.97	-1.67
10	-	-	120.70	2.32	0.83	0.71	120.36±3.89	2.92±3.47	0.98	-0.58
11	-	-	-	-	-	-	125.71±3.82	1.69±2.75	0.93	-3.99
12	140.53	0.80	140.87	0.72	0.98	0.57	140.99±5.39	0.83±1.41	0.99	0.65

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.69	0.98	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	36.42±1.55	4.52±5.18	0.89	-2.72
3	47.17	0.99	48.15	3.38	0.98	-0.76	48.87±1.27	3.85±2.17	0.99	-1.15
4	91.02	0.93	91.37	1.12	0.97	-2.09	91.14±1.25	1.57±1.40	0.98	-1.48
5	-	-	-	-	-	-	125.40±0.27	1.82±0.26	1.00	-0.18
6	140.33	0.84	139.51	1.44	0.82	-1.34	139.19±0.60	1.80±0.40	0.88	-3.03
7	156.15	0.78	-	-	-	-	155.90±1.10	1.36±1.53	0.98	0.22

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	0.65	0.82	-	-	-	-	-	-	-	-
2	1.10	0.83	-	-	-	-	-	-	-	-
3	48.54	0.97	-	-	-	-	48.36±1.54	3.69±2.90	0.98	1.01
4	-	-	-	-	-	-	92.48±4.50	1.83±8.85	0.98	2.86

Impact 18

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
18	P6 (quarterspan of exterior beam)	v	no	400	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	37.01	0.73	-	-	-	-	36.82±5.34	3.03±7.20	0.96	-2.73
2	-	-	48.89	2.28	0.87	-7.19	-	-	-	-
3	-	-	-	-	-	-	56.35±0.38	1.48±0.72	0.96	1.36
4	69.14	0.85	67.52	1.76	0.96	1.35	68.65±1.83	2.52±1.35	0.97	1.40
5	-	-	-	-	-	-	90.89±0.48	1.30±0.45	0.97	-0.91
6	92.87	0.86	92.72	0.66	0.95	-0.50	92.77±1.01	0.82±0.68	0.99	0.05
7	-	-	96.71	0.68	0.90	5.03	96.50±1.08	1.19±0.79	0.96	-0.18
8	103.52	0.86	103.10	0.97	0.96	-1.05	103.49±3.33	1.08±1.86	0.97	-1.47
9	-	-	121.16	2.02	0.92	1.46	121.29±8.05	2.63±8.04	0.98	-0.04
10	-	-	-	-	-	-	126.01±1.32	2.21±3.65	0.94	-2.31
11	-	-	-	-	-	-	138.33±0.39	1.24±1.71	0.85	6.79
12	140.63	0.81	140.87	0.83	0.99	0.52	141.08±1.03	0.94±1.13	0.99	0.69
13	-	-	-	-	-	-	147.03±2.23	1.45±1.88	0.75	10.21
14	-	-	155.18	0.66	0.75	8.66	-	-	-	-

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	36.68±0.82	3.34±4.56	0.94	-2.95
2	47.17	0.98	48.70	3.08	0.98	-1.68	48.70±0.81	3.90±0.75	0.99	-1.57
3	-	-	-	-	-	-	68.43±4.19	4.08±4.98	0.94	1.36
4	91.11	0.92	-	-	-	-	92.71±0.31	0.73±0.44	0.96	-1.41
5	-	-	-	-	-	-	120.64±2.96	2.64±4.71	0.98	0.41
6	-	-	-	-	-	-	125.79±0.39	1.82±0.54	0.99	-1.67
7	140.92	0.90	-	-	-	-	138.03±2.18	1.64±4.67	0.88	-5.13
8	156.45	0.80	-	-	-	-	155.69±0.43	1.47±0.43	0.98	1.40

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	29.17±9.39	4.04±25.61	0.97	-2.45
2	-	-	-	-	-	-	47.57±8.39	4.88±19.18	0.77	-1.09
3	-	-	-	-	-	-	96.74±26.06	3.25±18.29	0.95	1.95
4	-	-	-	-	-	-	123.36±9.72	2.50±8.87	0.83	10.52
5	-	-	-	-	-	-	141.73±14.98	10.17±9.25	0.93	1.97
6	-	-	-	-	-	-	139.52±6.89	6.57±2.98	0.69	6.47
7	-	-	-	-	-	-	137.80±22.03	10.50±8.26	0.97	1.23
8	-	-	-	-	-	-	139.13±9.01	8.32±7.93	0.81	0.08
9	-	-	-	-	-	-	142.91±3.05	8.56±2.00	0.99	2.80

Impact 19

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
19	P3 (midspan of middle beam)	v	yes	400	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	36.48±5.98	12.27±7.77	0.90	-0.71
2	-	-	-	-	-	-	37.53±0.56	1.49±5.90	0.80	3.61
3	41.99	0.99	41.96	1.10	0.96	1.77	41.92±0.68	1.73±2.23	0.97	-1.06
4	56.45	0.98	55.22	2.03	0.87	0.85	56.08±0.21	1.54±0.97	1.00	-0.14
5	-	-	-	-	-	-	76.68±0.89	1.39±1.79	0.96	3.48
6	92.58	0.91	92.02	0.77	0.95	0.47	91.79±0.28	1.31±0.33	0.81	-2.65
7	103.61	0.85	103.53	1.23	0.88	-1.46	103.45±0.92	1.73±0.64	0.88	-1.60
8	-	-	106.48	0.63	0.75	6.07	-	-	-	-
9	-	-	125.97	1.08	0.79	-10.26	-	-	-	-

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.95	-	-	-	-	8.51±0.22	1.89±3.52	0.99	-0.10
2	-	-	-	-	-	-	36.33±1.74	9.32±4.86	0.80	-11.99
3	-	-	-	-	-	-	37.37±0.59	1.18±1.58	0.88	-2.21
4	41.60	0.97	40.93	1.85	0.90	6.03	40.52±1.79	1.92±3.00	0.97	0.76
5	56.54	0.87	-	-	-	-	56.05±0.27	1.40±0.58	0.95	-0.52
6	92.58	0.91	91.64	1.31	0.93	-4.82	91.78±1.35	1.32±1.31	0.99	-2.04
7	-	-	-	-	-	-	102.53±4.47	1.53±3.70	0.96	-0.07
8	-	-	-	-	-	-	125.46±4.37	2.98±3.11	0.97	2.32
9	-	-	-	-	-	-	139.47±1.27	2.59±0.75	0.81	1.33

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	36.61±0.55	1.93±2.05	0.86	-2.23
2	40.45	0.82	-	-	-	-	40.54±0.45	0.90±1.10	0.96	-1.34
3	-	-	-	-	-	-	92.57±1.33	1.45±1.35	0.96	0.92
4	-	-	-	-	-	-	141.12±3.12	9.48±3.08	0.94	0.69

Impact 20

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
20	P3 (midspan of middle beam)	v	no	400	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	35.44±4.88	10.49±7.95	0.78	-3.80
2	-	-	-	-	-	-	37.41±0.20	1.08±0.58	0.79	5.09
3	42.19	0.98	42.01	1.25	0.95	1.55	41.93±0.76	1.65±3.43	0.97	-1.10
4	56.45	0.98	-	-	-	-	56.16±0.23	1.51±0.38	0.99	0.51
5	92.58	0.84	92.12	0.73	0.94	-5.46	-	-	-	-
6	-	-	96.19	0.70	0.89	-4.26	-	-	-	-
7	103.61	0.78	103.16	1.15	0.82	-1.50	103.25±0.69	1.37±0.82	0.84	-3.19
8	-	-	-	-	-	-	126.49±7.86	2.43±4.76	0.84	11.56

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.69	0.98	-	-	-	-	-	-	-	-
2	37.21	0.73	36.94	1.86	0.97	-4.96	-	-	-	-
3	41.60	0.97	41.08	1.68	0.89	6.37	-	-	-	-
4	56.35	0.95	56.23	1.11	0.95	-0.11	56.12±0.23	1.49±0.50	0.98	-0.76
5	92.58	0.90	91.85	1.34	0.91	-5.49	91.61±1.30	1.43±2.14	0.93	-3.92
6	-	-	-	-	-	-	102.90±0.59	1.62±0.37	0.89	3.94
7	-	-	154.87	0.55	0.86	7.44	154.93±0.30	1.37±0.24	0.99	-0.76

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	7.98	0.96	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	36.89±1.09	2.45±2.53	0.93	-1.31
3	-	-	-	-	-	-	40.68±0.60	0.65±2.34	0.92	-3.42
4	-	-	-	-	-	-	72.93±3.62	2.62±6.62	0.81	1.18
5	-	-	-	-	-	-	141.24±7.49	8.03±3.81	0.97	6.15

Impact 21

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
21	P4 (quarterspan of middle beam)	v	yes	400	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	37.18±11.53	12.74±35.64	0.98	-0.97
2	-	-	37.41	0.69	0.74	5.73	-	-	-	-
3	42.09	0.99	42.01	0.96	0.97	0.51	41.98±1.20	1.49±1.12	0.98	-0.90
4	56.45	0.96	56.24	1.44	0.94	-2.15	56.06±0.33	1.82±0.71	0.99	-0.05
5	65.33	0.77	65.07	0.57	0.93	-0.94	-	-	-	-
6	68.55	0.81	68.39	0.67	0.91	-6.38	68.34±1.44	1.32±2.49	0.97	-1.41
7	-	-	77.22	1.58	0.74	-13.29	77.08±2.23	1.54±2.05	0.97	2.82
8	-	-	96.60	0.96	0.76	-4.16	-	-	-	-
9	103.81	0.96	103.62	0.91	0.97	0.04	103.54±5.35	1.35±1.65	0.97	-0.03
10	-	-	112.47	0.20	0.79	8.71	-	-	-	-
11	-	-	122.21	1.84	0.91	0.74	121.68±4.91	2.49±4.19	0.97	-1.12
12	-	-	127.19	0.82	0.85	3.44	126.17±6.47	2.29±4.62	0.88	2.76
13	-	-	139.26	0.36	0.87	3.39	-	-	-	-
14	-	-	141.29	0.73	0.93	0.84	141.22±1.38	0.77±1.33	0.98	-0.26
15	-	-	155.50	0.58	0.84	-0.20	155.08±2.13	1.28±0.14	0.76	-0.66
16	-	-	170.38	1.06	0.86	-6.52	-	-	-	-

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.69	0.99	-	-	-	-	8.55±0.08	3.12±3.66	0.99	-3.33
2	-	-	-	-	-	-	37.54±3.23	5.73±18.09	0.87	1.47
3	41.70	0.97	40.99	1.75	0.95	4.01	40.86±0.39	2.19±2.60	0.96	3.24
4	56.54	0.84	-	-	-	-	56.37±0.63	1.34±1.48	0.98	-0.52
5	-	-	-	-	-	-	90.90±3.92	2.78±2.07	0.88	-3.35
6	-	-	103.32	0.54	0.91	-5.78	103.05±1.26	1.14±1.79	0.99	0.04
7	-	-	-	-	-	-	122.03±2.53	2.43±2.22	0.98	0.45
8	-	-	-	-	-	-	126.46±4.87	2.67±5.51	0.99	0.41
9	-	-	139.49	1.10	0.94	3.24	139.23±0.27	1.39±0.30	0.96	-1.85
10	155.47	0.97	-	-	-	-	155.08±2.32	1.05±0.79	0.99	0.44

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	14.61	0.93	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	36.89±0.80	1.57±1.92	0.78	-0.58
3	40.49	0.77	-	-	-	-	41.05±3.06	1.72±9.06	0.96	-1.69
4	56.11	0.92	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	142.05±3.01	6.15±2.26	0.97	0.05

Impact 22

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
22	P4 (quarterspan of middle beam)	v	no	400	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	36.19±2.85	11.42±20.25	0.96	-1.87
2	-	-	-	-	-	-	37.54±5.19	1.21±5.01	0.82	3.80
3	42.29	0.98	42.07	0.89	0.96	1.25	41.52±0.40	2.06±1.74	0.90	3.84
4	56.54	0.96	56.45	1.50	0.98	-0.92	56.61±1.53	1.35±6.17	0.98	0.30
5	-	-	65.06	0.42	0.75	-5.73	65.45±5.38	1.21±17.45	0.87	1.58
6	68.55	0.79	68.38	0.62	0.89	-4.17	68.30±1.20	1.20±3.33	0.97	5.10
7	-	-	71.65	1.68	0.95	-6.15	71.18±3.91	2.93±17.77	0.88	-5.64
8	-	-	-	-	-	-	77.05±1.91	1.87±1.75	0.94	2.90
9	-	-	-	-	-	-	91.98±2.38	1.14±1.98	0.86	0.70
10	-	-	96.37	0.84	0.84	-2.73	95.40±2.51	1.85±3.92	0.97	-0.09
11	104.00	0.92	103.68	1.03	0.90	-0.29	103.71±1.51	1.67±1.10	0.82	0.13
12	-	-	122.55	1.80	0.90	1.04	122.27±1.97	2.80±1.12	0.98	0.31
13	-	-	126.54	1.07	0.86	3.12	126.75±0.99	1.60±1.41	0.86	-6.26
14	140.33	0.83	141.09	0.79	0.99	0.17	140.79±0.94	0.76±0.90	0.99	0.09
15	-	-	154.98	1.01	0.73	-8.87	154.60±0.98	1.29±1.40	0.90	-1.48
16	-	-	-	-	-	-	169.28±3.10	1.82±1.21	0.83	-3.12

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.69	0.96	-	-	-	-	-	-	-	-
2	40.63	0.97	41.13	1.59	0.95	4.42	-	-	-	-
3	-	-	56.33	0.61	0.79	-5.85	-	-	-	-
4	-	-	139.92	1.08	0.94	4.68	139.59±0.40	1.35±0.29	0.95	-2.77
5	155.18	0.93	155.31	0.86	0.95	-1.30	155.28±0.85	1.13±0.52	0.99	-0.00

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	37.17±1.38	1.45±4.22	0.98	-0.75
2	-	-	-	-	-	-	39.96±2.72	0.50±8.67	0.91	-3.54
3	-	-	-	-	-	-	78.72±5.09	5.17±10.66	0.99	2.22

Impact 23

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
23	P4 (quarterspan of middle beam)	v	yes	500	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	37.15±1.15	3.76±2.92	0.97	-0.37
2	40.23	0.88	40.01	1.04	0.87	12.15	-	-	-	-
3	57.23	0.91	56.56	1.42	0.96	-1.47	56.70±6.44	1.99±13.85	0.98	-0.36
4	-	-	65.44	0.67	0.73	-6.76	-	-	-	-
5	69.24	0.73	69.73	0.67	0.71	-0.67	-	-	-	-
6	-	-	76.53	1.35	0.82	-8.58	-	-	-	-
7	-	-	-	-	-	-	83.42±6.65	1.94±5.98	0.98	0.05
8	-	-	94.02	0.68	0.76	-0.35	-	-	-	-
9	104.30	0.97	104.04	1.03	0.98	-0.76	103.76±1.80	1.25±1.83	0.98	-0.43
10	-	-	121.64	2.17	0.76	-9.49	122.25±1.04	3.31±3.08	0.73	4.20
11	-	-	140.42	1.16	0.73	9.31	140.79±2.11	1.43±1.15	0.80	13.05
12	-	-	143.21	0.62	0.80	0.89	143.79±2.57	0.85±2.20	0.98	1.25
13	-	-	156.58	0.81	0.81	10.21	155.29±1.74	1.52±1.87	0.81	7.24

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.98	-	-	-	-	8.59±0.09	1.83±1.15	0.99	-3.15
2	40.14	0.81	39.68	0.28	0.89	3.35	-	-	-	-
3	57.13	0.86	-	-	-	-	56.46±0.19	1.73±0.54	0.97	2.12
4	91.99	0.90	-	-	-	-	-	-	-	-
5	104.00	0.91	-	-	-	-	103.45±1.07	1.04±0.79	1.00	-0.25
6	119.92	0.91	-	-	-	-	-	-	-	-
7	156.84	0.91	156.12	0.74	0.92	-5.63	155.98±0.39	1.38±0.27	0.98	-0.67

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	37.54±3.10	2.28±6.65	0.73	-3.43
2	61.60	0.77	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	87.34±16.12	6.74±17.93	1.00	-0.10
4	-	-	-	-	-	-	140.01±9.18	7.93±5.13	0.86	-2.06

Impact 24

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
24	P4 (quarterspan of middle beam)	v	no	500	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	40.33	0.89	40.18	1.33	0.86	12.63	-	-	-	-
2	57.32	0.87	56.72	1.42	0.97	0.01	56.68±0.50	1.72±0.49	0.95	0.26
3	69.24	0.81	71.50	0.53	0.87	-10.49	70.26±1.83	1.53±1.21	0.98	-0.41
4	82.13	0.84	-	-	-	-	83.42±2.45	2.06±3.92	0.98	0.15
5	-	-	93.57	0.71	0.86	6.09	-	-	-	-
6	104.39	0.96	104.09	1.13	0.95	-0.93	104.08±1.32	1.27±0.96	0.97	-1.12
7	140.82	0.79	140.91	0.85	0.84	5.85	141.54±1.45	1.22±1.47	0.94	4.06
8	-	-	143.49	0.69	0.83	-0.77	-	-	-	-
9	-	-	156.57	0.90	0.72	13.91	156.17±0.77	1.51±0.86	0.91	8.38

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.97	-	-	-	-	8.59±0.08	1.90±2.19	0.99	-2.55
2	40.33	0.82	39.84	1.11	0.90	5.50	-	-	-	-
3	57.32	0.89	-	-	-	-	56.67±0.61	2.00±1.20	0.99	-0.71
4	92.09	0.72	92.29	0.56	0.78	-0.24	-	-	-	-
5	104.49	0.80	104.02	0.60	0.88	-5.91	-	-	-	-
6	120.31	0.88	120.82	1.15	0.94	-0.79	-	-	-	-
7	-	-	141.10	1.02	0.82	8.79	-	-	-	-
8	156.54	0.94	156.07	0.96	0.95	-1.67	156.03±0.37	1.48±0.59	0.98	-0.18

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.10	0.87	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	37.32±3.46	5.44±8.31	0.80	-1.76
3	-	-	-	-	-	-	72.05±3.82	2.83±4.28	0.84	2.30

Impact 25

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
25	P3 (midspan of middle beam)	v	yes	500	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	40.14	0.76	40.58	1.15	0.75	-0.68	39.82±1.38	2.25±8.79	0.97	1.30
2	45.21	0.74	-	-	-	-	-	-	-	-
3	57.23	0.87	56.14	0.87	0.95	-0.85	56.31±0.35	1.95±0.45	0.97	0.56
4	65.53	0.81	65.40	0.61	0.89	4.37	-	-	-	-
5	-	-	81.68	0.44	0.71	6.44	-	-	-	-
6	93.46	0.90	93.07	0.62	0.94	-4.26	93.28±3.12	0.59±5.93	0.99	1.35
7	103.81	0.92	103.58	1.25	0.91	-1.07	103.83±2.30	1.38±3.94	0.98	-0.71
8	-	-	125.40	1.51	0.76	-7.97	125.11±0.98	2.19±1.21	0.98	0.47
9	-	-	131.03	0.42	0.75	5.71	-	-	-	-

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.69	0.98	-	-	-	-	-	-	-	-
2	36.62	0.76	36.73	3.03	0.97	-5.63	-	-	-	-
3	40.14	0.84	-	-	-	-	-	-	-	-
4	57.32	0.93	-	-	-	-	56.69±1.37	1.87±2.53	0.92	0.80
5	81.54	0.91	-	-	-	-	-	-	-	-
6	93.55	0.94	92.83	1.16	0.91	-5.16	92.81±0.49	1.31±0.43	0.92	-4.45
7	103.32	0.83	103.40	0.49	0.88	-6.30	103.54±2.02	1.37±1.00	0.99	-1.41
8	-	-	-	-	-	-	140.58±1.27	1.51±0.41	0.98	-2.35

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	36.62	0.97	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	36.85±1.53	1.15±4.00	0.68	-1.80
3	-	-	-	-	-	-	41.51±2.04	1.35±4.34	0.71	3.39
4	72.02	0.76	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	77.19±2.06	2.74±3.56	0.95	1.67
6	-	-	-	-	-	-	92.47±2.73	0.57±3.04	0.91	8.29
7	-	-	-	-	-	-	134.08±25.85	3.64±6.18	0.91	10.94
8	-	-	-	-	-	-	141.99±3.06	8.14±2.53	0.96	4.65

Impact 26

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
26	P3 (midspan of middle beam)	v	no	500	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	37.48±0.70	1.96±0.72	0.97	-0.04
2	40.33	0.82	-	-	-	-	-	-	-	-
3	45.41	0.80	-	-	-	-	-	-	-	-
4	57.32	0.88	-	-	-	-	56.60±0.27	1.60±0.46	0.96	0.04
5	-	-	65.39	0.34	0.81	-2.21	-	-	-	-
6	-	-	76.60	0.86	0.72	-15.15	-	-	-	-
7	-	-	82.18	0.21	0.86	1.38	-	-	-	-
8	93.55	0.90	93.33	0.58	0.93	1.48	93.28±0.62	0.76±0.75	0.99	-0.14
9	104.00	0.92	103.86	1.14	0.90	-0.25	103.81±0.92	1.22±1.77	0.96	-1.28
10	-	-	125.81	1.36	0.75	-7.02	125.28±3.18	2.71±2.90	0.92	2.38
11	-	-	131.01	0.13	0.75	9.96	-	-	-	-

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.69	0.98	-	-	-	-	-	-	-	-
2	-	-	37.01	2.04	0.93	-5.33	-	-	-	-
3	40.04	0.74	39.76	1.60	0.89	6.87	-	-	-	-
4	57.32	0.93	-	-	-	-	56.47±0.57	1.82±0.63	0.96	-0.63
5	93.46	0.96	93.17	1.11	0.91	-3.51	93.47±5.08	1.16±8.33	0.94	-4.55
6	103.52	0.77	103.33	0.34	0.80	-2.20	103.72±0.56	1.24±0.29	0.98	-0.65
7	-	-	-	-	-	-	119.34±5.76	2.35±3.11	0.98	-2.61
8	125.49	0.75	-	-	-	-	125.80±3.51	1.96±2.12	0.99	-2.23
9	-	-	-	-	-	-	155.58±1.09	2.00±1.61	0.95	7.48

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	37.07±1.91	1.35±6.24	0.74	-3.70
2	-	-	-	-	-	-	43.27±12.56	5.15±30.44	0.90	5.42
3	-	-	-	-	-	-	73.03±4.98	0.96±6.90	0.54	-19.81
4	93.02	0.75	-	-	-	-	93.00±3.39	1.48±4.36	0.94	-1.31
5	-	-	-	-	-	-	116.67±19.96	1.65±29.10	0.79	-5.04
6	-	-	-	-	-	-	135.07±5.19	3.32±2.81	0.76	-8.61
7	-	-	-	-	-	-	137.07±5.46	5.25±3.03	0.51	-6.99

Impact 27

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
27	P5 (top of middle column)	v	yes	500	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	57.48	1.11	0.94	0.51	57.09±1.66	1.30±9.54	0.98	1.06
2	-	-	69.17	1.60	0.85	-4.80	69.44±1.73	1.79±2.52	0.90	1.13
3	-	-	-	-	-	-	83.82±2.61	2.33±4.10	0.84	0.12
4	93.55	0.96	93.40	0.72	0.98	0.86	93.32±0.21	0.89±0.42	0.95	3.37
5	-	-	-	-	-	-	95.58±3.16	1.29±3.20	0.95	-1.39
6	-	-	141.75	0.82	0.80	10.41	-	-	-	-
7	156.54	0.85	156.42	1.02	0.88	-2.95	156.22±0.45	1.41±0.26	0.96	2.82

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.69	0.99	-	-	-	-	8.61±0.04	2.02±0.91	0.99	-1.98
2	91.02	0.98	93.04	0.84	0.97	-0.38	-	-	-	-
3	156.45	0.87	156.34	1.09	0.90	3.36	156.35±0.44	1.48±0.21	0.99	-0.07

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	5.66	0.94	-	-	-	-	-	-	-	-
2	8.06	0.80	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	69.89±3.34	2.50±4.59	0.72	8.00
4	-	-	-	-	-	-	92.43±0.63	1.22±0.57	0.98	3.20
5	93.10	0.75	-	-	-	-	-	-	-	-

Impact 28

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
28	P5 (top of middle column)	v	no	500	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	40.64	1.06	0.93	4.17	-	-	-	-
2	-	-	57.51	1.06	0.95	0.80	-	-	-	-
3	-	-	68.99	1.49	0.95	-1.73	-	-	-	-
4	-	-	72.72	0.66	0.71	0.22	-	-	-	-
5	-	-	78.11	1.28	0.81	-3.68	-	-	-	-
6	-	-	91.48	0.69	0.82	0.74	91.74±1.68	0.81±1.82	0.84	7.87
7	93.55	0.96	93.30	0.87	0.98	1.10	93.40±0.40	0.85±0.47	0.93	4.03
8	-	-	131.74	0.62	0.77	-6.13	-	-	-	-
9	-	-	141.84	0.85	0.83	9.92	-	-	-	-
10	156.54	0.86	156.92	0.87	0.90	1.92	156.29±0.62	1.43±0.40	0.96	2.42

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.69	0.99	-	-	-	-	8.62±0.06	2.45±1.79	0.99	-1.99
2	70.12	0.79	-	-	-	-	-	-	-	-
3	93.65	0.98	93.20	0.70	0.98	-1.23	-	-	-	-
4	156.45	0.94	-	-	-	-	156.56±1.00	1.38±0.18	0.98	-0.38

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.54	0.73	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	93.22±0.81	0.74±0.83	0.96	5.76
3	-	-	-	-	-	-	121.34±7.47	1.81±7.54	0.82	4.04
4	-	-	-	-	-	-	136.04±7.27	4.38±6.07	0.88	0.35
5	-	-	-	-	-	-	141.27±5.39	7.63±5.07	0.99	-2.07

Impact 29

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
29	P7 (midspan of exterior beam)	v	yes	500	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	1.37	1.00	-	-	-	-	-	-	-	-
2	37.11	0.80	-	-	-	-	35.21±2.50	4.39±2.58	0.99	-0.13
3	-	-	48.39	2.55	0.98	0.24	48.40±0.74	2.54±1.63	1.00	0.08
4	-	-	81.61	1.36	0.74	-2.94	81.66±4.73	1.71±2.19	0.95	-0.33
5	93.55	0.89	93.32	0.57	0.90	-2.09	93.55±1.70	0.89±1.70	0.92	3.43
6	-	-	95.95	0.85	0.94	-0.24	-	-	-	-
7	103.91	0.92	103.69	0.97	0.95	-1.48	103.34±0.92	0.89±0.63	0.99	0.01
8	-	-	141.21	0.77	0.79	4.22	141.01±2.40	0.73±0.80	0.95	2.95
9	-	-	156.97	0.88	0.80	10.67	156.64±3.09	1.21±1.11	0.94	4.09

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.69	0.98	-	-	-	-	-	-	-	-
2	48.83	0.98	47.41	3.77	0.96	-1.95	-	-	-	-
3	93.55	0.90	93.10	0.32	0.95	4.28	-	-	-	-
4	104.20	0.83	-	-	-	-	-	-	-	-
5	156.74	0.72	-	-	-	-	156.48±0.22	1.40±0.28	0.99	0.58

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	43.25	0.90	-	-	-	-	-	-	-	-
2	45.74	0.87	-	-	-	-	-	-	-	-
3	48.50	0.84	-	-	-	-	47.25±4.84	3.12±16.81	1.00	-0.70
4	-	-	-	-	-	-	131.59±7.12	3.82±15.16	0.81	-8.69

Impact 30

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	Columns fixed
30	P7 (midspan of exterior beam)	v	no	500	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	1.27	1.00	-	-	-	-	-	-	-	-
2	37.21	0.91	37.25	1.53	0.99	0.31	36.42±2.17	3.30±3.86	0.97	-0.55
3	52.73	0.82	48.43	1.21	0.96	1.98	48.93±2.42	2.22±3.67	1.00	0.48
4	-	-	66.57	0.36	0.85	3.05	-	-	-	-
5	93.65	0.89	93.33	0.65	0.87	-0.10	93.56±0.70	0.97±0.80	0.86	3.49
6	-	-	96.03	0.69	0.87	-1.09	95.87±0.98	0.80±1.24	0.97	-0.18
7	104.10	0.91	103.94	0.91	0.95	-1.42	104.37±3.67	1.24±1.50	0.99	-0.52
8	-	-	131.70	1.07	0.88	-3.43	-	-	-	-
9	-	-	141.38	0.69	0.85	3.23	141.42±1.13	0.78±0.87	0.96	0.29
10	-	-	-	-	-	-	156.98±0.92	1.29±0.61	0.96	1.41

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.69	0.82	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	36.67±1.46	2.68±5.98	0.93	-2.96
3	-	-	48.25	2.85	0.97	-1.48	48.66±0.81	2.75±1.38	0.99	-0.87
4	93.75	0.90	93.54	0.35	0.87	-3.39	93.38±2.24	0.85±1.65	0.98	2.59
5	-	-	-	-	-	-	95.49±1.08	1.93±1.09	0.95	-1.73
6	104.10	0.73	-	-	-	-	103.74±0.77	1.14±0.84	1.00	-0.47
7	-	-	-	-	-	-	141.52±0.64	0.61±0.82	0.99	0.73
8	-	-	-	-	-	-	156.58±0.28	1.41±0.52	0.99	1.77

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	48.38	0.88	-	-	-	-	48.29±0.64	3.20±1.10	0.99	1.15
2	-	-	-	-	-	-	91.58±10.47	2.55±8.95	0.75	5.23
3	-	-	-	-	-	-	133.41±18.04	4.20±8.63	0.84	-1.79
4	-	-	-	-	-	-	141.80±13.57	10.25±11.94	0.72	6.29

Impact 31

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
31	P2 (exterior column (top))	h	yes	500	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.99	8.60	1.44	0.95	-0.81	8.57±0.02	1.60±0.95	1.00	-0.61
2	-	-	-	-	-	-	57.31±0.65	1.50±2.38	0.80	-0.19
3	-	-	-	-	-	-	62.24±1.39	1.68±1.76	0.88	0.87
4	-	-	69.13	1.20	0.75	-2.65	69.15±7.40	1.89±13.51	0.96	2.01
5	-	-	91.29	0.67	0.85	-0.59	91.50±0.85	1.26±1.09	0.92	1.26
6	-	-	-	-	-	-	93.47±3.38	1.21±5.83	0.98	4.16
7	-	-	-	-	-	-	95.73±2.48	1.55±2.03	0.91	-5.22
8	-	-	104.26	0.86	0.73	-1.95	-	-	-	-
9	-	-	-	-	-	-	118.14±0.61	1.97±0.50	0.83	9.96
10	-	-	125.09	1.61	0.74	-0.04	125.88±12.36	1.68±3.01	0.94	0.41
11	-	-	-	-	-	-	156.41±1.33	1.89±0.76	0.83	5.09
12	-	-	-	-	-	-	172.78±5.39	2.37±3.57	0.94	-0.77

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.99	8.59	1.63	0.99	-4.62	8.58±0.24	1.63±1.77	0.99	-3.70
2	91.31	1.00	90.92	2.26	0.99	-2.69	91.24±11.70	2.10±5.42	0.99	-3.56
3	-	-	-	-	-	-	103.49±3.87	1.94±3.15	0.77	1.51
4	-	-	-	-	-	-	125.76±1.07	2.15±1.18	0.97	1.74
5	-	-	-	-	-	-	156.53±1.10	1.53±1.12	0.97	2.50

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	120.27±14.62	4.65±15.08	0.89	-2.50
2	-	-	-	-	-	-	135.41±15.68	6.53±12.86	0.58	-4.01

Impact 32

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
32	P2 (exterior column (top))	h	no	500	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.97	8.56	1.74	0.99	-1.00	8.57±0.03	1.68±0.42	1.00	-0.48
2	-	-	69.14	0.75	0.77	-6.75	-	-	-	-
3	-	-	90.93	1.05	0.73	4.93	-	-	-	-
4	-	-	104.30	0.77	0.71	-2.04	-	-	-	-
5	124.41	0.71	125.65	1.57	0.88	-0.47	125.82±4.04	2.06±1.66	0.95	1.64

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.99	8.58	1.58	0.99	-3.99	8.58±0.02	1.67±0.39	0.99	-3.12
2	91.50	0.99	91.20	2.16	1.00	-1.85	91.28±6.08	2.29±6.60	0.99	-2.84
3	-	-	-	-	-	-	104.75±1.23	2.15±1.88	0.89	6.26
4	-	-	125.08	0.66	0.89	-9.01	126.37±2.66	1.74±7.29	0.99	1.02
5	-	-	-	-	-	-	141.21±3.27	1.56±1.52	0.98	-1.13
6	-	-	-	-	-	-	156.30±0.95	1.63±0.68	0.98	0.64

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	78.59±20.93	5.38±23.71	0.85	6.65
2	-	-	-	-	-	-	135.43±8.82	6.84±13.13	0.55	4.64
3	-	-	-	-	-	-	136.83±7.85	4.77±6.12	0.92	3.30
4	-	-	-	-	-	-	141.89±6.18	7.92±3.52	0.99	1.06
5	-	-	-	-	-	-	167.49±8.16	14.12±4.53	0.59	-5.84

Impact 33

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
33	P1 (exterior column (mid-height))	h	yes	500	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.99	-	-	-	-	8.59±0.03	1.65±0.22	1.00	-0.34
2	41.41	0.87	-	-	-	-	-	-	-	-
3	-	-	69.66	1.18	0.83	-7.68	-	-	-	-
4	81.64	0.82	81.13	1.88	0.86	2.16	-	-	-	-
5	91.60	0.92	90.82	1.43	0.81	-2.62	90.87±1.79	1.66±0.39	0.85	0.32
6	-	-	106.24	0.96	0.86	9.98	-	-	-	-
7	160.35	0.82	160.23	1.34	0.93	-1.72	166.89±3.49	3.46±1.04	0.95	-1.04

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.98	8.60	1.54	0.99	-2.96	8.62±0.04	1.95±0.46	0.99	-3.14
2	90.14	0.99	90.79	1.87	0.99	0.32	90.89±0.42	1.54±0.68	1.00	-2.06
3	-	-	103.99	0.52	0.83	0.09	-	-	-	-
4	-	-	141.14	0.26	0.86	2.23	-	-	-	-
5	-	-	-	-	-	-	167.82±6.62	3.59±1.43	0.97	1.25

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	73.88±7.98	2.34±13.22	0.68	12.59
2	-	-	-	-	-	-	76.14±9.63	2.27±7.05	0.87	7.46
3	-	-	-	-	-	-	134.66±6.43	3.64±4.11	0.70	-13.42
4	-	-	-	-	-	-	138.63±9.03	6.85±6.11	0.89	-10.26
5	-	-	-	-	-	-	139.20±8.59	9.38±8.06	0.88	5.18
6	-	-	-	-	-	-	142.43±17.74	8.53±4.79	0.90	-6.53

Impact 34

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
34	P1 (exterior column (mid-height))	h	no	500	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.99	-	-	-	-	8.59±0.03	1.60±0.51	1.00	0.06
2	-	-	70.10	0.97	0.76	-4.18	-	-	-	-
3	81.64	0.90	-	-	-	-	-	-	-	-
4	91.60	0.92	91.08	1.35	0.83	-0.48	90.98±0.31	1.53±0.12	0.88	-0.93
5	-	-	106.06	0.93	0.96	2.24	-	-	-	-
6	-	-	-	-	-	-	121.88±4.60	0.86±2.25	0.77	1.33
7	-	-	135.47	1.17	0.76	5.61	-	-	-	-
8	-	-	170.09	1.63	0.91	0.05	167.89±8.56	2.85±3.17	0.94	-0.59

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.99	8.59	1.52	0.99	-2.89	8.62±1.87	1.50±9.19	0.99	-3.15
2	-	-	-	-	-	-	51.55±1.90	4.24±4.22	0.96	-3.35
3	91.70	0.99	91.18	1.35	0.99	-1.11	91.51±2.52	1.57±4.30	1.00	0.07
4	-	-	103.97	0.27	0.86	-3.31	104.55±0.97	0.72±0.88	0.98	-1.42
5	-	-	-	-	-	-	157.23±1.84	1.70±1.39	0.99	1.69
6	-	-	-	-	-	-	167.54±5.23	3.44±1.71	0.93	-1.01

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	8.95±1.46	4.57±17.03	0.75	-12.36
2	-	-	-	-	-	-	60.95±25.24	4.21±33.22	0.61	1.54
3	-	-	-	-	-	-	74.22±3.69	2.60±4.70	0.67	4.58
4	-	-	-	-	-	-	95.61±9.17	4.30±10.40	0.95	0.16
5	-	-	-	-	-	-	105.54±13.58	4.16±19.26	0.99	0.77
6	-	-	-	-	-	-	130.22±13.91	3.84±11.29	0.51	18.63
7	-	-	-	-	-	-	137.17±7.19	4.63±9.82	0.73	6.28
8	-	-	-	-	-	-	139.26±6.34	8.05±5.28	0.85	-0.14

Impact 35

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	Columns fixed
35	P1 (exterior column (mid-height))	h	yes	500		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.67	0.99	-	-	-	-	9.54±0.06	1.87±0.48	1.00	0.41
2	-	-	72.84	2.41	0.93	1.38	-	-	-	-
3	90.43	0.97	89.39	1.14	0.96	-0.37	89.36±0.88	1.26±0.38	0.97	0.71
4	-	-	-	-	-	-	97.01±1.83	2.01±2.78	0.89	2.94
5	103.52	0.82	-	-	-	-	103.03±1.35	1.38±0.48	0.93	-3.91
6	-	-	144.53	0.22	0.79	4.30	-	-	-	-
7	166.70	0.89	-	-	-	-	168.96±4.12	3.33±2.23	0.98	-0.68

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.67	0.98	9.58	1.96	0.99	-2.81	9.61±0.73	1.96±6.04	0.99	-3.32
2	73.54	0.83	72.58	1.28	0.88	2.16	-	-	-	-
3	90.43	0.99	89.46	1.18	0.99	-1.32	89.43±0.20	1.27±0.11	0.99	-3.06
4	-	-	-	-	-	-	167.69±2.79	3.23±1.98	0.92	3.50

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	70.32±8.98	3.59±11.01	0.79	-8.19
2	-	-	-	-	-	-	72.91±7.13	2.81±6.18	0.94	-1.51
3	-	-	-	-	-	-	93.67±8.75	3.14±7.62	0.83	-1.81
4	-	-	-	-	-	-	104.61±32.78	4.42±25.05	0.96	-3.99
5	-	-	-	-	-	-	114.75±11.99	1.15±8.55	0.68	0.70
6	-	-	-	-	-	-	138.12±16.47	5.85±8.17	0.72	1.71
7	-	-	-	-	-	-	138.68±16.10	8.63±8.36	0.53	-19.46
8	-	-	-	-	-	-	139.37±5.30	7.38±4.97	0.78	2.13
9	-	-	-	-	-	-	142.48±5.92	8.58±2.54	0.96	-1.18
10	-	-	-	-	-	-	142.70±11.72	9.38±3.52	0.85	-2.27

Impact 36

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
36	P1 (exterior column (mid-height))	h	no	500		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.67	0.99	9.60	1.87	1.00	-0.51	9.56±0.04	1.93±0.38	1.00	0.37
2	-	-	73.97	2.04	0.90	3.92	-	-	-	-
3	89.55	0.94	89.48	1.17	0.95	-1.58	89.44±0.62	1.22±0.47	0.97	-0.04
4	103.52	0.85	-	-	-	-	-	-	-	-
5	-	-	144.72	1.06	0.90	-3.20	144.30±1.24	1.47±1.42	0.93	-1.22
6	163.96	0.85	171.69	1.63	0.96	-0.22	168.93±5.68	3.54±3.03	0.97	-1.09

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.67	0.99	9.59	2.01	0.98	-5.64	9.64±4.27	2.36±29.84	0.99	-3.48
2	74.12	0.71	72.83	1.44	0.86	0.93	-	-	-	-
3	89.55	0.99	89.61	1.29	0.99	-1.54	89.56±0.26	1.37±0.19	1.00	-2.75
4	-	-	-	-	-	-	167.88±2.55	3.26±2.46	0.92	6.19

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	9.82±2.07	8.56±22.70	0.70	15.96
2	93.71	0.90	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	139.61±5.00	7.60±4.79	0.67	-3.11
4	-	-	-	-	-	-	139.86±5.84	7.52±7.38	0.87	0.05

Impact 37

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
37	P2 (exterior column (top))	h	yes	500		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.57	1.00	9.58	1.74	0.98	3.24	9.54±0.02	1.76±0.19	1.00	0.31
2	89.65	0.82	89.34	1.36	0.91	1.73	89.26±0.54	1.21±0.45	0.96	-2.22
3	-	-	95.26	1.34	0.93	-3.59	95.10±0.74	1.47±0.41	0.98	-2.17
4	128.22	0.85	128.65	1.31	0.89	1.83	128.88±0.58	1.54±0.42	0.99	-0.15

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.57	0.99	9.57	1.76	0.99	-3.89	9.57±0.06	2.21±0.85	0.99	-3.46
2	89.65	0.99	89.21	1.57	1.00	-1.75	94.00±2.45	1.98±2.45	1.00	-2.19
3	-	-	-	-	-	-	123.54±2.31	1.82±0.72	0.99	1.78
4	-	-	128.67	0.95	0.78	-8.04	128.22±1.49	1.57±0.75	0.99	0.93
5	-	-	-	-	-	-	156.58±2.35	2.21±2.32	0.95	-5.63

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.56	0.74	-	-	-	-	8.95±1.90	3.15±18.68	0.66	17.65
2	-	-	-	-	-	-	43.27±5.25	3.39±16.86	0.77	8.59
3	-	-	-	-	-	-	88.40±26.12	5.21±30.83	0.70	0.89
4	-	-	-	-	-	-	122.84±29.33	4.75±33.48	0.72	2.40
5	-	-	-	-	-	-	138.69±6.70	6.99±3.70	0.89	9.63
6	-	-	-	-	-	-	140.90±14.21	7.86±5.04	0.89	-2.16
7	-	-	-	-	-	-	142.49±7.53	8.56±4.24	0.86	-6.38

Impact 38

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	Columns fixed
38	P2 (exterior column (top))	h	no	500		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.67	0.98	9.62	2.30	0.82	2.98	9.57±0.02	1.88±0.17	1.00	0.30
2	-	-	41.69	0.81	0.76	-0.08	-	-	-	-
3	-	-	74.12	0.54	0.71	3.77	-	-	-	-
4	89.65	0.81	89.42	1.14	0.91	0.53	89.57±0.80	1.13±1.30	0.98	-1.32
5	95.61	0.75	95.24	1.30	0.93	-6.93	95.29±0.54	1.36±0.46	0.99	-2.40
6	129.39	0.86	129.02	1.35	0.89	1.20	129.43±0.69	1.77±0.62	0.97	0.84
7	-	-	-	-	-	-	131.85±0.84	0.70±0.77	0.91	-0.04
8	-	-	-	-	-	-	137.40±2.17	1.41±1.33	0.97	-0.20
9	-	-	-	-	-	-	143.78±1.66	1.15±1.44	0.81	-7.46

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.67	0.99	9.60	1.78	0.99	-3.82	9.59±0.06	2.23±0.77	0.99	-3.39
2	89.65	0.99	89.63	1.29	1.00	1.31	-	-	-	-

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	62.62	0.97	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	72.11±1.11	0.53±1.62	0.50	-5.42

Impact 39

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
39	P7 (midspan of exterior beam)	v	yes	500		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	1.27	1.00	-	-	-	-	-	-	-	-
2	-	-	39.07	3.72	0.92	-0.62	39.44±0.85	2.87±2.58	0.79	-12.14
3	42.19	0.74	42.07	0.82	0.95	-1.34	-	-	-	-
4	60.74	0.87	60.75	0.28	0.86	0.06	-	-	-	-
5	-	-	65.41	0.83	0.84	-0.27	70.46±1.23	4.80±4.50	0.73	-9.86
6	-	-	-	-	-	-	80.44±1.51	1.94±3.93	0.80	-2.08
7	-	-	-	-	-	-	85.23±4.29	2.04±3.86	0.79	-8.23
8	-	-	89.72	0.94	0.92	2.89	-	-	-	-
9	-	-	95.29	1.08	0.93	-1.83	95.16±0.64	1.27±0.37	0.96	0.35
10	-	-	97.68	0.93	0.96	2.16	97.71±0.55	1.27±0.64	0.99	1.71
11	103.71	0.73	103.08	1.16	0.97	-1.12	102.74±0.47	1.51±0.50	0.96	-4.82
12	-	-	-	-	-	-	120.70±2.25	2.59±1.27	0.85	-2.33
13	-	-	128.27	1.36	0.92	-2.34	-	-	-	-
14	-	-	131.97	0.14	0.80	8.18	-	-	-	-
15	-	-	-	-	-	-	157.91±5.48	1.35±2.60	0.76	9.69

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.38	0.97	-	-	-	-	-	-	-	-
2	-	-	39.71	2.14	0.78	2.83	-	-	-	-
3	48.54	0.92	-	-	-	-	-	-	-	-
4	73.14	0.89	-	-	-	-	72.56±2.58	2.71±3.08	0.79	-4.58
5	90.04	0.89	89.93	0.82	0.84	-8.18	89.42±3.26	1.59±3.36	0.99	-1.48
6	-	-	-	-	-	-	121.90±3.00	2.91±1.06	0.88	-3.64
7	-	-	-	-	-	-	128.45±3.30	2.19±2.59	0.93	2.01
8	-	-	-	-	-	-	157.27±1.89	2.08±0.52	0.94	2.61

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	37.15	0.92	-	-	-	-	38.34±7.10	8.18±22.03	0.97	0.56
2	45.57	0.77	-	-	-	-	-	-	-	-

Impact 40

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
40	P7 (midspan of exterior beam)	v	no	500		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	1.46	1.00	-	-	-	-	-	-	-	-
2	-	-	38.37	2.04	0.88	0.18	39.30±0.41	1.39±1.30	0.84	-9.87
3	-	-	42.09	0.74	0.95	3.78	42.03±0.54	1.07±1.12	0.95	-3.51
4	60.74	0.96	60.97	0.32	0.88	0.15	-	-	-	-
5	-	-	-	-	-	-	71.46±3.43	4.31±2.41	0.72	-6.92
6	-	-	-	-	-	-	80.89±4.15	1.30±3.09	0.91	3.27
7	-	-	89.74	0.82	0.81	3.17	89.78±1.17	1.11±1.63	0.97	-1.16
8	-	-	95.26	1.09	0.89	-4.18	95.19±0.41	1.22±0.35	0.99	-0.41
9	-	-	97.86	0.97	0.96	1.22	98.06±2.55	1.35±1.23	0.98	1.74
10	-	-	-	-	-	-	102.67±2.72	1.62±1.25	0.83	9.15
11	-	-	-	-	-	-	122.78±2.12	2.10±1.11	0.87	-4.15
12	127.83	0.87	128.04	1.43	0.81	-4.63	128.72±3.60	1.75±2.36	0.98	-0.04
13	-	-	132.22	0.73	0.88	1.79	-	-	-	-

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.57	0.92	-	-	-	-	9.78±0.58	4.87±8.49	0.99	0.66
2	-	-	39.44	2.32	0.73	4.11	40.34±1.66	2.49±10.80	0.92	-3.86
3	-	-	-	-	-	-	72.09±2.19	3.20±3.50	0.91	3.87
4	90.14	0.89	-	-	-	-	95.17±1.28	1.19±1.35	0.99	3.10
5	-	-	-	-	-	-	123.29±1.31	1.66±2.13	0.97	-3.67
6	-	-	-	-	-	-	157.15±0.76	2.02±1.18	0.96	1.76

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	36.70	0.93	-	-	-	-	-	-	-	-
2	39.51	0.77	-	-	-	-	39.68±3.36	3.88±9.93	0.78	-0.25
3	40.45	0.74	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	141.59±19.49	9.46±4.21	0.95	5.26

Impact 41

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	Columns fixed
41	P6 (quarterspan of exterior beam)	v	yes	500		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	39.43±0.45	2.10±1.13	0.78	-11.69
2	42.19	0.81	-	-	-	-	-	-	-	-
3	-	-	60.77	0.03	0.96	0.10	-	-	-	-
4	-	-	74.15	0.66	0.84	1.16	-	-	-	-
5	-	-	95.28	1.22	0.88	-0.12	95.26±0.41	1.40±0.53	0.97	-3.86
6	-	-	97.65	1.03	0.91	2.32	97.64±1.23	1.18±0.74	0.97	2.73
7	-	-	103.23	1.27	0.91	1.15	-	-	-	-
8	123.83	0.85	123.17	1.80	0.93	1.81	123.27±1.88	1.97±1.12	0.97	3.30

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.28	0.89	-	-	-	-	9.57±0.39	4.23±8.51	0.99	-3.42
2	-	-	39.26	1.60	0.80	3.39	40.09±0.76	2.28±4.18	0.89	-3.25
3	-	-	48.32	2.22	0.99	-0.71	54.14±24.07	3.23±9.73	0.95	-0.16
4	72.36	0.80	-	-	-	-	71.34±2.20	4.29±3.76	0.80	-5.07
5	89.65	0.91	94.25	0.44	0.77	-10.37	89.13±1.21	1.76±1.44	0.99	-2.14
6	-	-	-	-	-	-	104.08±1.65	1.42±0.91	0.81	7.18
7	123.14	0.95	122.81	1.20	0.95	0.02	123.12±1.41	2.03±1.58	0.94	2.55
8	143.36	0.82	142.98	1.42	0.75	-5.51	143.51±2.48	1.19±2.18	0.89	1.58
9	-	-	157.31	1.13	0.74	1.68	158.17±0.82	2.00±2.91	0.92	-2.01
10	-	-	-	-	-	-	163.59±4.73	4.45±3.76	0.81	-3.26

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	38.58±1.23	7.59±2.97	1.00	0.34
2	-	-	-	-	-	-	96.87±4.52	2.30±3.56	0.99	2.54

Impact 42

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
42	P6 (quarterspan of exterior beam)	v	no	500		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	39.67±1.50	1.51±5.19	0.96	-1.50
2	-	-	74.03	0.56	0.81	-3.41	-	-	-	-
3	-	-	95.35	1.18	0.91	0.04	95.37±1.26	1.16±1.25	0.99	0.49
4	-	-	103.42	0.92	0.89	1.33	-	-	-	-
5	123.93	0.86	123.40	1.54	0.93	2.69	122.89±0.60	1.78±0.35	0.97	1.41

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.28	0.98	-	-	-	-	9.61±0.80	4.42±8.26	0.99	-3.88
2	-	-	39.10	1.45	0.81	3.67	-	-	-	-
3	73.44	0.80	-	-	-	-	71.49±2.46	3.96±2.14	0.87	-7.73
4	89.45	0.95	93.97	0.28	0.85	-4.94	89.09±1.38	1.53±1.82	0.99	0.96
5	123.73	0.89	123.10	1.21	0.95	-0.88	122.92±2.65	2.02±1.39	0.98	0.16
6	143.46	0.86	142.99	1.43	0.81	-3.52	142.73±0.13	1.58±0.52	0.93	-2.96
7	-	-	157.13	1.09	0.76	1.40	157.91±0.40	2.01±0.29	0.91	4.37

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	40.06±8.74	6.93±23.69	0.99	-1.74
2	-	-	-	-	-	-	73.37±9.29	3.47±12.90	0.86	0.47

Impact 43

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
43	P4 (quarterspan of middle beam)	v	yes	500		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	38.87	2.66	0.92	-0.44	39.04±0.77	1.67±4.46	0.96	2.27
2	-	-	-	-	-	-	41.28±1.19	2.31±3.86	0.89	-9.99
3	45.41	0.98	45.00	1.01	0.96	1.53	42.96±2.48	5.67±1.84	0.91	-2.97
4	-	-	61.84	2.10	0.95	3.21	-	-	-	-
5	63.96	0.89	-	-	-	-	-	-	-	-
6	-	-	73.82	1.32	0.71	12.52	-	-	-	-
7	-	-	-	-	-	-	79.71±3.49	2.39±2.58	0.94	-1.25
8	-	-	89.71	0.91	0.76	-1.48	89.63±1.71	1.68±2.02	0.95	-3.58
9	95.12	0.75	95.10	1.03	0.97	-0.18	95.03±1.00	1.44±0.37	0.94	-5.61
10	-	-	103.15	1.12	0.78	-3.77	103.52±0.56	1.15±1.21	0.90	-4.33
11	122.75	0.73	121.88	1.72	0.86	1.30	122.55±1.53	2.60±3.08	0.96	-4.03
12	-	-	-	-	-	-	137.78±2.71	1.69±1.27	0.75	6.57
13	-	-	-	-	-	-	167.17±1.32	1.68±0.92	0.88	-1.99

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.28	0.98	-	-	-	-	9.62±0.53	2.60±6.43	0.99	-0.50
2	39.36	0.80	39.30	1.66	0.90	-6.86	39.03±1.63	2.65±4.50	0.93	-5.60
3	45.41	0.89	-	-	-	-	-	-	-	-
4	63.77	0.72	-	-	-	-	62.64±1.22	3.21±4.37	0.91	-0.69
5	95.02	0.93	90.15	0.57	0.95	-4.51	93.17±0.94	1.76±1.48	0.99	2.49
6	-	-	-	-	-	-	105.17±0.94	1.92±0.94	0.98	1.02
7	122.56	0.98	122.91	1.81	0.98	-2.11	122.67±0.80	1.85±0.13	0.97	1.40
8	-	-	143.31	0.45	0.89	-1.32	-	-	-	-
9	157.32	0.93	157.69	1.35	0.92	-5.92	157.51±0.40	1.63±0.50	0.94	4.74

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	11.64	0.82	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	39.87±0.63	1.43±2.26	0.96	-1.89
3	-	-	-	-	-	-	82.46±6.02	1.82±4.80	0.89	-5.45
4	-	-	-	-	-	-	138.20±8.20	5.16±6.88	0.66	-3.57
5	-	-	-	-	-	-	141.24±4.77	7.72±4.20	0.93	5.16

Impact 44

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
44	P4 (quarterspan of middle beam)	v	no	500		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	39.55	0.75	38.96	2.34	0.90	0.66	39.37±0.37	1.55±1.73	0.97	2.71
2	42.19	0.74	-	-	-	-	41.49±1.04	2.30±2.09	0.93	-5.59
3	45.41	0.97	45.09	0.86	0.93	1.63	44.91±1.34	2.45±3.56	0.98	-0.44
4	-	-	61.79	1.84	0.95	-3.18	61.98±1.91	1.90±1.95	0.99	0.61
5	64.06	0.90	63.71	0.99	0.73	-13.52	-	-	-	-
6	-	-	74.04	1.49	0.78	9.96	-	-	-	-
7	-	-	89.82	1.01	0.95	-1.36	90.08±1.57	1.61±1.41	0.95	2.50
8	95.12	0.80	95.33	1.03	0.99	1.11	95.07±0.76	1.14±0.74	0.96	-5.86
9	-	-	103.20	1.13	0.82	-2.72	-	-	-	-
10	122.95	0.77	122.51	1.95	0.85	5.72	-	-	-	-
11	-	-	143.23	0.89	0.81	0.92	-	-	-	-

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.38	0.98	-	-	-	-	9.54±0.17	2.68±4.88	0.99	-1.62
2	39.55	0.87	39.38	1.46	0.95	-5.86	-	-	-	-
3	42.09	0.75	-	-	-	-	-	-	-	-
4	45.31	0.86	-	-	-	-	-	-	-	-
5	63.57	0.72	-	-	-	-	-	-	-	-
6	89.65	0.96	93.23	0.59	0.98	3.91	-	-	-	-
7	123.14	0.98	123.22	1.53	0.99	-0.75	-	-	-	-
8	157.23	0.90	157.86	1.43	0.91	-6.28	157.62±0.41	1.88±0.27	0.93	-4.76

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	38.74	0.94	-	-	-	-	39.63±2.80	2.16±5.78	0.95	-3.96
2	-	-	-	-	-	-	137.87±5.36	2.77±3.29	0.97	0.00

Impact 45

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
45	P3 (midspan of middle beam)	v	yes	500		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	1.46	0.99	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	39.47±0.34	1.84±0.95	0.70	-13.10
3	45.31	0.97	45.18	1.40	0.95	1.87	43.22±2.87	7.26±3.48	0.92	-0.88
4	-	-	-	-	-	-	57.92±2.32	1.89±5.03	0.94	-3.36
5	65.33	0.83	65.31	0.56	0.84	3.91	65.36±1.24	0.84±1.77	0.99	0.70
6	-	-	68.51	1.00	0.86	8.66	68.29±0.64	1.39±0.60	0.94	4.13
7	-	-	-	-	-	-	81.43±4.16	1.49±7.12	0.73	-5.27
8	-	-	-	-	-	-	94.29±0.82	1.24±2.42	0.92	-4.62
9	-	-	97.46	0.99	0.96	0.07	97.15±2.53	1.10±1.18	0.95	-0.95
10	-	-	101.49	1.33	0.86	-0.64	102.42±4.88	2.83±1.17	0.85	0.17
11	-	-	121.32	1.23	0.88	-0.85	120.23±1.91	2.03±2.88	0.90	3.64
12	128.03	0.75	128.39	1.28	0.92	-2.37	128.22±0.34	1.61±0.54	0.97	-0.32
13	-	-	-	-	-	-	158.09±3.46	2.88±1.65	0.81	1.78

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	39.21	2.45	0.92	-4.54	39.50±0.41	2.24±1.54	0.87	-3.02
2	45.21	0.92	-	-	-	-	-	-	-	-
3	54.59	0.72	-	-	-	-	-	-	-	-
4	95.12	0.84	94.81	1.05	0.83	-6.35	-	-	-	-
5	127.44	0.80	128.15	0.91	0.81	-2.61	128.07±0.99	1.69±0.95	0.99	0.70

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	14.61	0.96	-	-	-	-	-	-	-	-
2	39.79	0.93	-	-	-	-	38.72±3.84	1.81±8.97	0.96	-0.91
3	41.02	0.75	-	-	-	-	-	-	-	-

Impact 46

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
46	P3 (midspan of middle beam)	v	no	500		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	8.71	17.41	0.88	0.24	-	-	-	-
2	-	-	39.52	0.72	0.89	-4.51	39.37±0.25	1.66±1.01	0.93	3.88
3	-	-	41.42	0.61	0.73	16.69	41.53±0.94	2.31±2.93	0.81	7.48
4	45.41	0.97	45.16	1.67	0.96	1.12	45.06±1.55	1.75±3.19	0.99	-0.22
5	61.72	0.70	61.70	1.44	0.78	1.95	-	-	-	-
6	-	-	63.21	0.15	0.82	-6.40	-	-	-	-
7	-	-	95.02	1.16	0.73	-9.02	94.91±0.71	1.27±1.17	0.93	-0.69
8	-	-	97.75	1.15	0.95	-2.26	97.76±0.70	1.42±0.77	0.95	-0.94
9	103.22	0.73	103.07	1.10	0.91	-3.75	103.10±6.18	1.59±0.87	0.87	-1.56
10	-	-	106.43	1.07	0.77	-10.43	107.16±1.22	1.40±1.29	0.77	11.16
11	-	-	122.15	0.95	0.92	0.10	122.55±2.84	1.30±2.94	0.96	2.74
12	128.22	0.85	128.61	1.39	0.92	-2.03	128.66±0.37	1.73±0.40	0.99	0.03
13	-	-	137.61	0.70	0.76	-9.39	137.37±1.17	0.72±0.81	0.78	-9.69
14	-	-	153.41	0.45	0.80	3.55	157.25±5.58	2.65±2.88	0.84	3.67

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.28	0.95	-	-	-	-	-	-	-	-
2	39.55	0.83	39.37	1.77	0.93	-4.87	39.53±0.38	1.92±0.93	0.90	-2.73
3	45.21	0.89	-	-	-	-	-	-	-	-
4	54.30	0.72	-	-	-	-	-	-	-	-
5	62.11	0.73	-	-	-	-	-	-	-	-
6	95.31	0.92	95.13	0.98	0.89	7.70	94.86±1.87	1.23±2.25	0.97	3.81
7	-	-	-	-	-	-	105.76±1.01	2.95±1.11	0.97	-5.41
8	-	-	-	-	-	-	122.50±1.19	1.26±1.02	0.99	1.32
9	128.22	0.77	-	-	-	-	128.70±0.41	1.56±0.72	0.99	0.45
10	-	-	-	-	-	-	141.61±1.82	2.19±0.75	0.74	-8.29

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	39.14	0.85	-	-	-	-	39.28±1.19	1.55±1.71	0.93	-1.97
2	-	-	-	-	-	-	72.05±18.42	1.42±17.40	0.59	-10.92
3	-	-	-	-	-	-	142.86±12.95	8.35±6.81	0.96	3.72
4	-	-	-	-	-	-	144.05±3.87	9.92±5.13	0.99	0.10

Impact 47

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
47	P3 (midspan of middle beam)	v	yes	650		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	36.24	3.92	0.90	-1.65	35.94±2.97	3.73±8.67	0.85	-0.16
2	39.06	0.74	-	-	-	-	39.79±0.51	3.07±1.34	0.90	-4.48
3	-	-	40.45	1.16	0.88	0.44	-	-	-	-
4	43.16	0.90	43.13	1.37	0.97	0.88	42.76±2.70	1.94±11.08	0.99	-1.18
5	51.07	0.94	-	-	-	-	-	-	-	-
6	-	-	62.27	1.04	0.89	-0.89	61.84±0.55	3.43±2.12	0.77	-3.30
7	-	-	73.54	0.86	0.84	-3.93	73.65±6.92	1.81±9.52	0.93	-4.36
8	-	-	-	-	-	-	79.60±3.18	1.40±3.16	0.72	-5.84
9	-	-	-	-	-	-	93.84±1.20	1.04±1.24	0.86	4.24
10	96.39	0.83	96.28	1.03	0.91	-3.22	95.73±1.00	1.55±0.71	0.95	1.76
11	103.42	0.77	103.54	1.23	0.94	-1.75	102.97±1.34	1.92±0.87	0.81	-1.45
12	-	-	106.47	0.97	0.82	2.56	-	-	-	-
13	-	-	-	-	-	-	114.49±2.15	1.29±1.67	0.84	-0.18
14	127.83	0.74	128.03	1.24	0.91	-4.11	127.25±1.63	2.20±1.83	0.87	-3.62
15	-	-	-	-	-	-	141.18±2.11	1.97±6.63	0.83	4.40
16	-	-	154.08	0.89	0.79	-1.23	154.20±2.11	2.40±2.55	0.88	0.65

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.47	0.98	-	-	-	-	-	-	-	-
2	39.06	0.89	39.10	3.26	0.94	-6.89	38.71±1.57	4.86±2.93	0.94	-6.61
3	43.16	0.81	-	-	-	-	41.99±1.12	2.83±1.79	0.75	10.75
4	45.21	0.81	-	-	-	-	-	-	-	-
5	51.07	0.96	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	61.74±0.99	4.30±2.09	0.98	0.48
7	96.58	0.85	-	-	-	-	95.09±0.89	3.56±0.89	0.78	-6.60
8	-	-	-	-	-	-	104.61±1.47	2.50±0.65	0.91	-1.11
9	127.15	0.85	-	-	-	-	127.18±2.04	1.87±0.31	0.95	1.87
10	-	-	-	-	-	-	142.38±3.02	2.45±1.06	0.90	-0.31

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	0.77	0.73	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	38.33±4.92	5.20±8.61	0.96	-0.19
3	39.71	0.75	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	107.79±21.46	1.02±15.95	0.68	6.05

Impact 48

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
48	P3 (midspan of middle beam)	v	no	650		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	39.16	0.78	39.56	2.04	0.88	-2.95	37.01±1.62	4.57±5.29	0.80	1.48
2	-	-	40.53	1.23	0.89	1.00	39.98±0.74	2.95±1.94	0.93	-1.30
3	43.36	0.87	43.36	1.47	0.97	1.90	42.85±0.94	2.14±4.62	0.99	-1.58
4	51.07	0.93	-	-	-	-	-	-	-	-
5	-	-	74.10	1.01	0.93	-2.66	-	-	-	-
6	-	-	83.89	0.65	0.76	3.69	-	-	-	-
7	-	-	94.23	0.37	0.75	13.14	-	-	-	-
8	96.68	0.86	96.52	1.00	0.95	-4.26	-	-	-	-
9	103.52	0.81	103.74	1.04	0.90	-1.15	-	-	-	-
10	-	-	106.38	0.81	0.77	8.49	-	-	-	-
11	-	-	114.28	1.14	0.84	0.52	-	-	-	-
12	-	-	123.80	0.84	0.87	0.50	-	-	-	-
13	-	-	129.16	1.19	0.87	-3.43	128.68±1.67	2.27±1.46	0.88	4.04
14	-	-	-	-	-	-	142.32±4.35	2.38±0.75	0.85	-5.22
15	-	-	155.79	0.37	0.76	-0.47	156.56±1.70	2.05±1.50	0.94	2.16

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.38	0.89	-	-	-	-	-	-	-	-
2	39.16	0.94	39.29	2.65	0.94	-7.48	38.83±0.68	4.35±3.24	0.89	-7.04
3	43.26	0.82	-	-	-	-	42.41±0.54	2.55±0.95	0.91	6.70
4	51.07	0.85	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	62.63±1.08	2.63±0.53	0.99	-0.77
6	96.97	0.85	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	104.67±0.45	2.45±0.48	0.87	-2.11
8	-	-	-	-	-	-	125.58±3.26	1.54±1.11	0.98	-0.27
9	129.30	0.92	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	142.86±1.68	2.06±1.41	0.90	2.88

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	38.52±3.99	7.14±12.36	0.74	-3.12
2	-	-	-	-	-	-	137.16±9.17	6.85±7.30	0.61	3.46
3	-	-	-	-	-	-	136.02±6.28	4.69±11.80	0.67	-21.62
4	-	-	-	-	-	-	139.31±17.28	9.69±19.18	0.73	-17.19

Impact 49

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
49	P5 (top of middle column)	v	yes	650		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	43.85	0.98	43.35	1.34	0.99	-0.10	43.37±0.70	1.63±1.86	0.99	0.39
2	52.34	0.95	51.86	1.21	0.96	-0.39	51.89±0.77	1.36±3.38	0.98	2.82
3	-	-	62.52	0.87	0.75	8.74	62.27±3.90	1.92±2.02	0.98	-3.23
4	63.48	0.75	63.28	0.77	0.95	-0.53	-	-	-	-
5	-	-	-	-	-	-	68.99±0.62	1.18±1.08	0.96	-0.22
6	73.73	0.79	73.42	1.25	0.93	-3.08	73.29±9.79	1.11±8.63	0.98	-0.06
7	-	-	79.62	0.81	0.86	-2.42	79.53±0.32	1.21±0.24	0.88	2.12
8	-	-	-	-	-	-	84.37±1.31	1.48±1.21	0.88	4.69
9	-	-	-	-	-	-	93.69±3.62	1.17±2.75	0.94	1.81
10	-	-	94.07	0.93	0.95	-4.88	94.13±0.32	1.17±0.45	0.94	0.92
11	96.09	0.92	96.16	0.83	0.96	-2.66	96.08±2.64	2.06±1.05	0.92	1.23
12	-	-	114.35	0.88	0.91	-0.12	114.19±0.68	1.13±0.22	0.93	-0.11
13	129.30	0.86	129.16	1.55	0.96	-1.49	129.13±0.78	2.13±0.57	0.80	-4.60
14	-	-	132.43	0.52	0.78	-2.19	-	-	-	-
15	-	-	142.58	1.28	0.78	-3.63	143.06±1.23	2.29±1.06	0.81	5.96
16	-	-	154.82	0.95	0.81	4.55	154.38±1.43	1.09±1.16	0.97	1.02
17	-	-	158.40	0.90	0.89	-4.29	158.51±0.92	1.20±0.56	0.97	-0.31

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.28	0.96	-	-	-	-	9.44±0.25	3.06±2.08	0.98	-2.92
2	-	-	-	-	-	-	62.79±1.39	2.33±1.55	0.95	-3.36
3	73.44	0.70	-	-	-	-	-	-	-	-
4	91.41	0.99	-	-	-	-	93.81±0.58	1.24±0.54	1.00	-2.44
5	127.93	0.85	-	-	-	-	128.40±0.26	1.67±1.11	1.00	-0.11
6	158.20	0.90	158.60	1.08	0.85	4.02	158.51±5.15	1.72±1.80	0.92	-7.30

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	41.09±8.32	8.25±26.80	0.96	2.06
2	-	-	-	-	-	-	79.22±9.50	1.02±9.61	0.82	7.45
3	-	-	-	-	-	-	96.48±0.89	1.99±0.89	0.88	3.37
4	-	-	-	-	-	-	139.54±7.57	10.58±4.69	0.99	0.41
5	-	-	-	-	-	-	142.14±7.16	8.26±5.05	0.92	-3.66

Impact 50

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
50	P5 (top of middle column)	v	no	650		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	9.41±0.18	2.55±3.49	1.00	1.72
2	-	-	-	-	-	-	40.89±1.02	2.41±3.31	0.93	-2.33
3	44.04	0.99	43.67	1.25	0.99	0.75	43.71±4.63	2.33±6.19	0.99	0.09
4	52.44	0.97	52.00	1.08	0.98	-0.16	51.76±0.56	1.50±0.56	0.94	1.09
5	63.77	0.79	63.44	0.81	0.84	-3.77	63.46±0.86	0.78±1.33	0.97	-1.79
6	73.83	0.85	73.57	1.05	0.96	-2.53	73.41±0.61	1.08±0.57	0.98	-0.92
7	-	-	-	-	-	-	76.84±3.17	2.05±1.55	0.72	4.20
8	-	-	79.73	1.01	0.93	1.03	79.63±0.52	1.18±1.31	0.90	2.89
9	-	-	-	-	-	-	84.44±3.31	1.86±2.78	0.86	-8.53
10	-	-	94.25	0.86	0.97	-2.18	94.17±0.46	1.09±0.75	0.99	-0.51
11	96.39	0.91	96.47	0.95	0.96	-2.41	96.42±1.68	2.00±1.15	0.96	0.64
12	-	-	105.75	0.61	0.79	8.32	105.61±0.91	1.19±1.84	0.71	7.67
13	114.65	0.77	114.43	0.93	0.86	-0.98	114.35±0.27	1.09±0.15	0.86	-0.34
14	-	-	123.81	0.86	0.85	-1.36	123.79±2.68	1.17±7.60	0.96	1.68
15	129.30	0.77	129.50	1.48	0.93	-2.86	129.03±1.86	1.85±0.50	0.98	0.21
16	-	-	133.30	0.24	0.81	-1.64	-	-	-	-
17	-	-	142.04	0.99	0.79	-5.04	-	-	-	-
18	-	-	154.57	0.74	0.77	4.89	153.95±1.73	1.08±0.99	0.95	0.63
19	-	-	158.49	0.92	0.90	-3.19	158.60±2.69	1.23±1.03	0.97	1.06

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.28	0.99	-	-	-	-	9.46±0.11	3.21±1.17	0.99	-4.56
2	24.22	0.92	-	-	-	-	-	-	-	-
3	52.25	0.93	-	-	-	-	51.67±0.55	1.46±1.09	0.93	-1.35
4	88.18	0.98	94.60	0.92	0.98	0.94	95.93±0.98	1.91±0.92	0.92	0.47
5	128.52	0.78	-	-	-	-	-	-	-	-
6	158.89	0.81	158.57	0.89	0.83	-1.78	157.46±5.65	1.51±2.18	0.98	1.09

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.06	0.79	-	-	-	-	8.26±0.25	1.63±4.35	0.57	-7.50
2	14.61	0.83	-	-	-	-	16.37±11.36	11.01±39.71	0.71	-7.15
3	-	-	-	-	-	-	85.90±12.90	2.66±14.75	0.55	1.30
4	-	-	-	-	-	-	96.99±2.84	1.25±5.02	0.76	5.06
5	-	-	-	-	-	-	139.71±9.83	4.76±22.11	0.66	-5.67
6	-	-	-	-	-	-	144.82±22.06	14.40±23.97	0.80	0.48

Impact 51

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
51	P3 (midspan of middle beam)	v	yes	650		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	1.46	1.00	-	-	-	-	-	-	-	-
2	-	-	38.47	2.69	0.90	3.31	-	-	-	-
3	43.85	0.75	43.54	1.57	0.97	0.95	-	-	-	-
4	60.84	0.87	-	-	-	-	-	-	-	-
5	72.95	0.71	72.60	0.92	0.80	-4.37	-	-	-	-
6	-	-	79.85	0.58	0.92	-2.20	-	-	-	-
7	-	-	89.01	0.56	0.80	-13.62	-	-	-	-
8	96.58	0.80	96.22	1.33	0.98	-1.41	96.32±0.79	1.81±0.45	0.98	-1.23
9	104.10	0.77	-	-	-	-	-	-	-	-
10	127.54	0.90	126.97	1.50	0.96	0.44	-	-	-	-
11	-	-	131.78	0.64	0.80	-1.66	-	-	-	-

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.28	0.96	-	-	-	-	-	-	-	-
2	-	-	44.60	3.98	0.73	-13.07	-	-	-	-
3	73.24	0.92	-	-	-	-	72.36±1.21	2.24±1.50	0.97	1.58
4	89.16	0.78	-	-	-	-	88.97±0.61	1.17±0.80	0.99	3.63
5	-	-	-	-	-	-	97.11±3.47	2.28±1.53	0.95	-5.18
6	-	-	-	-	-	-	104.36±0.52	1.67±0.46	0.99	1.20
7	-	-	-	-	-	-	126.74±1.45	3.06±2.39	0.98	-3.06
8	-	-	-	-	-	-	158.20±0.43	1.95±0.29	0.91	5.67

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	7.98±0.75	4.95±18.18	0.66	-3.28
2	38.70	0.85	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	39.13±3.76	14.55±5.00	1.00	-0.71
4	-	-	-	-	-	-	41.77±3.75	1.71±10.67	0.99	0.28

Impact 52

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
52	P3 (midspan of middle beam)	v	no	650		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	1.56	1.00	-	-	-	-	-	-	-	-
2	51.17	0.78	-	-	-	-	-	-	-	-
3	60.74	0.97	-	-	-	-	-	-	-	-
4	73.14	0.84	72.64	1.29	0.82	-7.82	-	-	-	-
5	-	-	88.80	0.70	0.93	-4.41	-	-	-	-
6	96.68	0.83	96.39	1.19	0.98	-1.67	96.47±0.79	1.39±0.41	0.97	0.56
7	104.10	0.76	104.37	0.85	0.87	0.14	-	-	-	-
8	127.73	0.92	127.88	1.69	0.99	-0.09	-	-	-	-
9	-	-	132.01	0.62	0.75	0.03	-	-	-	-
10	-	-	154.46	0.69	0.76	1.40	-	-	-	-

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	73.05	0.87	-	-	-	-	-	-	-	-
2	89.16	0.76	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	96.67±0.48	1.60±0.61	0.94	-0.90
4	-	-	-	-	-	-	158.62±0.49	1.90±0.72	0.92	5.09

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	5.74	0.85	-	-	-	-	-	-	-	-
2	8.18	0.75	-	-	-	-	-	-	-	-
3	36.25	0.72	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	38.54±0.82	9.69±2.81	0.98	-2.62
5	-	-	-	-	-	-	40.13±2.19	2.00±5.97	0.96	-1.17
6	-	-	-	-	-	-	71.48±3.92	0.76±17.47	0.57	-5.50
7	-	-	-	-	-	-	77.82±11.55	2.65±12.09	0.73	-4.50
8	-	-	-	-	-	-	134.64±11.41	5.19±10.00	0.87	0.56

Impact 53

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
53	P2 (exterior column (top))	h	yes	650		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.47	1.00	9.50	1.67	0.97	1.36	9.47±0.06	1.68±0.79	1.00	0.10
2	-	-	73.87	0.92	0.73	-8.02	-	-	-	-
3	-	-	88.21	1.43	0.81	2.39	88.26±0.55	2.31±1.01	0.84	-4.93
4	93.95	0.92	93.41	0.97	0.89	2.32	94.12±4.34	1.14±3.17	0.98	0.21
5	-	-	123.56	0.87	0.88	-0.59	123.55±0.41	1.09±0.49	0.97	1.88
6	128.22	0.71	128.42	1.45	0.95	0.77	128.76±0.31	1.58±0.69	0.99	0.71
7	-	-	158.64	0.88	0.81	1.31	-	-	-	-

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.47	0.99	9.49	1.67	0.99	-3.80	9.49±0.06	2.07±0.84	0.99	-3.64
2	93.85	1.00	92.55	2.00	1.00	0.63	-	-	-	-
3	-	-	128.43	0.74	0.77	-1.47	128.14±1.45	1.85±1.27	0.98	0.49
4	-	-	157.43	0.56	0.83	-0.79	-	-	-	-

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	94.11±19.46	5.64±19.47	0.60	-4.33
2	-	-	-	-	-	-	110.53±8.60	3.10±7.18	0.54	21.07
3	-	-	-	-	-	-	125.88±11.27	2.25±10.74	0.61	-17.03
4	-	-	-	-	-	-	137.63±6.55	4.58±11.04	0.59	17.14

Impact 54

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	Columns fixed
54	P2 (exterior column (top))	h	no	650		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.47	0.99	9.51	2.01	0.94	1.23	9.48±0.01	1.74±0.12	1.00	0.07
2	-	-	73.88	0.85	0.79	-5.03	-	-	-	-
3	-	-	88.06	1.64	0.77	1.62	-	-	-	-
4	94.04	0.94	93.82	1.12	0.97	-2.67	93.95±0.90	1.15±1.25	0.96	-3.17
5	-	-	104.40	0.80	0.73	-0.15	-	-	-	-
6	-	-	123.69	0.92	0.91	-0.27	123.55±0.41	1.06±0.44	0.98	1.29
7	128.22	0.73	128.50	1.36	0.96	0.66	128.64±0.55	1.54±0.30	0.98	1.94
8	-	-	158.64	0.91	0.78	1.95	-	-	-	-

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	10.45	0.98	9.50	1.69	0.99	-3.67	9.50±0.08	1.98±0.66	0.99	-3.63
2	93.75	0.99	88.35	1.72	0.99	-0.01	-	-	-	-
3	-	-	128.29	0.96	0.83	2.67	128.01±1.05	1.72±0.75	0.98	0.88

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.36	0.86	-	-	-	-	-	-	-	-
2	32.67	0.73	-	-	-	-	-	-	-	-
3	54.28	0.76	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	89.19±8.10	1.73±12.97	0.88	10.52
5	94.20	0.93	-	-	-	-	93.42±7.75	2.24±4.66	0.98	0.48
6	130.62	0.75	-	-	-	-	143.79±73.22	7.95±3.01	0.99	-1.69
7	-	-	-	-	-	-	137.71±5.62	8.47±4.72	0.52	15.94

Impact 55

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	Columns fixed
55	P1 (exterior column (mid-height))	h	yes	650		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.47	0.98	9.51	1.66	0.99	-0.18	9.48±0.05	1.68±0.28	1.00	0.37
2	73.44	0.71	70.78	0.74	0.85	2.53	72.23±1.10	4.00±1.53	0.97	-0.53
3	-	-	-	-	-	-	84.45±2.20	1.36±3.37	0.97	-2.19
4	88.96	0.87	88.61	0.99	0.93	-1.01	89.02±0.72	3.34±0.88	0.88	1.54
5	93.65	0.86	-	-	-	-	93.05±1.87	1.65±3.01	0.89	-3.67
6	-	-	104.12	0.93	0.86	-2.03	103.93±0.54	1.24±0.47	0.93	-2.82
7	-	-	-	-	-	-	106.60±0.94	1.44±0.41	0.85	-2.88
8	-	-	-	-	-	-	113.11±5.35	2.19±4.26	0.98	-0.53
9	-	-	131.68	0.82	0.81	-0.80	-	-	-	-
10	-	-	-	-	-	-	154.94±4.15	1.21±0.66	0.99	-0.25
11	165.72	0.84	164.17	2.21	0.92	-2.47	164.94±1.58	2.79±0.69	0.93	-2.23

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.47	0.99	9.50	1.78	0.99	-4.00	9.50±0.06	1.91±0.41	0.99	-3.59
2	-	-	71.20	1.66	0.97	-0.97	72.58±3.64	6.21±1.88	0.98	-1.51
3	88.57	0.98	90.39	2.50	0.99	0.37	88.90±2.51	1.98±3.30	1.00	-0.54
4	-	-	104.24	0.15	0.85	1.74	105.00±0.46	1.25±0.77	0.96	0.16
5	-	-	-	-	-	-	112.16±3.77	2.64±1.98	0.93	-3.90
6	-	-	-	-	-	-	165.66±2.00	3.01±2.21	0.94	-2.00

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.44	0.71	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	39.27±19.81	12.92±37.75	0.80	-1.63
3	-	-	-	-	-	-	92.44±7.01	3.12±9.27	0.87	-7.47
4	116.41	0.88	-	-	-	-	134.26±6.27	5.90±7.10	0.86	6.75
5	-	-	-	-	-	-	136.12±16.21	7.61±5.16	0.98	1.66

Impact 56

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	Columns fixed
56	P1 (exterior column (mid-height))	h	no	650		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.47	0.98	-	-	-	-	9.49±0.07	1.91±0.57	1.00	0.11
2	-	-	-	-	-	-	69.16±0.52	1.24±0.73	0.92	-2.27
3	73.34	0.76	71.87	1.33	0.95	1.73	72.55±1.23	3.64±1.37	0.96	-1.28
4	88.77	0.89	88.47	1.09	0.93	3.20	88.35±0.57	2.77±1.40	0.83	13.34
5	-	-	-	-	-	-	93.28±2.35	1.37±3.44	0.88	-8.27
6	-	-	104.12	0.89	0.86	-2.20	103.86±0.59	1.29±0.33	0.90	-3.44
7	-	-	-	-	-	-	110.78±0.68	1.23±0.45	0.87	-1.43
8	123.93	0.70	-	-	-	-	123.38±3.67	1.39±1.26	0.98	0.80
9	-	-	-	-	-	-	154.53±1.46	1.26±1.03	0.98	0.03
10	166.41	0.89	167.34	1.70	0.91	-1.88	165.47±0.55	2.84±0.95	0.93	-3.02

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.47	0.99	9.51	1.87	0.98	-3.59	9.51±0.09	2.14±0.61	0.99	-3.65
2	71.68	0.77	71.66	0.64	0.96	-0.99	-	-	-	-
3	88.77	0.99	88.62	1.24	0.98	3.08	-	-	-	-
4	-	-	-	-	-	-	165.86±3.25	3.01±1.27	0.91	-2.35

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	5.37	0.99	-	-	-	-	-	-	-	-
2	9.44	0.83	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	88.84±5.43	1.68±5.98	0.69	-8.20
4	-	-	-	-	-	-	139.55±5.91	6.93±6.38	0.51	4.69
5	-	-	-	-	-	-	141.50±10.55	8.82±7.26	0.72	-0.19

Impact 57

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	Columns fixed
57	P2 (exterior column (top))	h	yes	650	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.99	8.61	1.48	0.85	4.94	8.59±0.03	1.64±0.28	1.00	-0.52
2	96.58	0.89	96.41	0.66	0.95	-1.19	-	-	-	-
3	-	-	104.73	0.88	0.71	-1.69	-	-	-	-
4	-	-	123.70	1.74	0.75	6.21	-	-	-	-

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.99	8.59	1.49	0.99	-2.92	8.61±0.22	1.89±2.40	0.99	-3.42
2	94.63	0.99	89.94	2.58	1.00	-1.14	91.12±4.83	1.80±7.65	0.99	-3.07
3	-	-	-	-	-	-	125.66±2.41	3.34±1.23	0.98	-2.18
4	-	-	155.62	0.64	0.81	-0.37	-	-	-	-

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.42	0.83	-	-	-	-	8.39±0.39	1.63±4.81	0.66	10.27
2	-	-	-	-	-	-	96.57±2.82	2.48±2.36	0.52	5.24

Impact 58

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
58	P2 (exterior column (top))	h	no	650	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.99	8.59	1.31	0.99	-0.22	8.60±0.02	1.66±0.43	1.00	-0.05
2	-	-	-	-	-	-	68.86±2.90	2.98±3.91	0.90	3.09
3	-	-	-	-	-	-	89.61±1.32	0.90±1.89	0.96	-1.14
4	96.78	0.88	96.56	0.64	0.96	-0.13	96.38±1.41	1.62±0.73	0.93	-4.04
5	-	-	123.47	1.20	0.74	6.56	-	-	-	-
6	-	-	-	-	-	-	140.58±0.84	1.29±0.47	0.78	-7.78
7	-	-	-	-	-	-	157.27±0.86	1.32±0.19	0.96	2.26
8	-	-	-	-	-	-	168.43±1.90	1.66±0.55	0.89	-2.59

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.99	8.59	1.43	0.99	-4.10	8.61±0.03	2.18±1.13	0.99	-3.33
2	90.23	0.98	93.53	3.18	0.99	-3.35	90.95±7.28	1.75±14.57	0.99	-3.12
3	-	-	-	-	-	-	104.78±2.41	1.17±3.68	0.96	3.62
4	-	-	124.84	0.24	0.81	-0.15	-	-	-	-
5	-	-	-	-	-	-	140.70±7.34	2.01±3.25	0.97	-2.36
6	-	-	155.65	0.14	0.79	-1.64	157.44±0.99	1.53±1.16	0.97	0.36

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.34	0.94	-	-	-	-	-	-	-	-
2	8.59	0.84	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	54.92±13.95	3.72±28.14	0.99	-0.95
4	95.58	0.80	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	139.54±15.95	7.70±3.89	0.76	-10.05
6	-	-	-	-	-	-	138.94±39.34	6.70±30.72	0.81	-0.32

Impact 59

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	Columns fixed
59	P1 (exterior column (mid-height))	h	yes	650	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.99	8.60	1.32	1.00	-0.58	-	-	-	-
2	80.96	0.91	80.67	1.55	0.89	1.18	-	-	-	-
3	-	-	89.24	0.94	0.87	2.59	-	-	-	-
4	-	-	129.64	0.36	0.73	2.70	-	-	-	-
5	164.45	0.88	169.40	1.31	0.92	-1.26	167.05±3.26	2.61±1.04	0.95	-1.29

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.99	8.59	1.45	0.98	-4.91	8.64±0.33	1.75±3.72	0.99	-3.28
2	89.16	0.99	91.43	2.60	0.99	-0.27	91.46±0.62	3.12±0.35	0.99	-2.63
3	-	-	104.70	0.23	0.83	0.73	104.77±0.53	1.15±0.78	0.95	0.37
4	-	-	-	-	-	-	157.92±1.20	1.14±1.19	0.94	-1.73
5	-	-	165.28	0.66	0.78	-6.78	162.16±2.53	2.99±0.54	0.95	-3.21

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.14	0.80	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	31.40±10.77	8.80±29.76	0.59	-4.97
3	-	-	-	-	-	-	40.01±6.41	5.29±18.52	0.89	-3.45
4	-	-	-	-	-	-	69.75±14.37	2.35±18.54	0.53	-2.65
5	-	-	-	-	-	-	77.24±4.24	1.64±8.02	0.71	-4.65
6	-	-	-	-	-	-	103.58±14.55	2.11±13.75	0.57	-23.06
7	-	-	-	-	-	-	133.43±23.70	6.73±12.91	0.51	4.92
8	-	-	-	-	-	-	142.17±5.22	8.05±2.39	0.96	-6.78
9	-	-	-	-	-	-	138.93±6.91	3.48±4.32	0.74	2.43

Impact 60

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	Columns fixed
60	P1 (exterior column (mid-height))	h	no	650	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.99	-	-	-	-	8.61±0.04	1.38±0.40	1.00	-0.15
2	-	-	-	-	-	-	73.73±1.34	3.17±3.23	0.96	-3.49
3	81.45	0.91	79.60	1.19	0.93	1.43	-	-	-	-
4	-	-	89.39	0.78	0.75	0.30	-	-	-	-
5	-	-	102.27	0.11	0.85	-4.22	-	-	-	-
6	-	-	-	-	-	-	120.96±2.90	1.59±3.76	0.85	-0.70
7	163.18	0.81	168.83	1.69	0.91	-1.36	166.70±2.51	3.28±1.44	0.93	-1.36

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	0.99	8.60	1.37	0.99	-3.00	8.62±0.04	1.81±0.67	0.99	-3.24
2	92.38	0.99	90.89	1.86	0.97	-5.56	91.72±1.18	2.65±0.89	0.99	-1.54

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	136.00±10.19	4.00±4.27	0.59	2.72

Impact 61

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
61	P7 (midspan of exterior beam)	v	yes	650	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	1.46	1.00	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	32.89±9.41	11.50±21.28	0.96	1.12
3	48.93	0.99	48.02	1.31	0.98	0.20	48.42±0.92	2.52±3.00	1.00	0.10
4	-	-	65.09	0.64	0.74	-1.82	-	-	-	-
5	-	-	84.12	0.90	0.84	-3.10	83.51±0.59	2.06±0.83	0.94	1.28
6	-	-	89.03	0.57	0.88	3.41	-	-	-	-
7	-	-	94.75	0.99	0.96	-1.30	-	-	-	-
8	-	-	97.54	0.80	0.95	-0.55	96.76±0.53	1.33±0.36	0.97	-2.03
9	104.88	0.89	104.66	0.99	0.98	-0.41	104.63±0.89	1.21±1.58	0.99	-0.60
10	-	-	-	-	-	-	121.04±2.12	1.05±1.08	0.96	1.70
11	-	-	-	-	-	-	157.65±0.57	1.25±0.49	0.95	1.58

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.69	0.98	-	-	-	-	8.62±0.15	4.33±3.83	0.99	-3.74
2	-	-	-	-	-	-	29.37±0.66	12.27±3.62	0.91	2.13
3	-	-	47.63	3.81	0.97	-2.82	48.37±1.22	2.19±3.14	1.00	-1.05
4	63.38	0.96	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	83.02±0.72	2.10±0.54	0.99	1.73
6	95.31	0.79	-	-	-	-	94.58±1.06	1.65±1.49	0.99	-0.69
7	105.18	0.80	-	-	-	-	104.44±0.43	1.20±0.36	0.99	-1.09
8	113.57	0.81	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	139.55±2.35	2.25±2.56	0.90	5.36
10	-	-	-	-	-	-	157.30±0.17	1.25±0.21	0.99	-0.74

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	1.67	0.74	-	-	-	-	-	-	-	-
2	5.25	0.96	-	-	-	-	-	-	-	-
3	8.18	0.72	-	-	-	-	8.86±1.95	19.33±36.68	0.75	-5.35
4	46.71	0.75	-	-	-	-	47.22±7.51	8.33±10.15	0.98	0.99
5	-	-	-	-	-	-	95.28±22.53	4.13±22.51	0.99	-0.86
6	-	-	-	-	-	-	140.73±4.40	7.46±2.46	0.90	-0.60

Impact 62

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
62	P7 (midspan of exterior beam)	v	no	650	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	1.37	1.00	-	-	-	-	-	-	-	-
2	-	-	48.68	1.38	0.96	0.27	48.73±1.45	2.58±6.96	1.00	-0.27
3	-	-	-	-	-	-	83.23±1.04	1.93±1.12	0.86	0.80
4	-	-	88.89	0.49	0.87	2.38	-	-	-	-
5	-	-	94.85	0.96	0.91	-2.93	-	-	-	-
6	-	-	97.73	0.72	0.95	-0.43	97.99±0.76	1.13±1.94	0.99	-1.44
7	104.88	0.93	104.67	0.90	0.99	-0.55	104.71±0.89	1.15±0.39	0.99	-0.67
8	-	-	130.16	1.19	0.85	-1.22	-	-	-	-
9	157.62	0.81	157.59	0.98	0.80	11.75	157.71±0.38	1.24±0.55	0.95	1.57

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.79	0.98	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	30.74±2.20	11.28±4.79	0.93	-2.77
3	48.73	0.97	47.90	2.99	0.97	-2.62	48.64±1.60	2.29±4.52	1.00	-0.65
4	63.77	0.83	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	82.62±0.75	1.83±3.94	0.97	3.45
6	95.21	0.86	-	-	-	-	95.30±2.49	2.23±5.62	0.97	-1.33
7	105.08	0.83	-	-	-	-	104.37±1.28	1.04±0.33	0.99	-0.94
8	-	-	-	-	-	-	157.37±0.17	1.32±0.19	0.99	2.24

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	1.63	0.92	-	-	-	-	-	-	-	-
2	8.06	0.82	-	-	-	-	-	-	-	-

Impact 63

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
63	P6 (quarterspan of exterior beam)	v	yes	650	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	32.42±6.76	11.97±16.53	0.98	-0.09
2	-	-	48.83	2.31	0.98	-0.86	48.41±2.24	2.50±6.81	1.00	-0.36
3	-	-	-	-	-	-	57.61±1.58	1.33±2.92	0.97	0.31
4	-	-	66.30	0.52	0.89	2.42	66.34±1.89	3.86±2.42	0.86	-5.73
5	-	-	82.08	0.93	0.93	0.72	82.90±2.23	1.22±1.18	0.95	-2.43
6	89.06	0.84	89.05	1.08	0.88	-2.65	89.36±1.20	1.20±2.32	0.92	-2.52
7	95.02	0.75	94.64	0.74	0.90	-5.46	95.07±0.55	1.01±0.75	0.98	1.55
8	104.98	0.86	104.58	1.09	0.92	-0.12	104.63±0.53	1.15±0.60	0.97	-1.08
9	-	-	-	-	-	-	124.73±7.63	2.50±5.38	0.92	2.73
10	-	-	141.89	0.29	0.82	-6.01	140.97±1.65	1.98±0.67	0.76	9.28
11	-	-	-	-	-	-	145.54±1.99	0.38±1.22	0.92	-0.00
12	-	-	157.28	0.87	0.80	-5.57	157.54±1.50	1.02±1.46	0.95	1.77

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.69	0.97	-	-	-	-	8.68±0.33	4.81±6.65	1.00	2.14
2	-	-	-	-	-	-	29.47±3.08	11.33±16.31	0.85	-1.36
3	-	-	47.70	3.77	0.98	-0.45	48.56±2.19	3.68±5.15	1.00	-0.95
4	-	-	-	-	-	-	64.74±2.64	4.67±7.81	0.99	-0.05
5	81.45	0.93	94.07	0.82	0.95	-3.40	-	-	-	-
6	104.49	0.71	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	123.55±2.42	3.02±4.11	0.99	-1.52
8	140.92	0.88	140.87	1.97	0.82	14.37	140.51±0.58	2.47±0.23	0.96	-2.55
9	-	-	-	-	-	-	156.49±3.12	1.46±0.82	0.98	2.34
10	-	-	-	-	-	-	162.54±7.80	3.44±3.87	0.84	-2.74

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	47.81	0.99	-	-	-	-	47.98±1.36	4.32±1.51	0.98	-2.25

Impact 64

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	Columns fixed
64	P6 (quarterspan of exterior beam)	v	no	650	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	33.78±2.73	9.08±9.43	0.97	-0.31
2	-	-	48.83	2.32	0.98	-1.59	48.67±0.48	3.25±0.99	1.00	-0.03
3	-	-	-	-	-	-	57.83±0.25	0.95±0.52	1.00	0.05
4	-	-	65.70	1.32	0.82	-5.89	66.92±1.44	2.61±1.93	0.86	-3.19
5	-	-	81.95	0.84	0.86	-3.31	82.28±2.62	1.49±3.00	0.92	-3.66
6	-	-	-	-	-	-	89.05±0.90	1.45±1.92	0.73	-5.32
7	95.02	0.77	94.43	0.80	0.84	5.51	95.16±2.86	1.14±1.00	0.98	1.09
8	104.98	0.82	104.54	1.13	0.89	0.34	104.63±1.42	1.27±0.83	0.96	-1.16
9	-	-	121.35	2.88	0.85	-0.32	123.99±1.14	2.77±1.94	0.90	1.81
10	-	-	-	-	-	-	131.88±4.97	1.50±6.27	0.77	-4.44
11	-	-	141.90	0.28	0.88	3.21	140.91±0.88	1.40±1.15	0.82	6.67
12	-	-	-	-	-	-	144.24±4.98	0.72±2.03	0.90	0.87
13	-	-	-	-	-	-	157.71±1.24	1.24±1.09	0.93	0.87

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	34.47±10.58	11.94±29.01	0.79	-9.68
2	-	-	48.40	2.96	0.98	-0.80	48.96±3.49	2.16±8.21	1.00	-0.99
3	-	-	-	-	-	-	64.45±3.68	5.41±2.65	0.90	-14.16
4	88.87	0.95	94.19	0.53	0.91	-5.29	94.61±5.06	1.20±4.49	1.00	0.40
5	-	-	-	-	-	-	105.04±2.62	1.13±1.75	0.99	1.60
6	141.99	0.93	141.03	1.73	0.81	3.14	140.79±0.28	2.91±0.54	0.84	-8.36
7	-	-	-	-	-	-	156.00±0.82	0.14±0.35	0.71	14.28
8	-	-	-	-	-	-	156.96±0.58	1.56±0.34	0.92	1.13

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	5.21	0.90	-	-	-	-	5.30±0.58	3.50±18.57	0.99	-0.58
2	7.81	0.85	-	-	-	-	8.30±0.17	2.72±2.68	0.58	-7.71
3	47.77	0.98	-	-	-	-	48.61±1.02	3.94±1.39	0.98	0.37
4	-	-	-	-	-	-	92.39±12.24	3.14±15.11	0.58	-16.07
5	-	-	-	-	-	-	140.29±14.72	12.52±26.24	0.93	-2.44
6	-	-	-	-	-	-	141.88±43.21	9.73±26.33	0.84	1.75

Impact 65

Test	Position	Orientation	Weight	P_0	Columns	
No.		vert/hor	yes/no	[kN]	pinned	fixed
65	P5 (top of middle column)	v	yes	650	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	39.55	0.92	-	-	-	-	-	-	-	-
2	-	-	57.58	1.11	0.86	-0.33	57.38±0.76	1.42±1.08	0.99	-0.04
3	68.95	0.82	68.82	1.05	0.75	0.04	-	-	-	-
4	-	-	-	-	-	-	73.02±4.28	3.39±3.23	0.88	-5.05
5	77.34	0.74	77.08	1.13	0.91	-1.64	-	-	-	-
6	-	-	84.42	1.10	0.90	0.75	84.50±0.23	1.49±0.22	0.98	1.50
7	88.57	0.85	93.54	1.26	0.87	3.54	-	-	-	-
8	94.73	0.88	94.67	0.80	0.85	-6.54	94.71±1.21	1.15±1.21	0.98	0.80
9	-	-	97.69	0.80	0.92	6.74	98.17±1.34	1.57±2.02	0.78	8.15
10	-	-	104.78	0.69	0.97	-1.30	104.70±6.19	0.72±5.17	0.96	-1.82
11	-	-	109.75	0.32	0.87	1.24	-	-	-	-
12	-	-	130.92	0.91	0.89	2.17	-	-	-	-
13	-	-	-	-	-	-	141.96±0.61	1.77±0.71	0.86	2.59
14	157.23	0.83	157.19	0.89	0.88	4.19	157.07±1.84	1.09±0.30	0.97	2.49

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.69	0.99	-	-	-	-	8.65±0.10	2.73±4.71	0.99	-1.70
2	57.91	0.84	-	-	-	-	57.80±0.43	1.17±0.66	0.98	0.23
3	94.73	0.98	94.07	0.85	0.97	-1.64	84.77±2.02	1.83±2.38	0.98	3.00
4	-	-	-	-	-	-	141.94±1.28	2.62±0.84	0.96	-0.80
5	-	-	-	-	-	-	156.32±0.27	0.04±0.23	0.76	14.38
6	-	-	157.15	0.89	0.90	4.39	156.99±0.71	1.15±0.54	0.99	0.46

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	14.53	0.81	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	93.38±0.85	1.40±1.32	0.98	-0.44
3	-	-	-	-	-	-	95.07±21.86	5.09±23.92	0.89	-0.05
4	-	-	-	-	-	-	137.29±30.31	6.52±15.61	0.96	1.32

Impact 66

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
66	P5 (top of middle column)	v	no	650	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f\pm2\sigma$ [Hz]	$\xi\pm2\sigma$ [Hz]	MPC [-]	MP [°]
1	39.84	0.97	39.50	1.18	0.98	0.09	39.73±2.82	2.53±7.90	0.99	1.17
2	-	-	57.71	1.12	0.82	-0.44	57.65±0.41	1.24±0.21	0.81	1.39
3	68.95	0.85	68.88	0.99	0.84	-2.41	69.12±0.83	1.89±0.71	0.92	-0.33
4	-	-	-	-	-	-	73.62±3.26	3.10±3.52	0.93	-5.53
5	77.34	0.78	77.04	1.09	0.98	1.33	76.94±1.44	0.81±2.49	0.91	7.54
6	-	-	84.50	1.01	0.82	-0.54	84.69±0.42	1.42±0.47	0.97	1.78
7	94.92	0.89	94.78	0.82	0.88	-4.41	94.69±0.41	0.93±0.58	0.98	0.46
8	-	-	97.71	0.93	0.82	10.60	98.06±7.05	1.39±2.34	0.94	1.98
9	-	-	-	-	-	-	105.30±1.13	1.45±0.77	0.71	-0.62
10	-	-	-	-	-	-	121.23±6.38	1.31±3.61	0.99	1.38
11	-	-	123.65	0.50	0.91	1.49	-	-	-	-
12	-	-	130.82	0.65	0.83	4.76	-	-	-	-
13	-	-	141.51	0.95	0.75	-6.89	141.54±0.79	1.41±1.26	0.85	4.96
14	157.32	0.85	157.32	0.91	0.91	3.43	157.16±1.24	1.05±0.41	0.97	2.81

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f\pm2\sigma$ [Hz]	$\xi\pm2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.69	0.94	-	-	-	-	-	-	-	-
2	44.04	0.84	-	-	-	-	43.94±0.37	0.34±0.99	0.90	-0.89
3	58.40	0.80	-	-	-	-	57.74±1.17	1.48±2.22	0.97	-0.16
4	-	-	-	-	-	-	68.59±3.25	2.52±3.58	0.79	-4.90
5	-	-	-	-	-	-	75.52±2.04	5.15±3.66	0.92	3.60
6	93.46	0.98	94.36	0.81	0.97	-0.86	94.84±0.38	1.07±1.13	1.00	-0.25
7	112.40	0.71	-	-	-	-	114.23±0.73	0.56±0.79	0.77	0.67
8	-	-	-	-	-	-	127.15±2.61	3.52±3.98	0.93	3.34
9	-	-	-	-	-	-	142.05±0.61	2.02±0.54	0.93	1.44
10	-	-	156.96	0.81	0.92	5.71	157.08±0.53	1.14±0.52	0.99	-0.17

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	18.39	0.81	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	94.80±4.30	2.75±3.72	0.92	6.39

Impact 67

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
67	P4 (quarterspan of middle beam)	v	yes	650	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	39.06	0.72	-	-	-	-	38.76±0.72	4.12±2.69	0.98	2.45
2	57.23	0.94	56.91	1.86	0.95	-2.03	57.06±2.55	2.54±8.82	0.99	-0.95
3	65.63	0.71	65.57	0.79	0.94	4.32	-	-	-	-
4	-	-	76.74	1.24	0.93	-7.21	76.55±1.81	0.88±3.55	0.97	-1.97
5	-	-	-	-	-	-	86.07±3.86	2.18±2.73	0.92	-2.68
6	-	-	93.88	0.78	0.75	-15.34	94.16±0.90	1.12±1.01	0.93	0.87
7	104.98	0.97	104.66	0.98	0.98	-0.10	104.74±0.89	1.09±0.43	0.98	-0.84
8	-	-	120.84	2.57	0.92	-4.36	119.47±4.46	3.78±10.03	0.98	-0.13
9	139.26	0.73	-	-	-	-	-	-	-	-

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.69	0.97	-	-	-	-	8.65±0.07	1.54±1.42	0.99	-0.24
2	-	-	38.46	2.12	0.78	4.08	-	-	-	-
3	56.93	0.89	-	-	-	-	56.83±0.73	1.76±1.31	0.96	-1.23
4	68.46	0.82	-	-	-	-	-	-	-	-
5	94.14	0.87	93.64	0.80	0.93	5.48	-	-	-	-
6	104.88	0.88	104.41	0.70	0.93	-2.63	104.76±1.11	1.05±0.97	1.00	1.19
7	-	-	121.05	1.32	0.92	-2.87	121.03±1.69	3.77±0.90	0.94	-4.08
8	-	-	-	-	-	-	139.69±0.56	1.88±0.33	0.99	0.82
9	156.93	0.88	155.98	0.69	0.97	0.99	156.42±0.45	1.37±0.46	0.95	1.66

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	14.49	0.80	-	-	-	-	14.45±1.87	14.67±29.51	0.98	-0.65
2	-	-	-	-	-	-	30.68±7.09	5.83±17.97	0.73	3.13
3	36.74	0.82	-	-	-	-	42.48±4.50	2.74±9.78	0.90	-1.57
4	77.15	0.77	-	-	-	-	74.73±5.52	2.27±2.89	0.61	7.28
5	-	-	-	-	-	-	77.41±2.71	0.47±4.10	0.99	-0.52
6	86.67	0.82	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	94.06±23.00	6.34±16.99	0.95	1.90
8	-	-	-	-	-	-	142.16±2.99	7.34±2.67	0.95	-1.45
9	-	-	-	-	-	-	140.55±15.99	9.10±8.57	0.91	8.21

Impact 68

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
68	P4 (quarterspan of middle beam)	v	no	650	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	34.81±5.04	9.09±5.86	0.75	-14.95
2	39.06	0.77	38.59	1.76	0.75	10.16	-	-	-	-
3	57.32	0.94	56.99	1.48	0.97	-0.69	56.75±0.27	1.80±0.68	0.98	-0.48
4	65.63	0.78	65.59	0.78	0.96	2.54	-	-	-	-
5	-	-	68.84	0.58	0.77	-1.58	-	-	-	-
6	77.05	0.73	76.78	1.22	0.96	-5.68	-	-	-	-
7	-	-	84.40	1.36	0.93	0.52	-	-	-	-
8	-	-	94.32	0.93	0.88	-5.34	-	-	-	-
9	104.98	0.96	104.73	0.90	0.95	-0.11	104.73±1.21	1.14±1.04	0.95	-0.59
10	-	-	110.54	0.63	0.74	3.14	-	-	-	-
11	-	-	119.28	1.99	0.90	-1.94	119.92±2.80	3.22±1.54	0.94	-2.98
12	139.45	0.70	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	157.04±0.92	1.14±1.93	0.83	3.52

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.69	0.98	-	-	-	-	8.62±0.13	1.79±2.80	0.99	-2.66
2	-	-	38.47	2.08	0.82	2.44	-	-	-	-
3	57.23	0.89	-	-	-	-	56.76±0.19	1.97±0.75	0.99	-1.06
4	67.87	0.81	-	-	-	-	68.54±2.22	3.49±4.10	0.81	12.89
5	94.43	0.96	93.82	0.68	0.91	7.12	94.28±1.08	0.86±1.86	0.99	1.20
6	104.69	0.75	-	-	-	-	104.40±1.05	1.09±0.87	1.00	0.20
7	-	-	121.37	1.15	0.91	-0.92	121.13±1.40	4.10±2.03	0.94	-5.14
8	-	-	-	-	-	-	139.85±0.68	1.61±0.34	0.97	-1.59
9	153.71	0.95	-	-	-	-	156.44±0.84	1.30±0.62	0.97	0.55

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	8.62±1.39	13.90±10.70	0.61	-9.09
2	-	-	-	-	-	-	41.96±3.87	1.95±13.73	0.91	0.60
3	-	-	-	-	-	-	63.15±9.21	3.13±14.40	0.81	4.35
4	77.11	0.91	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	137.11±34.46	8.86±24.67	0.82	-10.29

Impact 69

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	fixed
69	P3 (midspan of middle beam)	v	yes	650	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	40.92	0.79	-	-	-	-	-	-	-	-
2	57.13	0.90	-	-	-	-	56.28±1.45	2.44±4.73	0.98	1.50
3	65.63	0.89	65.62	0.78	0.95	3.83	-	-	-	-
4	-	-	68.69	0.28	0.82	-3.93	-	-	-	-
5	76.86	0.79	76.58	0.84	0.88	-2.34	-	-	-	-
6	94.24	0.86	92.74	1.14	0.95	2.58	93.77±3.53	1.32±2.96	0.95	3.86
7	104.69	0.88	104.35	1.21	0.95	-0.77	104.71±0.74	1.37±0.97	0.94	-1.84
8	-	-	139.70	1.00	0.82	-0.86	-	-	-	-

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.69	0.98	-	-	-	-	8.62±0.10	1.99±1.87	0.99	-0.22
2	38.87	0.75	38.37	4.08	0.85	2.60	-	-	-	-
3	57.13	0.96	-	-	-	-	56.17±2.48	2.85±3.80	0.99	-0.19
4	-	-	-	-	-	-	82.46±2.25	2.42±6.15	0.95	3.68
5	93.95	0.97	93.30	1.48	0.96	-1.59	94.14±2.73	1.44±2.38	1.00	0.06
6	104.20	0.83	-	-	-	-	104.51±0.55	1.22±1.21	1.00	0.53
7	-	-	-	-	-	-	124.11±0.82	2.81±2.24	0.92	-1.90
8	-	-	-	-	-	-	140.06±0.99	2.00±1.12	0.94	-3.26
9	-	-	-	-	-	-	159.40±3.31	1.94±1.59	0.87	-0.02

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.18	0.73	-	-	-	-	-	-	-	-
2	14.53	0.79	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	33.28±2.81	5.71±6.36	0.81	-7.12
4	40.81	0.85	-	-	-	-	41.06±2.76	0.31±6.90	0.99	-0.37
5	-	-	-	-	-	-	93.65±10.74	2.18±7.00	0.82	-3.20
6	-	-	-	-	-	-	138.60±8.65	8.49±2.87	0.90	-1.85

Impact 70

Test No.	Position	Orientation vert/hor	Weight yes/no	P_0 [kN]	Columns pinned	Columns fixed
70	P3 (midspan of middle beam)	v	no	650	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	14.37	13.99	0.92	0.67	-	-	-	-
2	57.32	0.84	57.05	0.98	0.80	-2.95	56.76±1.35	2.03±1.89	0.98	1.00
3	-	-	65.82	0.27	0.84	2.23	-	-	-	-
4	-	-	76.84	0.64	0.92	-0.89	76.51±2.59	0.67±3.05	0.97	-0.00
5	-	-	-	-	-	-	84.89±5.13	2.15±6.08	0.86	4.77
6	94.73	0.84	93.91	0.93	0.91	-11.79	93.89±0.73	1.24±0.50	0.92	-0.66
7	104.79	0.88	104.56	0.90	0.91	-1.04	104.58±0.88	1.23±0.83	0.96	-1.20
8	-	-	117.56	1.02	0.72	-1.84	-	-	-	-
9	-	-	125.76	1.12	0.80	-7.06	125.92±1.82	1.67±1.37	0.86	-0.25
10	-	-	131.26	0.62	0.77	-5.17	-	-	-	-
11	-	-	140.34	0.93	0.80	1.12	-	-	-	-

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.69	0.97	-	-	-	-	-	-	-	-
2	-	-	38.69	3.12	0.88	2.38	-	-	-	-
3	57.13	0.89	-	-	-	-	56.96±1.41	2.05±2.46	0.92	-0.60
4	59.96	0.81	-	-	-	-	-	-	-	-
5	94.82	0.96	94.13	1.35	0.94	-3.03	94.31±1.28	1.16±2.07	0.99	-0.22
6	-	-	104.28	0.64	0.91	4.46	104.40±1.51	1.46±0.62	0.99	-0.38
7	-	-	-	-	-	-	125.93±0.83	2.52±1.20	0.73	-7.30
8	-	-	-	-	-	-	141.25±0.78	1.94±0.56	0.95	-3.01

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	41.45±0.97	1.41±2.39	0.95	-2.49
2	-	-	-	-	-	-	94.26±4.30	2.39±3.59	0.90	-3.68
3	-	-	-	-	-	-	115.15±12.05	1.78±9.73	0.68	5.73
4	-	-	-	-	-	-	124.21±53.66	4.04±26.20	0.71	7.44
5	-	-	-	-	-	-	137.36±6.22	3.85±4.28	0.67	2.40
6	-	-	-	-	-	-	138.95±6.29	7.13±3.82	0.69	3.73
7	-	-	-	-	-	-	140.27±18.13	11.10±7.55	0.67	3.43

5.2.2 Shaker - single test results

Shaker 1

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
1	P7 (midspan of exterior beam)	h	400	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	1.00	-	-	-	-	8.59±0.00	1.71±0.00	1.00	-0.78
2	-	-	-	-	-	-	34.75±0.00	7.02±0.00	0.99	-0.49
3	-	-	-	-	-	-	47.01±0.00	2.39±0.00	0.97	-1.48
4	-	-	-	-	-	-	71.69±0.00	1.43±0.00	0.95	0.50

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.54	0.99	8.58	1.06	0.99	0.71	8.51±0.00	2.19±0.00	0.99	-4.09
2	-	-	-	-	-	-	68.67±0.00	2.71±0.00	0.99	-0.25
3	-	-	-	-	-	-	76.78±0.00	2.23±0.00	0.97	-0.12
4	-	-	-	-	-	-	135.45±0.00	1.13±0.00	0.96	-6.47
5	-	-	-	-	-	-	159.93±0.00	2.78±0.00	0.97	0.15

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.01	0.97	-	-	-	-	8.44±0.66	1.95±9.55	0.90	2.69
2	-	-	-	-	-	-	53.64±16.67	8.32±36.19	0.53	20.36
3	-	-	-	-	-	-	72.76±1.50	0.82±1.52	0.67	10.56
4	-	-	-	-	-	-	136.68±5.27	8.12±3.28	0.91	-9.80
5	-	-	-	-	-	-	138.49±3.68	4.88±2.42	0.66	10.10
6	-	-	-	-	-	-	142.08±4.55	8.31±1.12	0.99	1.35

Shaker 2

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
2	P7 (midspan of exterior beam)	h	400	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.58	1.00	8.53	0.86	1.00	-1.14	8.53±0.00	1.58±0.00	1.00	-0.46

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.54	0.99	8.52	1.64	0.99	0.77	8.52±0.00	2.21±0.00	0.99	-4.15
2	-	-	-	-	-	-	136.14±0.00	1.07±0.00	0.81	-1.70

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	8.56±0.28	2.42±4.13	0.68	-2.99
2	-	-	-	-	-	-	30.83±8.01	9.48±19.34	0.84	4.86
3	-	-	-	-	-	-	141.29±3.70	8.77±1.97	0.78	3.43
4	-	-	-	-	-	-	138.97±2.42	5.10±3.90	0.82	6.83
5	-	-	-	-	-	-	139.00±9.16	9.04±8.01	0.63	-3.19

Shaker 3

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
3	P7 (midspan of exterior beam)	h	400		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.49	1.00	9.46	0.46	0.99	0.06	9.47±0.00	1.58±0.00	1.00	0.29

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.41	0.99	9.58	1.63	0.99	-3.20	9.47±0.00	1.62±0.00	0.99	-4.43

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.46	0.86	-	-	-	-	9.45±1.44	4.12±21.66	0.84	-6.99
2	-	-	-	-	-	-	141.31±12.27	7.60±17.62	0.84	-2.82
3	-	-	-	-	-	-	142.65±1.19	8.57±0.91	0.96	-0.72

Shaker 4

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
4	P7 (midspan of exterior beam)	h	400		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.47	1.00	9.46	1.72	1.00	-0.30	9.47±0.00	1.57±0.00	1.00	0.29

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.49	0.99	-	-	-	-	9.47±0.00	1.64±0.00	0.99	-4.42
2	-	-	-	-	-	-	39.19±0.00	3.31±0.00	0.95	-0.17
3	-	-	-	-	-	-	71.52±0.00	3.42±0.00	0.98	-0.24

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.50	0.77	-	-	-	-	9.64±0.43	1.19±6.96	0.84	-7.46
2	-	-	-	-	-	-	10.24±2.43	19.14±23.80	0.74	6.39
3	-	-	-	-	-	-	52.54±16.93	3.26±18.08	0.69	13.78
4	-	-	-	-	-	-	56.17±36.33	2.09±21.68	0.68	-2.16
5	-	-	-	-	-	-	72.57±5.81	0.66±4.93	0.68	7.28
6	-	-	-	-	-	-	137.43±3.30	5.06±3.60	0.98	-3.86
7	-	-	-	-	-	-	142.40±1.26	7.69±2.52	0.67	-10.65
8	-	-	-	-	-	-	142.09±12.17	8.63±2.72	0.93	6.31
9	-	-	-	-	-	-	143.59±2.17	9.45±2.26	0.82	-7.16

Shaker 5

Test	Position	Orientation	P_0	Columns	
No.		vert/hor	[kN]	pinned	fixed
5	P7 (midspan of exterior beam)	v	400		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	38.11	0.96	-	-	-	-	38.11±0.00	2.25±0.00	0.99	0.08
2	-	-	-	-	-	-	44.15±0.00	2.16±0.00	0.97	0.95
3	-	-	57.34	3.38	0.99	0.54	56.98±0.00	4.06±0.00	0.99	0.11
4	-	-	-	-	-	-	77.10±0.00	0.38±0.00	0.94	2.12
5	-	-	-	-	-	-	82.95±0.00	1.10±0.00	0.93	0.10
6	-	-	-	-	-	-	115.86±0.00	0.22±0.00	0.95	-0.10

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	9.29±0.00	8.67±0.00	0.98	-2.81
2	37.83	0.94	38.28	2.30	0.98	-1.35	37.92±0.00	1.93±0.00	0.97	-2.12
3	-	-	-	-	-	-	43.72±0.00	1.42±0.00	0.88	11.86
4	57.15	0.87	-	-	-	-	56.81±0.00	4.25±0.00	1.00	-0.41
5	-	-	-	-	-	-	78.20±0.00	1.92±0.00	0.98	0.42

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	37.51	1.00	38.30	0.60	0.99	0.14	-	-	-	-
2	-	-	-	-	-	-	57.42±1.59	2.71±1.73	1.00	0.47

Shaker 6

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
6	P7 (midspan of exterior beam)	v	400		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	37.54	0.98	38.07	2.36	1.00	0.09	37.77±0.00	2.52±0.00	0.99	0.03
2	-	-	-	-	-	-	43.91±0.00	1.96±0.00	0.97	1.19
3	-	-	-	-	-	-	55.66±0.00	3.54±0.00	0.99	1.30
4	-	-	-	-	-	-	82.88±0.00	0.69±0.00	0.89	-0.51
5	-	-	-	-	-	-	106.13±0.00	0.80±0.00	0.84	-2.10
6	-	-	-	-	-	-	115.81±0.00	0.10±0.00	0.93	-1.83
7	-	-	-	-	-	-	120.33±0.00	0.37±0.00	0.79	-13.92

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	37.92	0.91	37.77	2.47	0.97	-0.98	-	-	-	-
2	-	-	-	-	-	-	43.53±0.00	2.28±0.00	0.85	12.41
3	-	-	-	-	-	-	55.70±0.00	3.84±0.00	1.00	-0.95

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	39.57	1.00	37.62	0.43	1.00	-0.79	38.10±0.58	3.07±1.24	0.99	1.86

Shaker 7

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
7	P7 (midspan of exterior beam)	v	400	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	35.72	0.92	35.80	2.11	0.99	-0.67	35.63±0.00	2.36±0.00	0.99	-0.58
2	-	-	-	-	-	-	39.60±0.00	1.91±0.00	0.96	-0.79
3	-	-	-	-	-	-	41.93±0.00	1.64±0.00	0.97	-1.71
4	48.89	0.98	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	75.02±0.00	0.38±0.00	0.76	-6.30
6	-	-	-	-	-	-	97.77±0.00	0.37±0.00	0.85	6.06
7	-	-	-	-	-	-	116.02±0.00	0.16±0.00	0.95	-2.30

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	35.15	0.88	36.02	2.12	0.91	-2.79	35.62±0.00	2.31±0.00	0.96	-3.62
2	-	-	-	-	-	-	40.88±0.00	2.04±0.00	0.96	3.59
3	48.72	0.96	-	-	-	-	51.57±0.00	4.28±0.00	0.98	-2.07
4	-	-	-	-	-	-	94.28±0.00	4.21±0.00	0.97	0.97
5	-	-	-	-	-	-	97.68±0.00	0.76±0.00	0.87	-2.22
6	-	-	-	-	-	-	156.29±0.00	1.17±0.00	0.97	-0.75

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	48.98	1.00	35.85	1.11	1.00	0.04	35.99±0.43	4.15±1.35	1.00	0.21
2	-	-	-	-	-	-	38.61±2.03	3.69±6.81	0.86	-4.19

Shaker 8

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
8	P7 (midspan of exterior beam)	v	400	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	35.19	0.98	36.13	2.26	0.99	0.03	35.97±0.00	2.61±0.00	0.98	-0.80
2	-	-	-	-	-	-	39.46±0.00	1.48±0.00	0.95	-1.74
3	-	-	-	-	-	-	41.93±0.00	1.74±0.00	0.97	-1.27
4	70.05	0.83	-	-	-	-	70.32±0.00	1.46±0.00	0.98	-0.15
5	-	-	-	-	-	-	85.82±0.00	1.58±0.00	0.98	-0.67
6	91.75	0.87	-	-	-	-	92.15±0.00	1.08±0.00	0.99	1.30
7	-	-	-	-	-	-	97.15±0.00	0.91±0.00	0.98	1.73
8	-	-	-	-	-	-	116.12±0.00	0.22±0.00	0.95	-3.16

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	35.04	0.94	36.20	2.02	0.93	-2.75	35.79±0.00	2.01±0.00	0.96	-3.57
2	-	-	-	-	-	-	41.97±0.00	2.65±0.00	0.80	10.05
3	-	-	70.64	1.12	0.81	-11.18	70.25±0.00	1.28±0.00	0.99	-2.28
4	-	-	-	-	-	-	72.99±0.00	2.52±0.00	0.75	3.79
5	-	-	82.55	1.73	0.92	-0.53	88.37±0.00	1.54±0.00	1.00	-0.30
6	91.62	0.87	92.61	0.61	0.75	-3.85	92.29±0.00	0.99±0.00	0.95	1.09
7	-	-	-	-	-	-	96.74±0.00	1.17±0.00	0.99	0.08
8	-	-	-	-	-	-	156.84±0.00	1.03±0.00	0.97	-1.82
9	-	-	-	-	-	-	168.52±0.00	4.01±0.00	0.79	-5.06
10	-	-	-	-	-	-	170.10±0.00	12.73±0.00	0.95	-0.39

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	35.26	0.98	35.53	0.71	1.00	-0.14	36.09±0.58	3.90±1.95	1.00	-0.01
2	-	-	-	-	-	-	84.05±2.75	1.72±3.32	0.93	-2.80
3	-	-	-	-	-	-	92.43±0.48	1.45±0.65	0.94	-2.12

Shaker 9

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
9	P7 (midspan of exterior beam)	v	500	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	36.04	0.93	-	-	-	-	35.97±0.00	2.36±0.00	0.96	0.30
2	48.49	0.98	48.72	2.16	0.98	0.57	-	-	-	-
3	69.92	0.86	-	-	-	-	70.23±0.00	1.40±0.00	0.99	-0.76
4	92.64	0.87	-	-	-	-	92.98±0.00	0.78±0.00	0.97	0.40
5	103.96	0.73	-	-	-	-	103.87±0.00	1.12±0.00	0.99	-0.12

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	35.08	0.96	36.17	1.94	0.92	-3.08	36.04±0.00	2.28±0.00	0.96	-3.18
2	48.31	0.97	-	-	-	-	-	-	-	-
3	70.47	0.95	70.57	1.18	0.80	10.10	70.31±0.00	1.38±0.00	0.98	-3.58
4	-	-	-	-	-	-	74.03±0.00	3.01±0.00	0.72	2.47
5	-	-	-	-	-	-	82.54±0.00	1.39±0.00	0.99	0.01
6	93.24	0.94	93.22	0.21	0.86	-1.87	92.87±0.00	0.75±0.00	0.99	-0.32
7	-	-	-	-	-	-	95.21±0.00	1.45±0.00	0.99	-0.25
8	-	-	104.36	0.33	0.89	2.73	103.88±0.00	1.31±0.00	0.98	-1.08
9	-	-	-	-	-	-	156.61±0.00	1.51±0.00	0.98	-3.14

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	35.20	1.00	-	-	-	-	48.77±5.62	2.64±7.64	1.00	-0.12
2	-	-	-	-	-	-	76.68±4.12	5.26±1.58	0.91	-4.41
3	-	-	-	-	-	-	92.83±0.63	0.62±0.64	0.99	0.47

Shaker 10

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
10	P7 (midspan of exterior beam)	v	500	x	

- Acceleration sensors

Mode No.	FDD f [Hz]	FDD MPC [-]	pLSCF f [Hz]	pLSCF ξ [%]	pLSCF MPC [-]	pLSCF MP [°]	SSIcov $f \pm 2\sigma$ [Hz]	SSIcov $\xi \pm 2\sigma$ [Hz]	SSIcov MPC [-]	SSIcov MP [°]
1	35.25	0.97	35.82	2.29	0.98	-0.72	35.99±0.00	2.32±0.00	0.96	0.25
2	48.31	0.98	48.80	1.73	0.90	1.62	-	-	-	-
3	70.24	0.86	70.27	1.20	0.93	4.46	70.35±0.00	1.51±0.00	0.99	-0.11
4	93.10	0.86	93.07	0.52	0.80	4.19	93.00±0.00	0.78±0.00	0.97	0.37
5	-	-	-	-	-	-	95.29±0.00	1.17±0.00	0.98	-3.37
6	104.23	0.74	103.54	0.42	0.84	-0.85	103.85±0.00	1.14±0.00	0.99	-0.08

- Tilt sensors

Mode No.	FDD f [Hz]	FDD MPC [-]	pLSCF f [Hz]	pLSCF ξ [%]	pLSCF MPC [-]	pLSCF MP [°]	SSIcov $f \pm 2\sigma$ [Hz]	SSIcov $\xi \pm 2\sigma$ [Hz]	SSIcov MPC [-]	SSIcov MP [°]
1	35.17	0.94	36.17	2.07	0.90	-1.93	36.03±0.00	2.29±0.00	0.96	-3.12
2	48.14	0.97	-	-	-	-	-	-	-	-
3	70.43	0.94	70.50	1.27	0.82	9.24	70.22±0.00	1.44±0.00	0.98	-3.57
4	-	-	-	-	-	-	74.23±0.00	3.20±0.00	0.73	3.29
5	-	-	-	-	-	-	82.45±0.00	1.55±0.00	0.99	0.25
6	93.54	0.94	93.14	0.23	0.89	-0.56	92.82±0.00	0.71±0.00	0.99	-0.93
7	-	-	-	-	-	-	95.04±0.00	1.67±0.00	0.99	-0.82
8	-	-	-	-	-	-	103.88±0.00	1.33±0.00	0.97	-1.10
9	-	-	-	-	-	-	156.66±0.00	1.52±0.00	0.97	-4.40

- FBG sensors

Mode No.	FDD f [Hz]	FDD MPC [-]	pLSCF f [Hz]	pLSCF ξ [%]	pLSCF MPC [-]	pLSCF MP [°]	SSIcov $f \pm 2\sigma$ [Hz]	SSIcov $\xi \pm 2\sigma$ [Hz]	SSIcov MPC [-]	SSIcov MP [°]
1	35.21	0.99	-	-	-	-	36.20±0.71	5.04±2.91	1.00	-0.13

Shaker 11

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
11	P7 (midspan of exterior beam)	v	500		x

- Acceleration sensors

Mode No.	FDD f [Hz]	FDD MPC [-]	pLSCF f [Hz]	pLSCF ξ [%]	pLSCF MPC [-]	pLSCF MP [°]	SSIcov $f \pm 2\sigma$ [Hz]	SSIcov $\xi \pm 2\sigma$ [Hz]	SSIcov MPC [-]	SSIcov MP [°]
1	-	-	39.34	2.83	0.97	0.51	40.03±0.00	4.97±0.00	0.98	1.80
2	-	-	-	-	-	-	44.50±0.00	2.18±0.00	0.94	-0.87
3	74.47	0.90	75.10	1.08	0.88	7.54	74.42±0.00	0.74±0.00	0.99	-0.10
4	-	-	-	-	-	-	76.30±0.00	0.89±0.00	0.93	-3.33
5	-	-	-	-	-	-	84.19±0.00	1.25±0.00	0.99	0.55
6	-	-	-	-	-	-	93.07±0.00	1.16±0.00	0.79	10.88
7	-	-	-	-	-	-	95.11±0.00	1.05±0.00	0.82	-4.55
8	-	-	-	-	-	-	97.35±0.00	0.96±0.00	0.99	0.21
9	104.74	0.76	104.82	1.15	0.90	0.88	104.97±0.00	1.27±0.00	0.97	-0.87

- Tilt sensors

Mode No.	FDD f [Hz]	FDD MPC [-]	pLSCF f [Hz]	pLSCF ξ [%]	pLSCF MPC [-]	pLSCF MP [°]	SSIcov $f \pm 2\sigma$ [Hz]	SSIcov $\xi \pm 2\sigma$ [Hz]	SSIcov MPC [-]	SSIcov MP [°]
1	39.17	0.83	38.79	2.19	0.97	-1.50	-	-	-	-
2	-	-	59.94	2.37	0.98	-0.75	59.74±0.00	2.44±0.00	0.99	-1.30
3	-	-	-	-	-	-	76.18±0.00	1.25±0.00	0.87	-1.97
4	84.28	0.82	-	-	-	-	84.31±0.00	1.08±0.00	0.99	-0.90
5	93.45	0.91	93.63	0.25	0.70	-0.84	93.21±0.00	0.86±0.00	0.97	2.12
6	-	-	-	-	-	-	105.06±0.00	1.11±0.00	0.97	6.89
7	-	-	-	-	-	-	158.17±0.00	1.50±0.00	0.90	0.48

- FBG sensors

Mode No.	FDD f [Hz]	FDD MPC [-]	pLSCF f [Hz]	pLSCF ξ [%]	pLSCF MPC [-]	pLSCF MP [°]	SSIcov $f \pm 2\sigma$ [Hz]	SSIcov $\xi \pm 2\sigma$ [Hz]	SSIcov MPC [-]	SSIcov MP [°]
1	37.94	0.99	38.67	1.48	1.00	-1.40	39.93±0.93	3.05±3.33	0.97	3.24
2	-	-	-	-	-	-	93.59±0.71	1.35±0.83	0.89	-0.90
3	-	-	-	-	-	-	97.76±1.51	1.90±1.19	0.95	1.23

Shaker 12

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
12	P7 (midspan of exterior beam)	v	500		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	39.25	1.88	0.99	0.20	40.54±0.00	4.42±0.00	0.94	0.13
2	-	-	-	-	-	-	44.89±0.00	1.59±0.00	0.96	-0.58
3	74.43	0.88	-	-	-	-	74.58±0.00	0.73±0.00	1.00	0.36
4	-	-	-	-	-	-	84.16±0.00	1.45±0.00	0.98	0.53
5	-	-	-	-	-	-	93.26±0.00	1.08±0.00	0.88	8.19
6	-	-	-	-	-	-	94.99±0.00	0.87±0.00	0.97	-2.58
7	-	-	-	-	-	-	97.20±0.00	0.99±0.00	0.99	-0.39
8	104.71	0.75	-	-	-	-	105.07±0.00	1.28±0.00	0.98	-0.62

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	38.87	0.76	38.81	2.10	0.98	-1.84	39.09±0.00	2.76±0.00	0.88	-1.55
2	-	-	-	-	-	-	43.80±0.00	3.41±0.00	0.72	-2.29
3	-	-	59.96	2.40	0.98	-0.71	59.73±0.00	2.36±0.00	0.99	-1.38
4	-	-	-	-	-	-	76.19±0.00	1.54±0.00	0.95	-4.79
5	84.07	0.82	-	-	-	-	84.35±0.00	1.20±0.00	0.98	0.84
6	93.61	0.93	-	-	-	-	94.51±0.00	2.17±0.00	1.00	-0.27
7	-	-	-	-	-	-	105.16±0.00	1.20±0.00	0.98	4.70
8	-	-	-	-	-	-	115.84±0.00	2.51±0.00	0.89	-0.64
9	-	-	-	-	-	-	158.47±0.00	1.61±0.00	0.90	-1.02

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	26.40±2.71	3.96±10.24	1.00	-0.27
2	40.71	1.00	38.87	2.93	1.00	-1.10	-	-	-	-
3	-	-	-	-	-	-	40.24±0.75	2.32±2.05	0.99	0.78
4	-	-	-	-	-	-	75.24±1.35	1.87±1.51	0.88	2.28
5	-	-	-	-	-	-	93.50±0.58	1.22±0.60	0.87	-0.00
6	-	-	-	-	-	-	97.10±4.59	1.20±3.36	0.86	2.39
7	-	-	-	-	-	-	142.25±3.62	7.94±0.76	0.97	-4.80

Shaker 13

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
13	P7 (midspan of exterior beam)	h	500		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.56	1.00	9.49	1.14	1.00	-0.33	9.52±0.00	1.56±0.00	1.00	0.38
2	-	-	-	-	-	-	96.49±0.00	1.35±0.00	0.92	-1.79
3	-	-	-	-	-	-	105.78±0.00	1.45±0.00	0.90	-0.79

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.57	0.99	9.53	0.79	0.99	-6.30	9.52±0.00	1.55±0.00	0.99	-4.34
2	-	-	-	-	-	-	164.95±0.00	9.12±0.00	0.98	0.20

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.51	0.74	-	-	-	-	9.55±0.17	2.01±1.62	0.95	0.47
2	-	-	-	-	-	-	123.75±9.64	3.01±4.77	1.00	0.64
3	-	-	-	-	-	-	141.65±2.27	9.38±1.53	0.93	-3.75

Shaker 14

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
14	P7 (midspan of exterior beam)	h	500		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.49	1.00	9.48	1.75	1.00	-0.92	9.52±0.00	1.57±0.00	1.00	0.38

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.50	0.99	9.69	1.37	0.99	-2.63	9.52±0.00	1.65±0.00	0.99	-4.38
2	-	-	-	-	-	-	179.62±0.00	17.22±0.00	0.98	0.38

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.50	0.78	-	-	-	-	9.53±1.21	5.51±13.46	0.99	1.09
2	-	-	-	-	-	-	15.71±3.53	3.45±22.78	0.78	14.14
3	-	-	-	-	-	-	65.43±25.89	4.65±38.19	0.60	8.17
4	-	-	-	-	-	-	68.53±21.16	3.71±22.87	0.92	-5.70
5	-	-	-	-	-	-	78.73±17.43	3.05±17.14	0.94	-0.62
6	-	-	-	-	-	-	136.56±6.51	4.43±4.48	0.93	1.64
7	-	-	-	-	-	-	137.65±6.48	6.33±3.38	0.88	-3.74
8	-	-	-	-	-	-	144.78±1.89	9.34±1.71	0.99	-0.03
9	-	-	-	-	-	-	143.94±3.53	8.40±1.73	0.98	-2.80

Shaker 15

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
15	P7 (midspan of exterior beam)	h	500	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.62	1.00	8.55	0.34	0.99	-2.92	8.55±0.00	1.58±0.00	1.00	-0.47
2	-	-	-	-	-	-	31.96±0.00	2.23±0.00	0.98	0.54
3	-	-	-	-	-	-	71.41±0.00	1.03±0.00	0.97	0.38
4	-	-	-	-	-	-	82.54±0.00	3.07±0.00	0.94	0.87
5	-	-	-	-	-	-	96.73±0.00	2.53±0.00	0.90	1.40
6	-	-	-	-	-	-	125.14±0.00	0.81±0.00	0.89	-2.33
7	-	-	-	-	-	-	144.02±0.00	0.94±0.00	0.72	8.38

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.42	0.99	8.54	0.95	0.99	-0.65	8.57±0.00	3.85±0.00	0.99	-3.86
2	-	-	-	-	-	-	55.55±0.00	2.47±0.00	0.90	-0.54
3	-	-	-	-	-	-	92.88±0.00	3.89±0.00	0.96	0.63
4	-	-	-	-	-	-	167.53±0.00	13.14±0.00	0.99	0.00

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.06	0.91	-	-	-	-	8.53±0.74	2.21±4.63	0.92	3.03
2	-	-	-	-	-	-	72.79±6.77	0.39±9.69	0.55	-3.74
3	-	-	-	-	-	-	137.85±8.39	6.99±8.63	0.74	-3.52
4	-	-	-	-	-	-	139.21±8.43	4.79±2.98	0.96	4.80
5	-	-	-	-	-	-	141.50±4.66	8.68±4.29	0.94	-2.06

Shaker 16

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
16	P7 (midspan of exterior beam)	h	500	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.60	1.00	8.54	1.41	1.00	0.49	8.56±0.00	1.57±0.00	1.00	-0.47

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.42	0.99	-	-	-	-	8.83±0.00	5.04±0.00	0.99	-1.48
2	-	-	-	-	-	-	167.21±0.00	12.46±0.00	0.98	0.04

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.04	0.94	-	-	-	-	8.42±0.13	0.66±1.82	0.95	2.88
2	-	-	-	-	-	-	37.94±9.41	7.72±16.08	0.93	-0.99
3	-	-	-	-	-	-	101.20±11.74	2.49±8.09	0.91	-0.42
4	-	-	-	-	-	-	138.62±3.54	7.31±1.45	0.93	5.38
5	-	-	-	-	-	-	138.72±7.20	5.22±3.68	0.82	-4.13
6	-	-	-	-	-	-	138.95±6.05	5.80±17.80	0.87	3.43
7	-	-	-	-	-	-	142.89±5.38	8.68±1.72	0.92	1.72

Shaker 17

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
17	P7 (midspan of exterior beam)	h	650	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.57	1.00	8.55	0.47	1.00	-1.31	8.56±0.00	1.61±0.00	1.00	1.01
2	-	-	-	-	-	-	35.37±0.00	4.83±0.00	1.00	0.14

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.53	0.99	8.57	0.58	1.00	0.10	8.54±0.00	1.73±0.00	0.99	-4.10

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.44	0.90	-	-	-	-	8.47±0.27	2.45±2.43	0.96	2.49
2	-	-	-	-	-	-	139.47±10.38	8.38±5.35	0.92	5.50

Shaker 18

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
18	P7 (midspan of exterior beam)	h	650	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.61	1.00	8.53	0.23	0.99	-2.02	8.55±0.00	1.56±0.00	1.00	1.06
2	-	-	-	-	-	-	34.79±0.00	1.79±0.00	1.00	-0.13

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.63	0.99	-	-	-	-	8.53±0.00	1.90±0.00	0.99	-4.07
2	-	-	-	-	-	-	33.77±0.00	4.68±0.00	0.95	3.82

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.14	0.96	-	-	-	-	8.29±0.08	1.05±0.98	0.95	3.09
2	-	-	-	-	-	-	136.11±4.53	4.81±4.29	0.99	0.54
3	-	-	-	-	-	-	138.79±7.30	3.88±2.26	0.92	-0.43
4	-	-	-	-	-	-	141.78±9.32	8.99±2.55	0.94	5.16
5	-	-	-	-	-	-	143.25±1.62	7.96±1.70	0.98	1.39

Shaker 19

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
19	P7 (midspan of exterior beam)	h	650		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.54	1.00	-	-	-	-	9.50±0.00	1.70±0.00	1.00	0.35

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.55	0.99	9.60	0.63	1.00	-0.99	9.50±0.00	1.60±0.00	0.99	-4.41
2	-	-	-	-	-	-	37.36±0.00	0.47±0.00	0.73	5.46
3	-	-	-	-	-	-	92.81±0.00	3.30±0.00	0.96	1.44
4	-	-	-	-	-	-	184.85±0.00	19.81±0.00	0.98	-0.14

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.14	0.81	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	82.36±10.36	0.85±12.64	0.54	2.41
3	-	-	-	-	-	-	137.93±2.88	6.29±2.52	0.73	-7.62
4	-	-	-	-	-	-	141.32±3.74	8.09±3.16	0.72	0.50
5	-	-	-	-	-	-	143.22±1.37	8.51±1.06	0.56	-7.26

Shaker 20

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
20	P7 (midspan of exterior beam)	h	650		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.49	1.00	9.45	0.26	0.99	0.29	9.50±0.00	1.67±0.00	1.00	0.36
2	-	-	-	-	-	-	44.43±0.00	3.37±0.00	0.95	-2.51
3	-	-	-	-	-	-	75.17±0.00	2.84±0.00	0.82	-9.31
4	-	-	-	-	-	-	104.41±0.00	1.53±0.00	0.92	-0.74

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.41	0.99	-	-	-	-	9.50±0.00	1.57±0.00	0.99	-4.36
2	-	-	35.97	0.07	0.99	0.92	-	-	-	-
3	-	-	-	-	-	-	37.23±0.00	0.46±0.00	0.84	1.22
4	-	-	-	-	-	-	92.66±0.00	2.43±0.00	0.99	1.37
5	-	-	-	-	-	-	171.14±0.00	13.68±0.00	0.99	0.09
6	-	-	-	-	-	-	180.63±0.00	19.25±0.00	0.99	-0.07

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	9.67±0.51	0.81±8.54	0.51	-4.13
2	-	-	-	-	-	-	10.27±1.06	6.39±9.94	0.68	4.05
3	-	-	-	-	-	-	113.34±28.14	5.18±22.18	0.73	7.58
4	-	-	-	-	-	-	141.28±5.92	8.12±1.50	0.79	-1.17

Shaker 21

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
21	P7 (midspan of exterior beam)	v	650		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	38.35	0.93	37.59	3.07	0.91	2.41	37.77±0.00	3.92±0.00	0.99	0.89
2	-	-	-	-	-	-	39.09±0.00	0.49±0.00	0.75	7.66
3	-	-	-	-	-	-	41.76±0.00	4.14±0.00	0.88	-0.41
4	54.34	0.99	54.28	1.42	0.99	-1.32	54.34±0.00	1.64±0.00	0.99	0.24
5	70.98	0.75	71.22	1.16	0.97	0.51	71.33±0.00	1.19±0.00	1.00	0.45
6	94.07	0.92	-	-	-	-	-	-	-	-

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	38.26	1.99	0.95	3.74	38.10±0.00	3.85±0.00	0.99	-2.22
2	54.42	0.98	54.40	1.44	0.99	-1.34	54.34±0.00	1.69±0.00	1.00	-0.99
3	-	-	-	-	-	-	71.43±0.00	0.81±0.00	0.98	-3.07
4	-	-	-	-	-	-	89.24±0.00	1.56±0.00	0.98	-2.25
5	-	-	-	-	-	-	89.42±0.00	0.91±0.00	0.99	-0.72
6	-	-	-	-	-	-	105.60±0.00	0.76±0.00	0.85	4.99
7	107.19	0.74	-	-	-	-	93.93±0.00	2.34±0.00	0.99	-0.28

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	38.07	0.96	38.12	2.81	0.98	-0.45	37.98±0.67	4.04±1.60	0.97	-0.37

Shaker 22

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
22	P7 (midspan of exterior beam)	v	650		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	38.52	0.89	-	-	-	-	37.83±0.00	4.27±0.00	0.99	1.33
2	-	-	-	-	-	-	38.57±0.00	0.55±0.00	0.81	-0.35
3	-	-	-	-	-	-	42.88±0.00	3.90±0.00	0.96	-0.56
4	54.58	0.99	54.35	1.42	0.99	-0.00	54.30±0.00	1.53±0.00	0.99	0.46
5	70.73	0.80	-	-	-	-	71.32±0.00	1.12±0.00	0.99	0.51
6	94.01	0.91	-	-	-	-	93.95±0.00	1.98±0.00	1.00	-0.21

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	38.52	0.91	38.14	1.99	0.96	0.74	37.85±0.00	4.18±0.00	0.97	-3.89
2	53.99	0.97	54.37	1.50	0.99	-1.21	54.37±0.00	1.53±0.00	1.00	-0.94
3	-	-	-	-	-	-	71.14±0.00	1.29±0.00	0.99	-3.04
4	-	-	-	-	-	-	79.23±0.00	1.25±0.00	0.89	0.21
5	88.82	0.92	-	-	-	-	89.29±0.00	1.44±0.00	0.99	0.93
6	106.85	0.72	-	-	-	-	106.14±0.00	1.62±0.00	0.94	2.44

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	35.90	0.96	38.09	2.77	0.98	0.22	38.01±0.69	4.03±1.66	0.97	-0.38
2	-	-	-	-	-	-	41.14±0.70	1.20±2.49	0.99	1.13
3	54.19	0.81	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	105.88±1.07	1.68±1.35	0.73	3.49

Shaker 23

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
23	P7 (midspan of exterior beam)	v	650	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	32.88	1.00	-	-	-	-	33.40±0.00	3.90±0.00	1.00	0.33
2	48.39	0.99	-	-	-	-	48.28±0.00	2.43±0.00	1.00	-0.07
3	66.97	0.75	67.26	1.51	0.95	1.09	67.16±0.00	1.66±0.00	0.99	0.78
4	-	-	-	-	-	-	73.33±0.00	1.70±0.00	0.95	4.37
5	-	-	-	-	-	-	81.77±0.00	1.39±0.00	0.90	-5.53
6	93.55	0.83	-	-	-	-	-	-	-	-
7	105.19	0.78	-	-	-	-	105.12±0.00	1.00±0.00	0.97	-1.55
8	-	-	-	-	-	-	144.13±0.00	0.29±0.00	0.71	-1.85

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	33.42±0.00	3.55±0.00	0.95	-4.25
2	-	-	-	-	-	-	39.10±0.00	1.22±0.00	0.88	6.96
3	48.17	0.98	48.27	2.39	0.99	-1.94	48.00±0.00	2.86±0.00	0.99	-1.45
4	-	-	67.37	1.48	0.85	4.28	67.21±0.00	2.03±0.00	0.98	-0.79
5	-	-	-	-	-	-	73.63±0.00	2.32±0.00	0.98	-1.09
6	81.80	0.80	-	-	-	-	83.17±0.00	1.72±0.00	0.99	0.38
7	93.61	0.91	-	-	-	-	94.05±0.00	0.67±0.00	1.00	1.02
8	105.33	0.80	-	-	-	-	105.09±0.00	1.07±0.00	1.00	0.11

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	33.05	0.91	47.65	0.24	0.92	0.74	33.03±1.22	7.34±5.15	1.00	0.79
2	-	-	-	-	-	-	40.58±1.92	2.61±5.13	0.85	5.66
3	-	-	-	-	-	-	64.41±8.69	4.67±10.42	0.70	-12.63

Shaker 24

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
24	P7 (midspan of exterior beam)	v	650	x	

- Acceleration sensors

Mode No.	FDD f [Hz]	FDD MPC [-]	pLSCF f [Hz]	pLSCF ξ [%]	pLSCF MPC [-]	pLSCF MP [°]	SSIcov $f \pm 2\sigma$ [Hz]	SSIcov $\xi \pm 2\sigma$ [Hz]	SSIcov MPC [-]	SSIcov MP [°]
1	33.47	0.99	-	-	-	-	33.65±0.00	3.49±0.00	1.00	0.44
2	48.16	0.99	48.19	2.52	0.99	-0.80	48.27±0.00	2.35±0.00	1.00	-0.38
3	67.03	0.77	67.14	1.45	0.93	0.10	67.04±0.00	1.68±0.00	1.00	0.61
4	-	-	-	-	-	-	73.75±0.00	1.78±0.00	0.91	8.08
5	-	-	-	-	-	-	78.29±0.00	1.21±0.00	0.98	-0.09
6	-	-	-	-	-	-	81.87±0.00	1.30±0.00	0.95	-2.24
7	-	-	-	-	-	-	85.13±0.00	1.40±0.00	0.97	3.25
8	93.73	0.83	-	-	-	-	-	-	-	-
9	105.02	0.78	-	-	-	-	105.09±0.00	0.95±0.00	0.97	-1.79

- Tilt sensors

Mode No.	FDD f [Hz]	FDD MPC [-]	pLSCF f [Hz]	pLSCF ξ [%]	pLSCF MPC [-]	pLSCF MP [°]	SSIcov $f \pm 2\sigma$ [Hz]	SSIcov $\xi \pm 2\sigma$ [Hz]	SSIcov MPC [-]	SSIcov MP [°]
1	32.90	0.89	-	-	-	-	33.68±0.00	2.80±0.00	0.97	-4.11
2	-	-	-	-	-	-	38.94±0.00	1.28±0.00	0.89	5.81
3	47.61	0.98	48.25	2.22	0.99	-1.70	48.21±0.00	2.33±0.00	1.00	-1.13
4	-	-	-	-	-	-	66.93±0.00	2.14±0.00	0.98	-1.40
5	-	-	-	-	-	-	73.62±0.00	2.18±0.00	0.98	2.02
6	81.84	0.81	-	-	-	-	82.30±0.00	1.61±0.00	0.99	-1.08
7	93.49	0.90	-	-	-	-	94.02±0.00	0.75±0.00	1.00	1.35
8	105.24	0.81	-	-	-	-	105.05±0.00	1.04±0.00	1.00	0.34

- FBG sensors

Mode No.	FDD f [Hz]	FDD MPC [-]	pLSCF f [Hz]	pLSCF ξ [%]	pLSCF MPC [-]	pLSCF MP [°]	SSIcov $f \pm 2\sigma$ [Hz]	SSIcov $\xi \pm 2\sigma$ [Hz]	SSIcov MPC [-]	SSIcov MP [°]
1	-	-	-	-	-	-	23.10±6.41	6.80±23.77	0.98	2.63
2	47.57	0.89	48.59	1.02	0.86	-0.66	33.82±1.55	7.87±6.58	1.00	1.01

Shaker 25

Test	Position	Orientation	P_0	Columns	
No.		vert/hor	[kN]	pinned	fixed
25	P3 (midspan of middle beam)	h	650	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.51	1.00	8.47	1.50	0.99	0.62	8.58±0.00	1.55±0.00	1.00	-0.42
2	-	-	-	-	-	-	34.59±0.00	0.58±0.00	0.99	-0.42
3	-	-	-	-	-	-	46.92±0.00	2.10±0.00	0.99	0.62
4	-	-	-	-	-	-	83.61±0.00	0.59±0.00	0.74	-0.37

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.62	0.99	-	-	-	-	8.57±0.00	1.77±0.00	0.99	-3.76
2	-	-	-	-	-	-	163.73±0.00	10.27±0.00	0.98	-0.04

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.10	0.73	-	-	-	-	8.39±0.10	0.45±1.07	0.63	4.39
2	8.65	0.75	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	135.48±7.02	6.35±7.94	0.69	7.13
4	-	-	-	-	-	-	141.88±4.57	8.75±2.49	0.95	2.25

Shaker 26

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
26	P3 (midspan of middle beam)	h	650	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.64	1.00	-	-	-	-	8.57±0.00	1.57±0.00	1.00	-0.45
2	-	-	-	-	-	-	34.49±0.00	0.55±0.00	0.99	-0.58
3	-	-	-	-	-	-	46.93±0.00	2.06±0.00	0.99	-0.29
4	-	-	-	-	-	-	83.61±0.00	0.60±0.00	0.73	-0.92

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.46	0.99	-	-	-	-	8.54±0.00	1.60±0.00	0.99	-2.62
2	-	-	-	-	-	-	160.82±0.00	7.67±0.00	0.99	-0.05

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.09	0.98	-	-	-	-	8.44±0.18	0.57±1.04	0.81	3.84
2	-	-	-	-	-	-	9.24±4.33	2.57±22.78	0.83	-4.27
3	-	-	-	-	-	-	137.24±7.99	5.78±5.49	0.91	-2.00
4	-	-	-	-	-	-	142.82±1.03	8.07±0.84	0.99	-0.85
5	-	-	-	-	-	-	138.49±7.98	5.91±3.51	0.72	-6.63
6	-	-	-	-	-	-	140.39±16.71	7.40±6.07	0.95	-0.08

Shaker 27

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
27	P3 (midspan of middle beam)	v	650	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	34.91±0.00	2.19±0.00	0.97	1.35
2	-	-	38.96	3.87	0.98	1.46	39.26±0.00	5.17±0.00	0.99	-0.13
3	56.60	0.88	57.01	1.18	0.94	3.37	56.93±0.00	1.38±0.00	0.99	1.28
4	-	-	-	-	-	-	74.80±0.00	1.19±0.00	0.96	2.11
5	93.41	0.86	-	-	-	-	-	-	-	-
6	104.30	0.88	104.51	1.04	0.93	0.01	104.43±0.00	1.15±0.00	0.97	-0.97
7	-	-	-	-	-	-	113.88±0.00	0.13±0.00	0.96	-0.90

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	39.07	4.06	0.92	0.77	38.86±0.00	5.56±0.00	0.96	5.02
2	56.93	0.92	-	-	-	-	56.90±0.00	1.41±0.00	0.99	-1.83
3	93.68	0.96	93.51	0.73	0.91	-6.10	-	-	-	-
4	104.24	0.89	-	-	-	-	104.50±0.00	1.05±0.00	0.99	2.78

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	36.71±1.18	3.45±0.91	0.90	2.38
2	-	-	-	-	-	-	39.54±4.77	5.41±14.96	0.94	0.37
3	41.42	0.84	-	-	-	-	40.97±0.69	0.88±1.91	0.98	1.76
4	-	-	-	-	-	-	60.02±13.52	3.63±26.22	0.99	3.10
5	-	-	-	-	-	-	75.10±6.05	5.41±9.34	0.89	5.41
6	-	-	-	-	-	-	93.89±0.69	1.42±1.21	0.70	-9.18
7	104.06	0.93	-	-	-	-	104.27±1.03	0.64±0.61	0.95	1.62

Shaker 28

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
28	P3 (midspan of middle beam)	v	650	x	

- Acceleration sensors

Mode No.	FDD f [Hz]	FDD MPC [-]	pLSCF f [Hz]	pLSCF ξ [%]	pLSCF MPC [-]	pLSCF MP [°]	SSIcov $f \pm 2\sigma$ [Hz]	SSIcov $\xi \pm 2\sigma$ [Hz]	SSIcov MPC [-]	SSIcov MP [°]
1	-	-	-	-	-	-	34.85±0.00	2.06±0.00	0.97	1.48
2	-	-	39.23	3.82	0.93	2.61	39.39±0.00	4.88±0.00	0.99	-0.10
3	56.96	0.90	56.98	1.33	0.98	1.96	56.90±0.00	1.36±0.00	0.98	1.61
4	93.43	0.86	93.34	0.62	0.80	-1.86	-	-	-	-
5	104.34	0.89	104.46	0.75	0.94	-1.06	104.52±0.00	1.05±0.00	0.98	-1.06
6	-	-	-	-	-	-	113.58±0.00	0.13±0.00	0.90	-1.09

- Tilt sensors

Mode No.	FDD f [Hz]	FDD MPC [-]	pLSCF f [Hz]	pLSCF ξ [%]	pLSCF MPC [-]	pLSCF MP [°]	SSIcov $f \pm 2\sigma$ [Hz]	SSIcov $\xi \pm 2\sigma$ [Hz]	SSIcov MPC [-]	SSIcov MP [°]
1	-	-	-	-	-	-	34.95±0.00	2.07±0.00	0.95	-4.72
2	-	-	39.24	3.38	0.92	2.13	39.05±0.00	5.16±0.00	0.97	5.10
3	-	-	-	-	-	-	48.25±0.00	2.28±0.00	0.99	-0.01
4	56.73	0.90	-	-	-	-	56.69±0.00	1.51±0.00	0.99	-2.29
5	-	-	-	-	-	-	75.22±0.00	2.17±0.00	0.97	3.58
6	-	-	-	-	-	-	82.81±0.00	0.64±0.00	1.00	0.18
7	93.47	0.95	-	-	-	-	93.47±0.00	0.92±0.00	1.00	0.68
8	104.29	0.90	-	-	-	-	104.55±0.00	1.03±0.00	0.99	3.04

- FBG sensors

Mode No.	FDD f [Hz]	FDD MPC [-]	pLSCF f [Hz]	pLSCF ξ [%]	pLSCF MPC [-]	pLSCF MP [°]	SSIcov $f \pm 2\sigma$ [Hz]	SSIcov $\xi \pm 2\sigma$ [Hz]	SSIcov MPC [-]	SSIcov MP [°]
1	-	-	-	-	-	-	34.92±0.65	3.44±1.94	0.70	7.60
2	38.05	0.73	-	-	-	-	38.85±3.96	6.50±7.54	0.92	-1.70
3	-	-	-	-	-	-	40.58±3.94	0.92±13.57	0.97	1.46
4	-	-	-	-	-	-	76.60±2.02	2.15±2.90	0.75	1.04
5	-	-	-	-	-	-	93.87±0.89	1.98±1.59	0.76	-6.47
6	-	-	-	-	-	-	106.23±4.69	2.94±5.30	0.77	3.11
7	-	-	-	-	-	-	137.36±6.30	5.07±2.67	0.99	-2.23
8	-	-	-	-	-	-	140.51±2.73	7.75±1.82	0.99	-1.84
9	-	-	-	-	-	-	143.90±1.08	8.01±0.71	0.92	-1.40

Shaker 29

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
29	P3 (midspan of middle beam)	v	650		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	9.62	8.57	0.99	0.96	-	-	-	-
2	38.67	0.87	38.62	1.70	0.98	-0.41	38.29±0.00	1.84±0.00	0.74	-13.86
3	-	-	41.82	2.24	0.98	0.07	41.14±0.00	1.72±0.00	0.99	1.28
4	-	-	64.48	1.50	0.98	-0.72	64.29±0.00	2.15±0.00	0.98	0.06
5	-	-	-	-	-	-	95.07±0.00	0.54±0.00	0.97	-0.63
6	96.04	0.75	-	-	-	-	95.55±0.00	0.91±0.00	0.95	-0.47
7	-	-	-	-	-	-	97.85±0.00	1.07±0.00	0.97	-1.16
8	104.21	0.83	104.34	0.99	0.93	0.07	104.22±0.00	0.81±0.00	0.99	-0.26

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	38.53	0.97	39.05	2.00	0.98	0.83	38.23±0.00	2.08±0.00	0.71	-1.31
2	-	-	-	-	-	-	41.91±0.00	2.77±0.00	0.97	2.40
3	-	-	-	-	-	-	65.19±0.00	1.69±0.00	0.96	-5.27
4	-	-	-	-	-	-	77.83±0.00	0.82±0.00	0.98	0.99
5	89.57	0.86	-	-	-	-	91.74±0.00	1.86±0.00	0.98	-3.13
6	103.81	0.87	-	-	-	-	104.44±0.00	1.88±0.00	0.98	1.26

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	38.77±1.40	3.37±2.81	0.70	-2.20
2	41.72	0.78	41.64	0.08	0.85	4.65	41.23±1.02	1.84±2.77	1.00	0.21
3	-	-	-	-	-	-	79.01±2.37	1.95±2.13	1.00	-0.02

Shaker 30

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
30	P3 (midspan of middle beam)	v	650		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	38.59	1.64	0.96	-1.29	38.74±0.00	2.11±0.00	0.99	-0.02
2	-	-	41.89	2.17	0.98	0.48	41.06±0.00	1.64±0.00	0.99	1.27
3	-	-	64.59	1.45	0.96	-1.47	64.74±0.00	2.07±0.00	0.97	0.53
4	-	-	-	-	-	-	95.12±0.00	0.46±0.00	0.97	-1.44
5	96.00	0.77	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	97.99±0.00	1.07±0.00	0.96	-1.49
7	103.74	0.86	104.20	1.11	0.95	0.12	104.26±0.00	0.84±0.00	1.00	-0.20

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	38.65	0.98	39.12	2.11	0.99	1.65	38.65±0.00	2.21±0.00	0.97	-2.97
2	-	-	-	-	-	-	41.92±0.00	2.73±0.00	0.97	2.71
3	-	-	-	-	-	-	64.51±0.00	1.93±0.00	0.95	-2.98
4	89.56	0.85	-	-	-	-	-	-	-	-
5	103.69	0.89	-	-	-	-	104.48±0.00	1.86±0.00	0.99	1.14

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	38.81±3.88	3.95±15.36	0.80	-1.26
2	41.55	0.76	41.40	0.68	0.66	5.51	42.35±0.69	2.13±2.07	0.95	-2.88
3	-	-	-	-	-	-	78.36±1.93	2.84±1.93	1.00	-0.15
4	-	-	-	-	-	-	88.56±18.40	4.79±8.22	0.65	-13.35
5	-	-	-	-	-	-	103.83±5.94	4.02±5.18	0.96	-1.13
6	-	-	-	-	-	-	107.54±0.71	1.04±0.78	0.79	1.01

Shaker 31

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
31	P3 (midspan of middle beam)	h	650		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.47	1.00	-	-	-	-	9.55±0.00	1.66±0.00	1.00	0.41
2	-	-	-	-	-	-	38.32±0.00	0.22±0.00	0.97	-3.76

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.47	0.99	9.64	0.46	0.99	-2.64	9.54±0.00	1.54±0.00	0.99	-3.30
2	-	-	-	-	-	-	38.37±0.00	0.71±0.00	0.90	-6.49
3	-	-	-	-	-	-	63.76±0.00	3.04±0.00	0.87	0.78
4	-	-	-	-	-	-	165.64±0.00	5.60±0.00	0.99	-0.06
5	-	-	-	-	-	-	167.71±0.00	6.43±0.00	0.94	0.98

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.69	0.90	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	112.93±10.05	2.97±9.70	0.82	1.23
3	-	-	-	-	-	-	137.86±3.38	6.11±3.58	0.98	0.11
4	-	-	-	-	-	-	140.19±6.81	6.91±9.14	0.77	-1.85
5	-	-	-	-	-	-	141.59±71.57	8.64±28.62	0.94	-0.33

Shaker 32

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
32	P3 (midspan of middle beam)	h	650		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	1.02	10.38	1.00	-0.09	-	-	-	-
2	9.61	1.00	-	-	-	-	9.54±0.00	1.65±0.00	1.00	0.42
3	-	-	-	-	-	-	38.34±0.00	0.29±0.00	0.98	-1.91

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.53	0.99	9.63	0.07	0.99	-1.47	9.54±0.00	1.54±0.00	0.99	-3.33
2	-	-	-	-	-	-	155.77±0.00	9.11±0.00	0.95	2.22

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	9.06±0.33	3.06±4.29	0.60	10.32
2	9.53	0.87	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	116.79±13.56	2.04±8.83	0.52	-22.35
4	-	-	-	-	-	-	136.07±11.41	6.44±10.10	0.57	18.84
5	-	-	-	-	-	-	140.14±4.92	8.04±5.07	0.51	-8.37

Shaker 33

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
33	P3 (midspan of middle beam)	h	500		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.46	1.00	9.52	0.35	1.00	2.10	9.51±0.00	1.65±0.00	1.00	0.39
2	-	-	-	-	-	-	38.12±0.00	0.49±0.00	0.89	-9.59

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.49	0.99	-	-	-	-	9.51±0.00	1.67±0.00	0.99	-3.26

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.34	0.97	-	-	-	-	9.60±1.05	1.99±7.11	0.91	-0.35
2	-	-	-	-	-	-	65.02±11.06	3.16±16.11	0.87	6.28
3	-	-	-	-	-	-	137.94±6.26	5.14±3.85	0.87	-3.89
4	-	-	-	-	-	-	145.00±1.67	8.74±1.33	0.65	-14.92
5	-	-	-	-	-	-	140.89±2.22	8.72±3.23	0.76	2.99

Shaker 34

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
34	P3 (midspan of middle beam)	h	500		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.53	1.00	9.52	0.27	1.00	0.90	9.52±0.00	1.63±0.00	1.00	0.39
2	-	-	-	-	-	-	38.00±0.00	0.39±0.00	0.83	1.74
3	-	-	-	-	-	-	43.48±0.00	4.77±0.00	0.93	1.23
4	-	-	-	-	-	-	48.00±0.00	1.71±0.00	0.95	0.15
5	-	-	-	-	-	-	72.03±0.00	1.98±0.00	0.77	-4.74

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.50	0.99	-	-	-	-	9.52±0.00	1.48±0.00	0.99	-3.38
2	-	-	-	-	-	-	81.34±0.00	3.97±0.00	0.99	0.04

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.26	0.97	-	-	-	-	9.56±0.15	0.91±0.81	0.91	0.84
2	-	-	-	-	-	-	21.55±7.73	8.95±17.50	0.97	-0.94
3	-	-	-	-	-	-	41.04±3.77	4.51±12.44	0.66	-5.75
4	-	-	-	-	-	-	65.46±9.97	3.55±13.13	0.89	5.44
5	-	-	-	-	-	-	119.86±19.53	3.95±13.59	0.76	-2.58
6	-	-	-	-	-	-	137.68±19.31	5.53±12.34	0.58	4.12
7	-	-	-	-	-	-	138.97±5.90	8.41±4.29	0.91	1.21
8	-	-	-	-	-	-	141.36±7.80	8.55±2.99	0.79	10.94
9	-	-	-	-	-	-	143.36±2.72	8.23±1.45	0.78	9.07
10	-	-	-	-	-	-	143.51±6.58	9.01±4.89	0.54	-5.29

Shaker 35

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
35	P3 (midspan of middle beam)	v	500		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	38.69±0.00	1.99±0.00	0.96	-4.67
2	-	-	40.14	2.49	0.98	0.13	40.87±0.00	2.86±0.00	0.97	-1.07
3	-	-	64.49	1.41	0.93	-1.76	64.61±0.00	2.12±0.00	0.99	0.79
4	-	-	-	-	-	-	74.10±0.00	1.24±0.00	0.86	-2.50
5	-	-	-	-	-	-	90.36±0.00	0.81±0.00	0.90	-1.69
6	-	-	-	-	-	-	96.60±0.00	1.15±0.00	0.99	-0.28
7	103.44	0.85	-	-	-	-	103.53±0.00	0.90±0.00	0.98	0.19
8	-	-	-	-	-	-	105.78±0.00	1.39±0.00	0.97	1.91

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	38.52	0.98	39.11	2.14	0.98	2.26	38.66±0.00	2.30±0.00	0.91	-4.17
2	-	-	-	-	-	-	41.30±0.00	1.96±0.00	0.91	0.84
3	-	-	-	-	-	-	64.57±0.00	2.24±0.00	0.95	-1.47
4	94.32	0.87	93.90	1.15	0.87	-7.29	91.43±0.00	1.50±0.00	0.99	-3.32
5	103.17	0.89	-	-	-	-	103.90±0.00	2.05±0.00	0.99	-0.49

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	39.05	0.77	39.05	0.63	0.57	-4.90	38.38±3.30	3.70±9.86	0.87	0.26
2	-	-	-	-	-	-	40.15±1.13	1.87±3.25	0.94	-3.43
3	41.50	0.70	-	-	-	-	40.95±1.21	1.43±3.75	0.93	1.70
4	-	-	-	-	-	-	95.10±4.47	1.29±4.38	0.96	1.21
5	-	-	-	-	-	-	97.22±1.21	1.34±1.31	0.85	-5.74
6	-	-	-	-	-	-	110.00±19.73	2.95±12.82	0.67	9.87
7	-	-	-	-	-	-	139.82±2.72	6.24±3.95	0.74	-7.83

Shaker 36

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
36	P3 (midspan of middle beam)	v	500		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	38.76±0.00	1.83±0.00	0.97	-4.04
2	-	-	39.70	2.38	0.97	0.51	47.05±0.00	1.18±0.00	0.98	-0.49
3	41.21	0.74	-	-	-	-	40.53±0.00	2.54±0.00	0.92	-3.77
4	-	-	-	-	-	-	64.49±0.00	2.16±0.00	0.99	0.11
5	-	-	-	-	-	-	74.95±0.00	1.18±0.00	0.87	-2.42
6	-	-	-	-	-	-	89.52±0.00	0.74±0.00	0.88	-2.65
7	-	-	-	-	-	-	93.96±0.00	0.64±0.00	0.74	0.97
8	-	-	-	-	-	-	94.82±0.00	1.92±0.00	0.93	-5.04
9	-	-	-	-	-	-	96.64±0.00	1.18±0.00	0.99	0.43
10	103.28	0.85	-	-	-	-	103.51±0.00	0.86±0.00	0.98	0.31
11	-	-	-	-	-	-	105.86±0.00	1.36±0.00	0.99	-0.02
12	-	-	-	-	-	-	133.53±0.00	0.44±0.00	0.76	6.11

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	38.41	0.98	38.81	2.16	0.97	-5.27	38.85±0.00	1.91±0.00	0.93	-4.46
2	-	-	-	-	-	-	40.93±0.00	2.15±0.00	0.96	1.55
3	-	-	-	-	-	-	65.18±0.00	1.84±0.00	0.98	-3.50
4	94.07	0.89	94.20	1.19	0.86	-8.04	-	-	-	-
5	102.99	0.91	-	-	-	-	103.84±0.00	2.05±0.00	0.99	-0.45

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	38.99	0.80	39.04	0.58	0.59	-4.65	39.05±0.93	1.82±3.16	0.67	-3.09
2	40.96	0.72	41.00	0.43	0.69	6.13	41.20±0.37	0.84±0.60	0.82	3.53
3	-	-	-	-	-	-	96.05±4.35	2.25±3.40	0.97	2.59

Shaker 37

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
37	P3 (midspan of middle beam)	v	500	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	39.35	0.82	39.15	3.03	0.98	0.43	39.60±0.00	3.30±0.00	0.84	2.64
2	56.74	0.94	-	-	-	-	56.98±0.00	1.25±0.00	0.98	0.61
3	-	-	-	-	-	-	71.52±0.00	1.53±0.00	0.75	-14.89
4	93.89	0.93	-	-	-	-	-	-	-	-
5	104.11	0.88	-	-	-	-	103.88±0.00	0.93±0.00	0.97	-1.12

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	36.26±0.00	3.61±0.00	0.87	-2.34
2	39.31	0.71	38.31	2.63	0.91	-0.79	47.14±0.00	4.56±0.00	0.88	-4.32
3	56.85	0.93	-	-	-	-	56.86±0.00	1.31±0.00	0.99	-1.42
4	-	-	-	-	-	-	74.92±0.00	3.21±0.00	0.95	-5.41
5	94.15	0.97	93.76	1.21	0.91	-4.71	95.84±0.00	2.18±0.00	0.98	2.50
6	103.68	0.91	-	-	-	-	103.79±0.00	0.94±0.00	1.00	0.31

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	36.25±2.04	3.58±4.29	0.72	-0.61
2	40.72	0.93	-	-	-	-	41.13±0.45	1.12±0.92	1.00	0.90
3	93.78	0.95	94.97	0.14	0.87	-9.91	93.79±9.84	1.41±9.72	0.85	-6.17

Shaker 38

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
38	P3 (midspan of middle beam)	v	500	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	36.26±0.00	2.97±0.00	0.78	-15.78
2	39.48	0.82	39.32	3.15	0.97	1.38	39.59±0.00	3.21±0.00	0.86	2.75
3	57.04	0.96	56.93	1.20	0.99	0.94	56.99±0.00	1.25±0.00	0.98	0.74
4	-	-	-	-	-	-	71.54±0.00	1.59±0.00	0.77	-13.56
5	-	-	-	-	-	-	75.63±0.00	1.52±0.00	0.93	-0.48
6	93.70	0.90	-	-	-	-	-	-	-	-
7	103.93	0.88	103.94	0.86	0.88	-1.87	103.92±0.00	0.95±0.00	0.98	-1.28

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	38.20	2.43	0.89	-2.77	36.26±0.00	3.00±0.00	0.92	-3.05
2	56.80	0.94	-	-	-	-	56.84±0.00	1.27±0.00	0.99	-1.47
3	94.06	0.97	93.93	1.18	0.90	-3.11	-	-	-	-
4	103.47	0.94	-	-	-	-	103.79±0.00	0.93±0.00	1.00	0.47

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	18.44±6.05	5.59±29.75	0.64	18.66
2	-	-	-	-	-	-	36.53±2.53	3.12±6.41	0.72	1.72
3	-	-	-	-	-	-	41.04±0.39	0.96±0.95	1.00	0.85
4	-	-	-	-	-	-	71.93±26.08	6.01±31.22	0.76	-4.95
5	-	-	-	-	-	-	84.11±7.42	4.83±14.44	0.96	-4.11
6	94.21	0.70	94.70	0.24	0.80	-8.41	93.90±0.65	2.14±1.23	0.84	-7.33

Shaker 39

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
39	P3 (midspan of middle beam)	h	500	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	1.00	-	-	-	-	8.57±0.00	1.77±0.00	1.00	-1.03

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.62	0.99	8.48	0.29	0.98	-2.43	8.53±0.00	2.02±0.00	0.99	-3.05
2	-	-	-	-	-	-	69.15±0.00	1.61±0.00	1.00	0.01

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.09	0.89	-	-	-	-	-	-	-	-

Shaker 40

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
40	P3 (midspan of middle beam)	h	500	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.59	1.00	8.53	1.05	1.00	0.76	8.57±0.00	1.54±0.00	1.00	-0.44

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.45	0.99	8.67	0.78	0.99	1.35	8.93±0.00	2.09±0.00	0.99	-0.05
2	-	-	-	-	-	-	109.61±0.00	7.10±0.00	0.84	0.32

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.09	0.97	-	-	-	-	-	-	-	-
2	8.31	0.79	-	-	-	-	8.50±0.08	0.70±0.54	0.65	1.66
3	-	-	-	-	-	-	81.73±10.16	3.24±18.13	0.60	19.10
4	-	-	-	-	-	-	136.62±17.61	6.48±10.91	0.99	0.31
5	-	-	-	-	-	-	139.51±4.89	7.48±2.10	0.96	0.78
6	-	-	-	-	-	-	142.45±4.11	7.75±1.17	0.98	-2.77

Shaker 41

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
41	P3 (midspan of middle beam)	h	400	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.52	1.00	8.47	1.85	1.00	0.95	8.53±0.00	1.59±0.00	1.00	-0.39
2	-	-	-	-	-	-	46.44±0.00	1.83±0.00	0.99	-0.29
3	-	-	-	-	-	-	70.16±0.00	2.96±0.00	0.91	5.39

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.60	0.99	-	-	-	-	8.61±0.00	2.01±0.00	0.99	-3.06

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	45.41±5.12	5.79±22.43	0.66	-6.26
2	-	-	-	-	-	-	96.58±35.45	4.15±24.93	0.53	13.82
3	-	-	-	-	-	-	139.83±13.28	5.85±10.14	0.63	-0.52
4	-	-	-	-	-	-	141.13±10.42	8.82±4.08	0.59	-0.15
5	-	-	-	-	-	-	141.86±2.92	8.49±3.83	0.58	-9.18

Shaker 42

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
42	P3 (midspan of middle beam)	h	400	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.51	1.00	8.50	1.30	1.00	0.54	8.40±0.00	1.73±0.00	1.00	1.07

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.55	0.99	-	-	-	-	8.67±0.00	1.93±0.00	0.99	0.58
2	-	-	-	-	-	-	58.02±0.00	5.53±0.00	0.99	0.01
3	-	-	-	-	-	-	167.27±0.00	12.50±0.00	0.98	0.21

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	8.61±0.10	0.80±1.86	0.53	-4.76
2	-	-	-	-	-	-	71.60±0.87	0.72±1.11	0.55	7.14
3	-	-	-	-	-	-	82.39±21.81	4.90±19.30	0.58	-9.51
4	-	-	-	-	-	-	103.27±6.19	1.45±4.69	0.58	-3.24
5	-	-	-	-	-	-	137.80±13.47	6.76±10.51	0.57	10.96
6	-	-	-	-	-	-	138.90±4.97	5.72±3.83	0.59	13.47
7	-	-	-	-	-	-	140.03±14.78	7.88±18.86	0.59	-0.07

Shaker 43

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
43	P3 (midspan of middle beam)	v	400	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	-	-	-	-	36.54±0.00	1.82±0.00	0.95	1.42
2	42.32	0.97	-	-	-	-	40.05±0.00	5.16±0.00	0.97	-1.32
3	55.91	0.91	-	-	-	-	56.37±0.00	1.20±0.00	0.99	0.97
4	-	-	-	-	-	-	91.96±0.00	0.68±0.00	0.73	13.19
5	92.22	0.85	92.39	0.93	0.86	-1.02	-	-	-	-
6	-	-	-	-	-	-	96.54±0.00	0.75±0.00	0.99	-1.32
7	103.59	0.84	103.65	1.15	0.83	-0.90	103.45±0.00	0.90±0.00	0.97	-1.70

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	36.23	0.96	38.55	2.54	0.89	-1.50	36.66±0.00	1.76±0.00	0.94	-2.91
2	55.99	0.90	56.43	1.13	0.89	1.30	56.35±0.00	1.12±0.00	0.99	-0.20
3	91.50	0.82	92.45	1.28	0.92	-3.10	92.41±0.00	1.23±0.00	0.93	-4.31
4	103.13	0.92	-	-	-	-	103.72±0.00	1.20±0.00	0.98	0.59

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	36.35	0.71	-	-	-	-	36.37±2.36	1.61±5.52	0.63	-0.42
2	40.76	0.96	-	-	-	-	41.45±14.46	5.91±33.66	0.99	-0.69
3	-	-	-	-	-	-	79.44±2.36	1.30±4.45	0.97	-0.79
4	-	-	-	-	-	-	92.52±3.38	1.34±2.90	0.83	-10.10

Shaker 44

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
44	P3 (midspan of middle beam)	v	400	x	

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	37.57	0.45	0.98	2.08	36.61±0.00	1.78±0.00	0.94	1.47
2	42.50	0.97	40.00	3.07	0.98	-0.78	-	-	-	-
3	56.26	0.92	56.40	1.05	0.97	-0.94	56.37±0.00	1.20±0.00	0.99	1.02
4	-	-	71.50	0.68	0.91	2.81	-	-	-	-
5	92.33	0.86	92.59	0.98	0.90	2.17	-	-	-	-
6	103.49	0.84	103.59	0.98	0.85	-1.74	-	-	-	-

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	36.31	0.94	-	-	-	-	36.68±0.00	1.82±0.00	0.95	-3.33
2	-	-	-	-	-	-	38.39±0.00	2.47±0.00	0.98	1.01
3	-	-	-	-	-	-	51.84±0.00	3.38±0.00	0.82	7.87
4	56.26	0.91	-	-	-	-	56.35±0.00	1.11±0.00	0.99	-0.22
5	-	-	-	-	-	-	71.36±0.00	3.14±0.00	0.96	-3.20
6	92.46	0.89	92.47	1.25	0.94	-4.02	93.42±0.00	1.18±0.00	0.99	2.13
7	103.57	0.88	-	-	-	-	103.35±0.00	1.30±0.00	0.99	0.44

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	36.37	0.94	-	-	-	-	36.84±1.65	2.35±5.36	0.56	-1.31
2	39.38	0.91	-	-	-	-	41.20±6.23	2.12±5.49	0.99	-1.22
3	92.61	0.85	-	-	-	-	92.49±0.49	1.33±0.66	0.78	-12.77

Shaker 45

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
45	P3 (midspan of middle beam)	v	400		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	37.87	0.77	37.97	2.96	0.99	0.26	38.19±0.00	2.68±0.00	0.95	1.77
2	-	-	-	-	-	-	39.58±0.00	1.96±0.00	0.98	1.96
3	44.51	0.87	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	61.68±0.00	1.57±0.00	0.96	2.94
5	63.97	0.75	-	-	-	-	64.10±0.00	1.47±0.00	0.95	-1.57
6	-	-	-	-	-	-	84.21±0.00	1.42±0.00	0.86	-3.41
7	93.81	0.84	93.96	0.90	0.83	-1.73	93.85±0.00	1.10±0.00	0.96	-3.34
8	-	-	-	-	-	-	95.84±0.00	1.65±0.00	0.84	12.37
9	103.87	0.79	104.13	1.20	0.88	-0.61	103.86±0.00	1.07±0.00	0.98	0.46
10	-	-	-	-	-	-	118.48±0.00	0.35±0.00	0.95	0.39
11	-	-	-	-	-	-	131.89±0.00	0.37±0.00	0.90	-2.35

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	37.91	0.85	38.43	2.21	0.94	0.40	37.86±0.00	2.52±0.00	0.93	-4.63
2	-	-	-	-	-	-	39.93±0.00	2.48±0.00	0.99	0.77
3	-	-	-	-	-	-	63.23±0.00	2.36±0.00	0.87	-7.47
4	-	-	-	-	-	-	84.96±0.00	1.98±0.00	0.98	-1.37
5	93.85	0.97	-	-	-	-	93.83±0.00	1.11±0.00	0.99	2.65
6	-	-	-	-	-	-	95.39±0.00	1.55±0.00	0.86	3.96
7	-	-	-	-	-	-	104.96±0.00	2.16±0.00	0.98	-1.48

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	38.13	0.88	-	-	-	-	37.58±2.01	3.72±4.55	0.90	0.90
2	-	-	-	-	-	-	44.66±1.42	4.70±3.18	0.96	6.60
3	-	-	-	-	-	-	64.23±8.14	1.84±14.16	0.87	9.52
4	-	-	-	-	-	-	80.63±1.71	2.40±1.36	0.93	0.71
5	93.40	0.77	-	-	-	-	93.83±0.72	1.31±0.74	0.88	-8.90
6	-	-	-	-	-	-	136.51±5.29	5.86±2.89	0.62	-0.56
7	-	-	-	-	-	-	138.18±5.09	4.69±3.06	0.98	-0.04
8	-	-	-	-	-	-	139.80±16.16	8.31±3.18	0.60	-3.50

Shaker 46

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
46	P3 (midspan of middle beam)	v	400		x

- Acceleration sensors

Mode No.	FDD f [Hz]	FDD MPC [-]	pLSCF f [Hz]	pLSCF ξ [%]	pLSCF MPC [-]	pLSCF MP [°]	SSIcov $f \pm 2\sigma$ [Hz]	SSIcov $\xi \pm 2\sigma$ [Hz]	SSIcov MPC [-]	SSIcov MP [°]
1	37.93	0.82	38.33	3.04	0.93	1.15	38.21±0.00	2.53±0.00	0.96	2.45
2	44.52	0.80	-	-	-	-	43.06±0.00	4.18±0.00	0.81	-4.68
3	-	-	-	-	-	-	61.71±0.00	1.53±0.00	0.95	3.41
4	-	-	-	-	-	-	64.12±0.00	1.35±0.00	0.94	-1.50
5	-	-	-	-	-	-	84.45±0.00	1.49±0.00	0.86	-3.77
6	93.95	0.89	-	-	-	-	93.84±0.00	1.16±0.00	0.98	-3.50
7	-	-	-	-	-	-	95.75±0.00	1.59±0.00	0.77	12.34
8	103.91	0.79	-	-	-	-	103.83±0.00	1.02±0.00	0.98	-1.15
9	-	-	-	-	-	-	118.63±0.00	0.32±0.00	0.94	-0.33
10	-	-	-	-	-	-	132.31±0.00	0.36±0.00	0.88	-2.65

- Tilt sensors

Mode No.	FDD f [Hz]	FDD MPC [-]	pLSCF f [Hz]	pLSCF ξ [%]	pLSCF MPC [-]	pLSCF MP [°]	SSIcov $f \pm 2\sigma$ [Hz]	SSIcov $\xi \pm 2\sigma$ [Hz]	SSIcov MPC [-]	SSIcov MP [°]
1	37.97	0.86	-	-	-	-	38.10±0.00	2.54±0.00	0.91	-7.36
2	-	-	-	-	-	-	39.72±0.00	3.19±0.00	0.96	3.27
3	-	-	-	-	-	-	51.31±0.00	2.56±0.00	0.93	3.70
4	-	-	-	-	-	-	63.35±0.00	2.29±0.00	0.87	-8.00
5	-	-	-	-	-	-	84.75±0.00	2.14±0.00	0.98	-1.55
6	94.06	0.97	94.07	0.84	0.93	-4.86	93.93±0.00	1.18±0.00	1.00	1.70
7	-	-	-	-	-	-	95.58±0.00	1.38±0.00	0.91	2.53
8	-	-	-	-	-	-	104.65±0.00	2.27±0.00	0.97	-1.43

- FBG sensors

Mode No.	FDD f [Hz]	FDD MPC [-]	pLSCF f [Hz]	pLSCF ξ [%]	pLSCF MPC [-]	pLSCF MP [°]	SSIcov $f \pm 2\sigma$ [Hz]	SSIcov $\xi \pm 2\sigma$ [Hz]	SSIcov MPC [-]	SSIcov MP [°]
1	40.46	0.82	-	-	-	-	38.03±1.38	5.00±3.47	0.85	1.01
2	-	-	-	-	-	-	43.84±1.36	3.57±2.79	1.00	0.05
3	-	-	-	-	-	-	79.37±1.77	2.49±2.17	0.92	-0.26
4	-	-	-	-	-	-	102.83±3.53	3.22±2.84	0.61	-8.54

Shaker 47

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
47	P3 (midspan of middle beam)	h	400		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.50	1.00	9.46	0.25	0.99	1.97	9.51±0.00	1.57±0.00	1.00	0.40

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.55	0.99	9.57	0.86	1.00	-2.97	9.51±0.00	1.48±0.00	0.99	-3.18
2	-	-	-	-	-	-	171.25±0.00	14.55±0.00	0.99	0.09

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.91	0.82	-	-	-	-	-	-	-	-
2	9.69	0.98	-	-	-	-	9.60±0.20	0.95±2.25	0.89	2.92
3	-	-	-	-	-	-	71.64±5.05	0.93±5.02	0.56	18.28
4	-	-	-	-	-	-	108.53±4.42	0.61±2.39	0.67	0.94
5	-	-	-	-	-	-	137.83±11.91	7.50±16.28	0.69	4.25
6	-	-	-	-	-	-	137.87±18.33	5.64±12.34	0.83	1.78
7	-	-	-	-	-	-	138.22±20.67	9.47±16.59	0.95	-1.81
8	-	-	-	-	-	-	143.74±1.40	8.47±1.04	1.00	-0.49
9	-	-	-	-	-	-	143.93±1.44	8.12±1.11	0.88	-7.94

Shaker 48

Test	Position	Orientation	P_0	Columns	
No.		vert/hor	[kN]	pinned	fixed
48	P3 (midspan of middle beam)	h	400		x

- Acceleration sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.49	1.00	9.43	0.36	1.00	0.03	9.51±0.00	1.57±0.00	1.00	0.38

- Tilt sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.48	0.99	-	-	-	-	9.50±0.00	1.49±0.00	0.99	-3.17

- FBG sensors

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.96	0.79	-	-	-	-	-	-	-	-
2	9.69	0.91	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	71.38±10.04	1.23±15.79	0.80	0.70
4	-	-	-	-	-	-	138.54±3.09	4.64±2.13	0.98	-3.31

5.2.3 Combinations of results for the six different structural systems

In what follows, the previous test results are combined according to the procedure described in chapter 4, section 4.2.1. The results are attributed to the six structural systems as defined in chapter 3, section 3.3.

System 1

Tab. 5.1: System 1 - Acceleration results

Mode No.	f_{mean} [Hz]	f_{COV} [-]	ξ_{mean} [%]	ξ_{COV} [-]	$MAC_{quality}$	$N_{samples}$
1	9.55	0.008	1.77	0.568	0.99	24
2	37.89	0.007	3.31	0.317	0.94	12
3	39.52	0.040	2.58	0.564	0.78	18
4	43.41	0.025	2.03	0.452	0.78	14
6	84.19	0.013	1.75	0.403	0.89	10
8	94.65	0.008	1.10	0.216	0.80	10
9	96.07	0.007	0.95	0.438	0.71	7
10	103.92	0.007	1.19	0.506	0.79	23

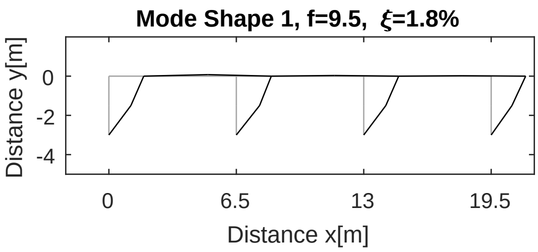
Tab. 5.2: System 1 - Tilt results

Mode No.	f_{mean} [Hz]	f_{COV} [-]	ξ_{mean} [%]	ξ_{COV} [-]	$MAC_{quality}$	$N_{samples}$
1	9.52	0.012	2.33	0.604	0.99	28
2	38.61	0.035	3.24	0.402	0.93	10
3	39.59	0.046	2.32	0.486	0.76	17
6	81.82	0.034	2.01	0.167	0.86	9
7	92.53	0.015	1.57	0.522	0.90	29
10	105.70	0.008	2.10	0.169	0.87	8

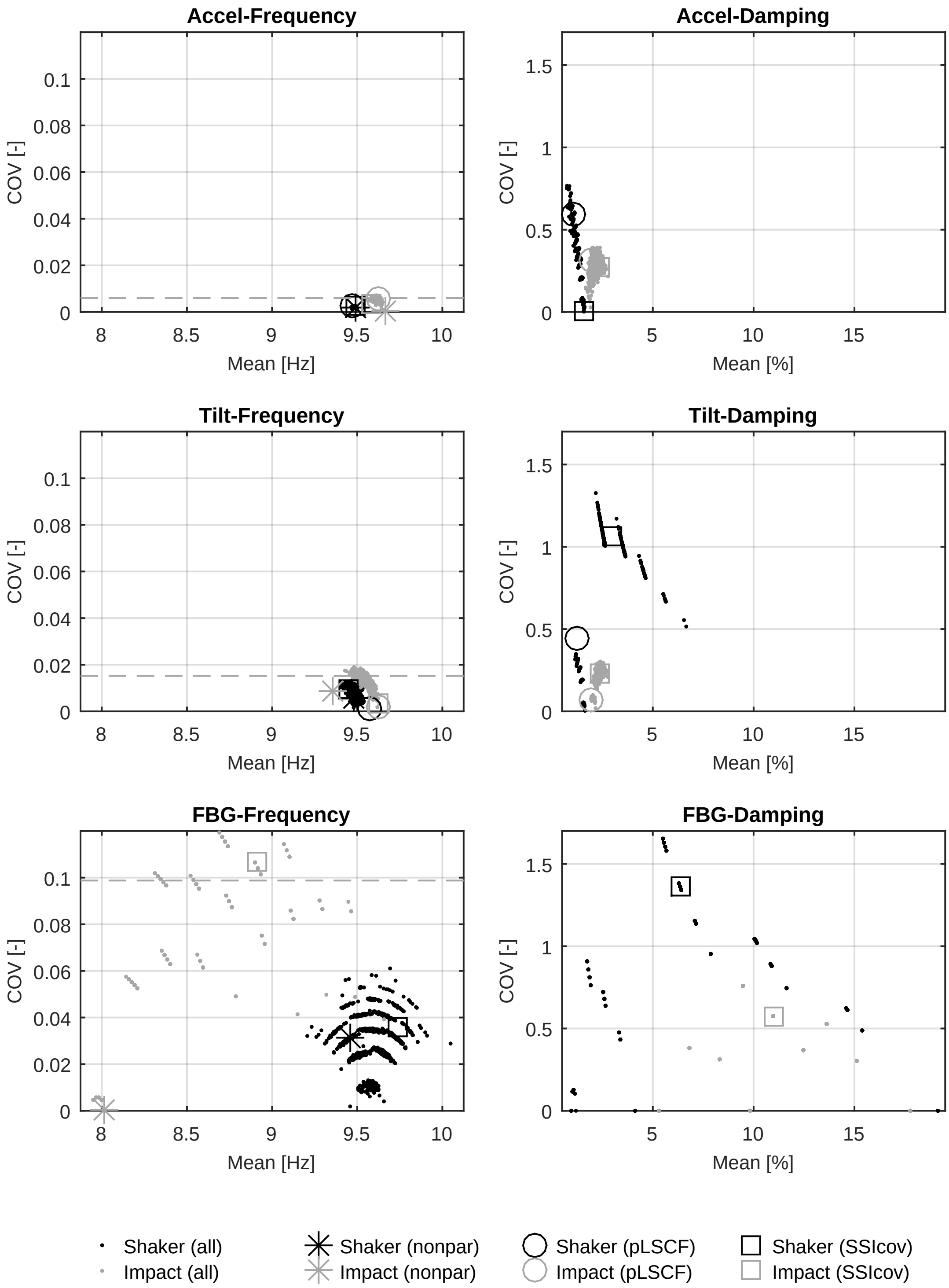
Tab. 5.3: System 1 - FBG results

Mode No.	f_{mean} [Hz]	f_{COV} [-]	ξ_{mean} [%]	ξ_{COV} [-]	$MAC_{quality}$	$N_{samples}$
1	9.21	0.076	8.39	0.814	0.71	14
3	40.31	0.048	3.39	0.733	0.77	16
5	73.29	0.022	1.25	0.442	0.78	8
11	139.51	0.019	7.56	0.208	0.71	7

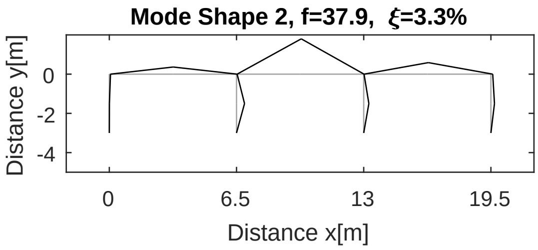
System 1 - Mode 1



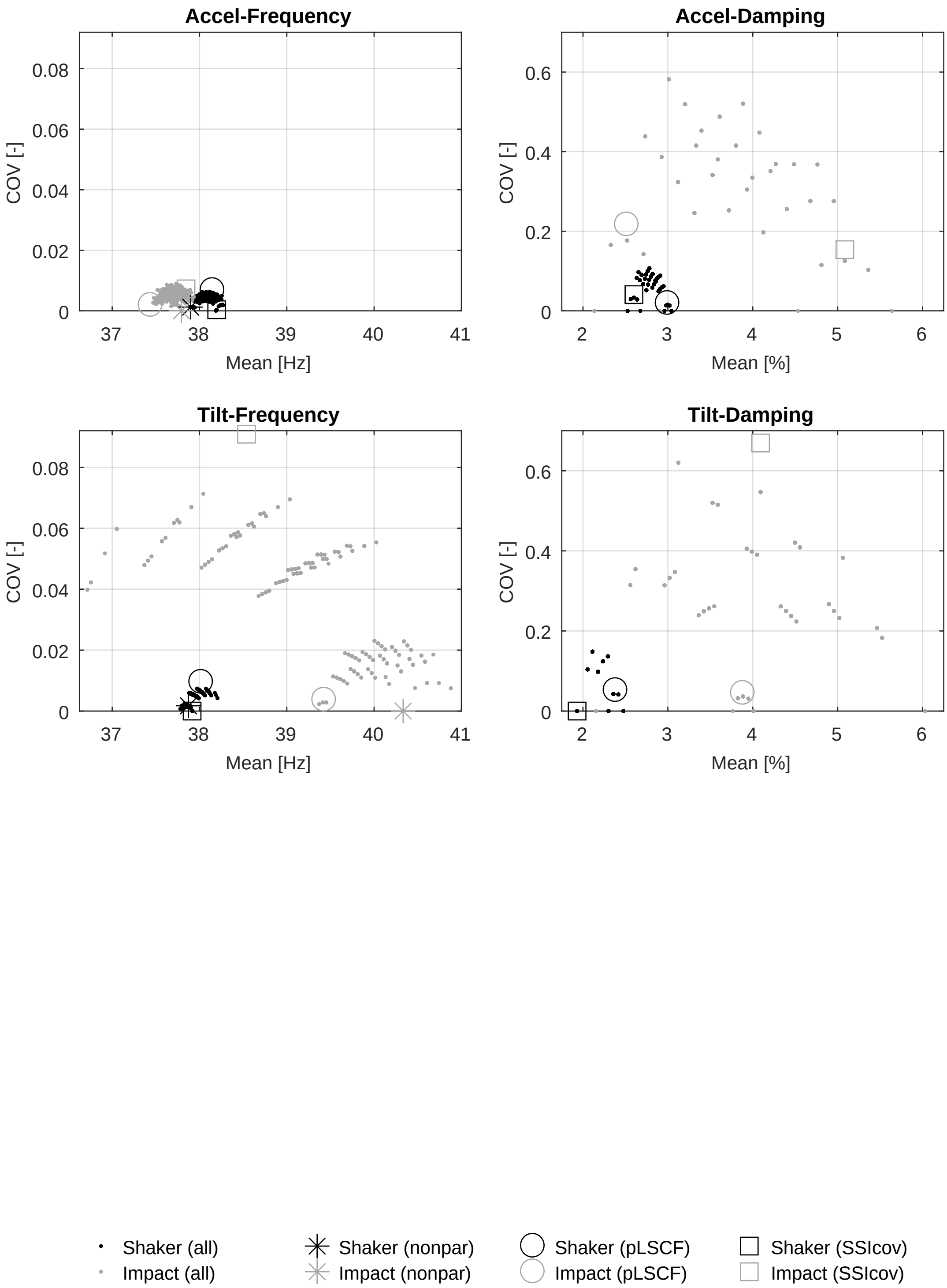
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.99	8	6	10
Tilt	0.99	9	6	13
FBG	0.71	7	-	7



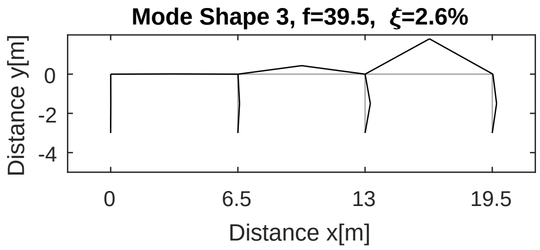
System 1 - Mode 2



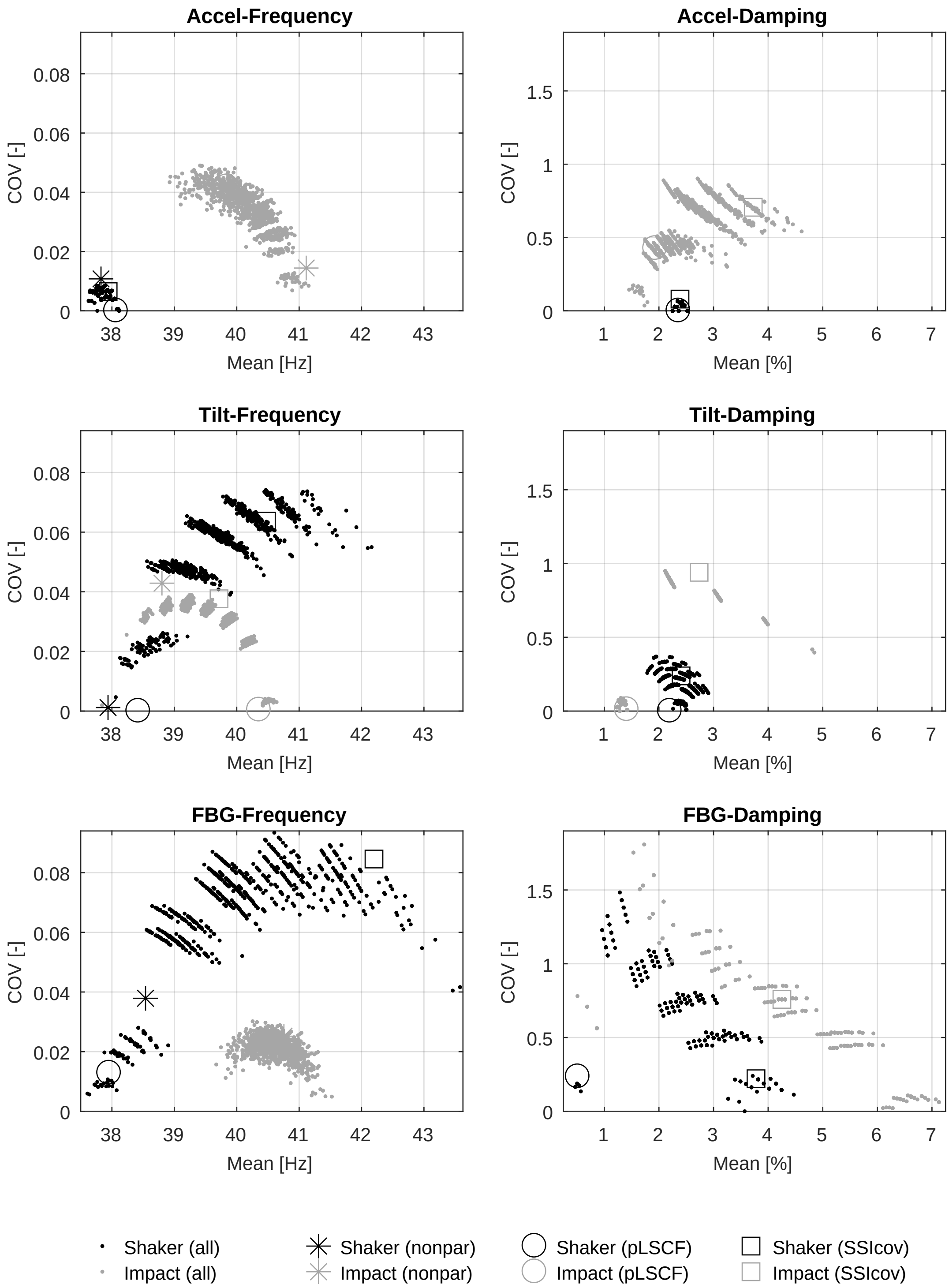
Sensor	$\text{MAC}_{\text{quality}}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.94	4	4	4
Tilt	0.93	3	4	3
FBG	-	-	-	-



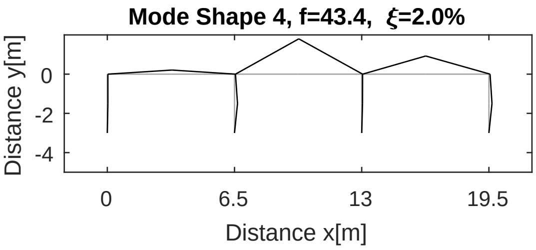
System 1 - Mode 3



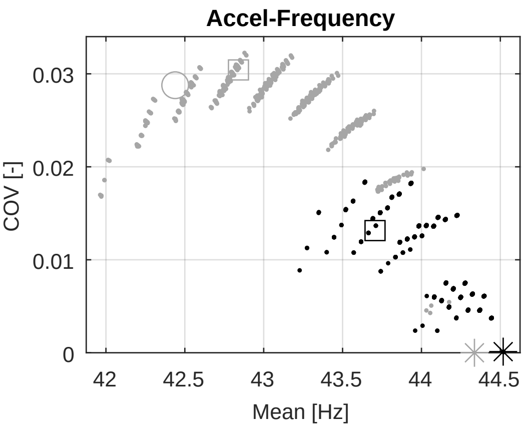
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.78	5	7	8
Tilt	0.76	5	3	9
FBG	0.77	6	2	8

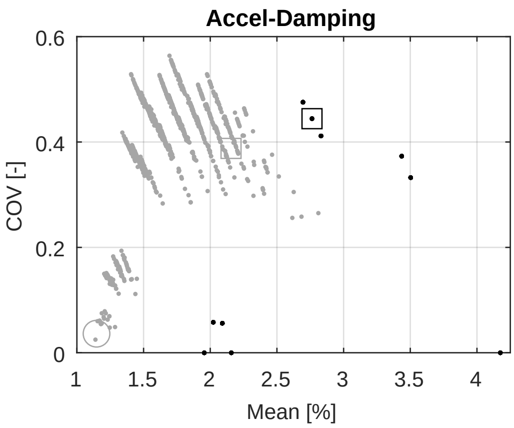


System 1 - Mode 4



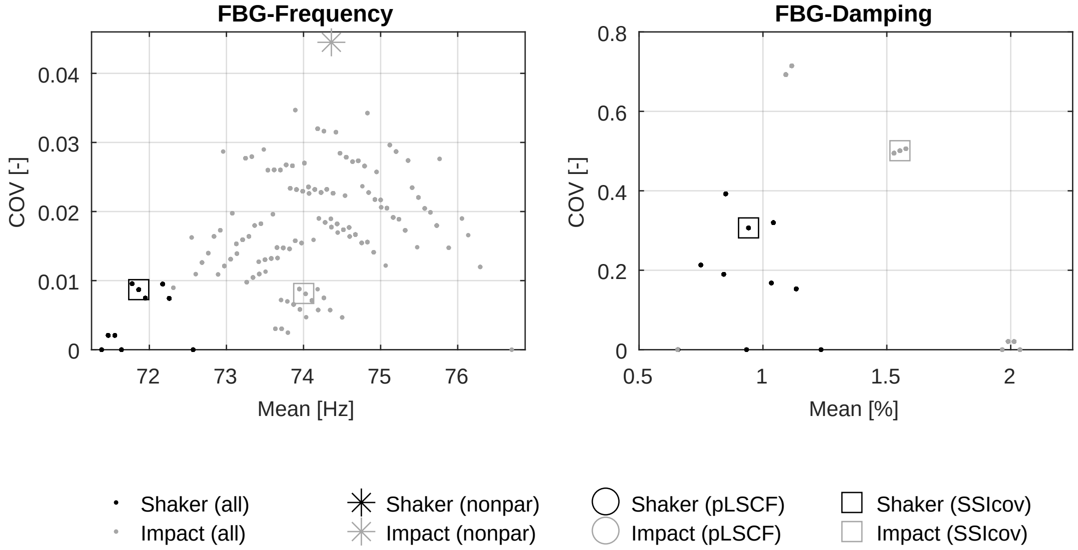
Sensor	$\text{MAC}_{\text{quality}}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.78	4	3	7
Tilt	-	-	-	-
FBG	-	-	-	-



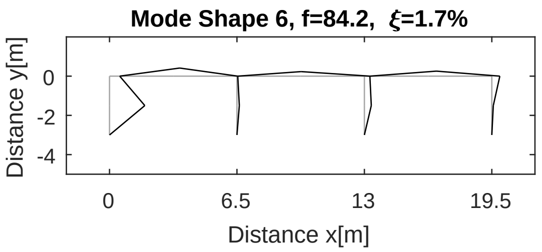


System 1 - Mode 5

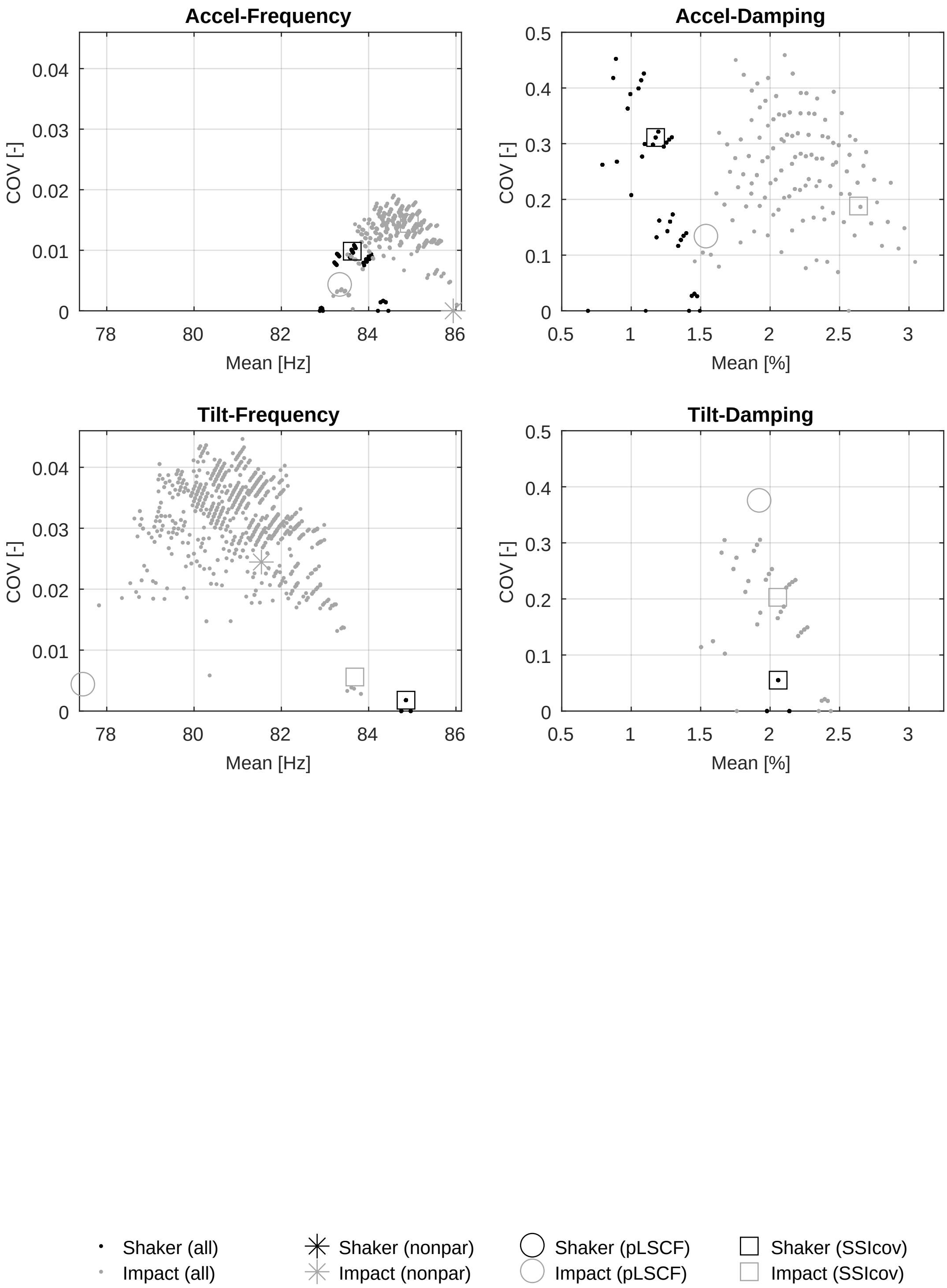
Sensor	$\mathrm{MAC}_{\mathrm{quality}}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	-	-	-	-
Tilt	-	-	-	-
FBG	0.78	2	-	6



System 1 - Mode 6

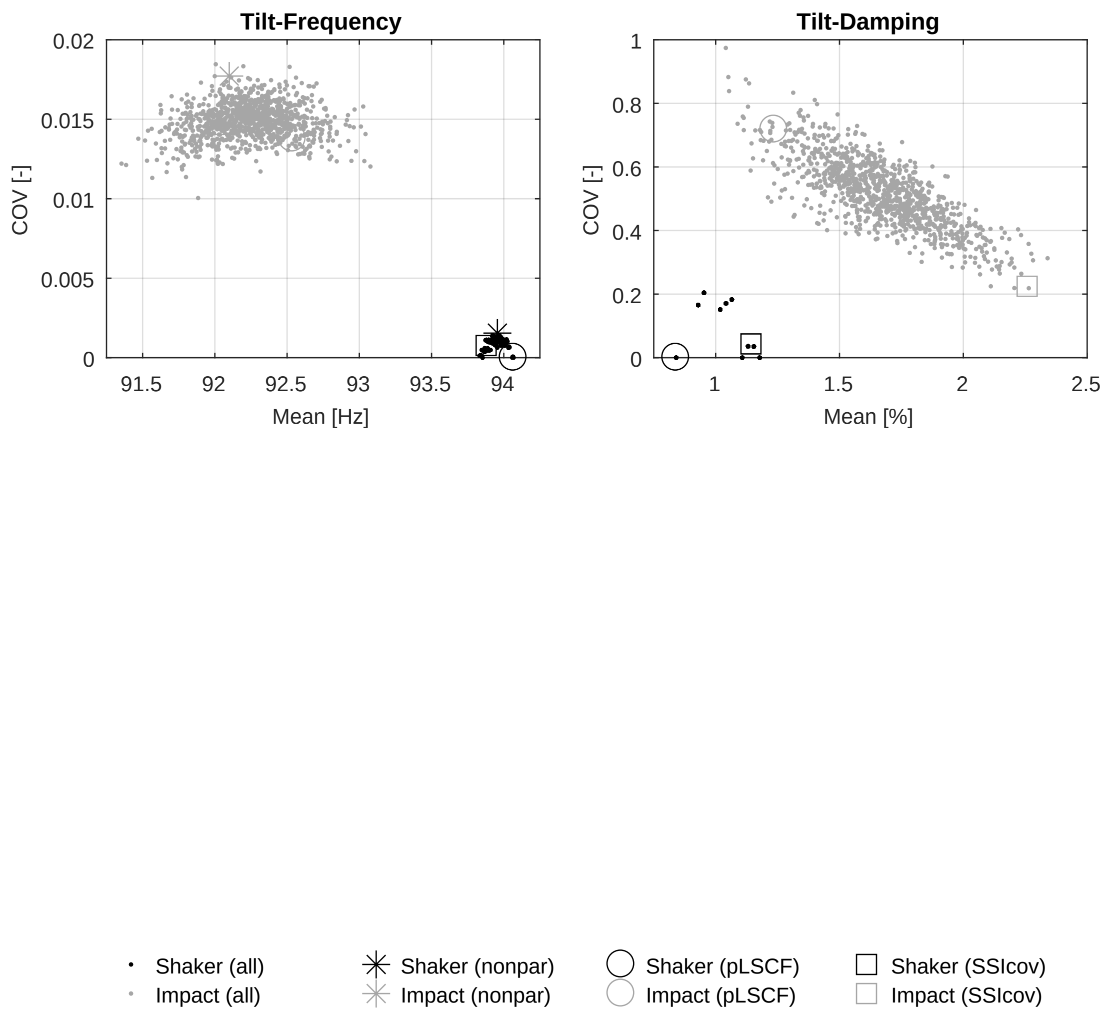


Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.89	1	2	7
Tilt	0.86	3	2	4
FBG	-	-	-	-

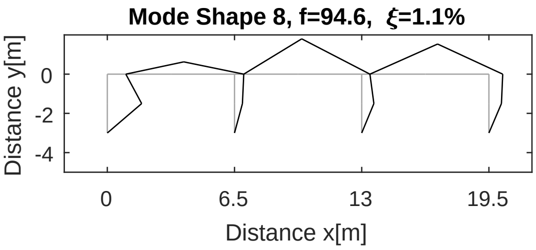


System 1 - Mode 7

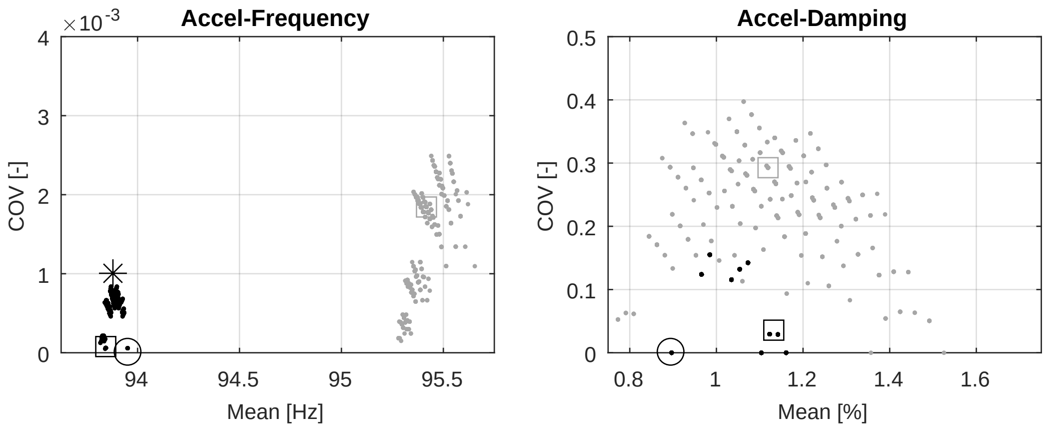
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	-	-	-	-
Tilt	0.90	12	9	8
FBG	-	-	-	-

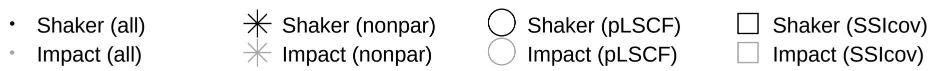


System 1 - Mode 8

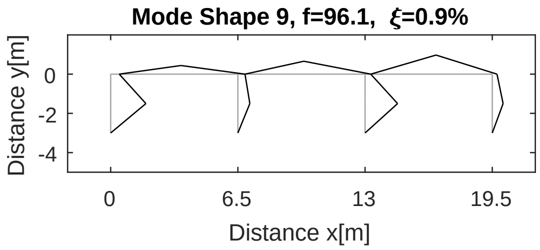


Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.80	2	1	7
Tilt	-	-	-	-
FBG	-	-	-	-

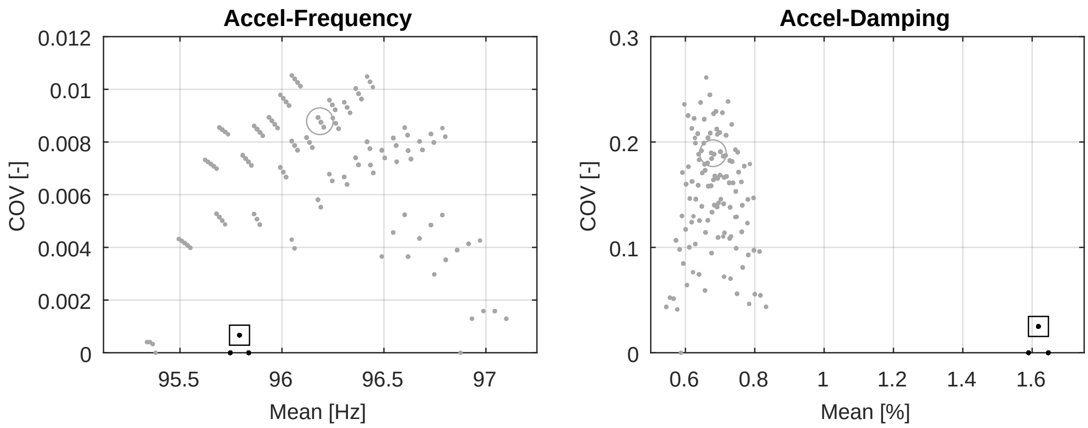


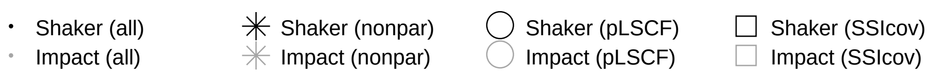


System 1 - Mode 9

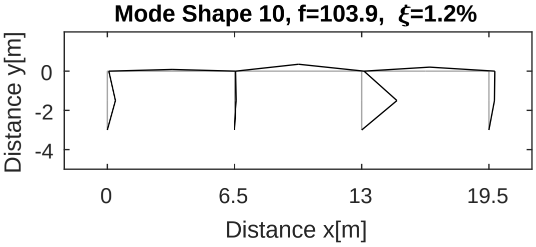


Sensor	$\mathrm{MAC}_{\mathrm{quality}}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.71	-	5	2
Tilt	-	-	-	-
FBG	-	-	-	-

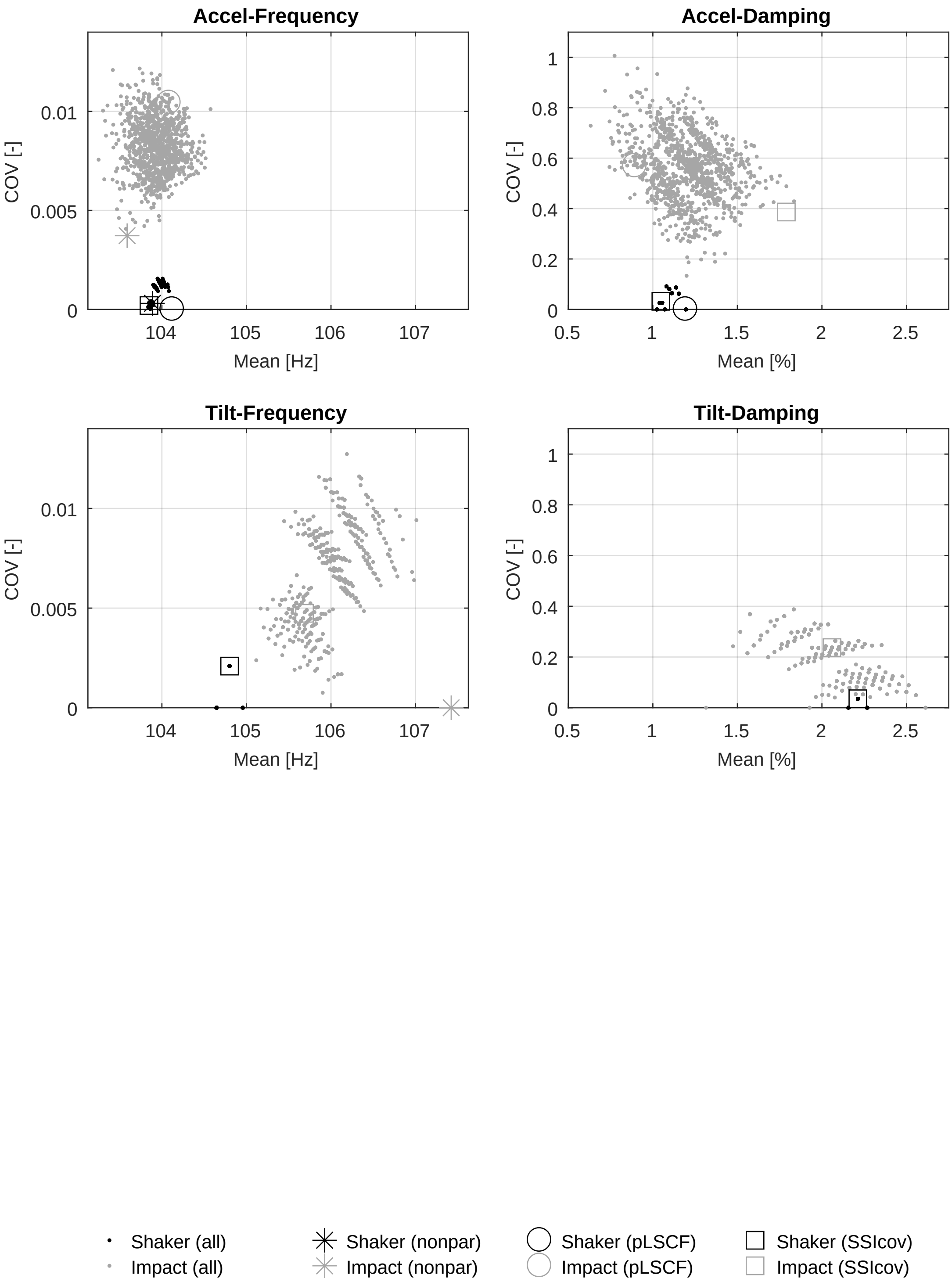




System 1 - Mode 10

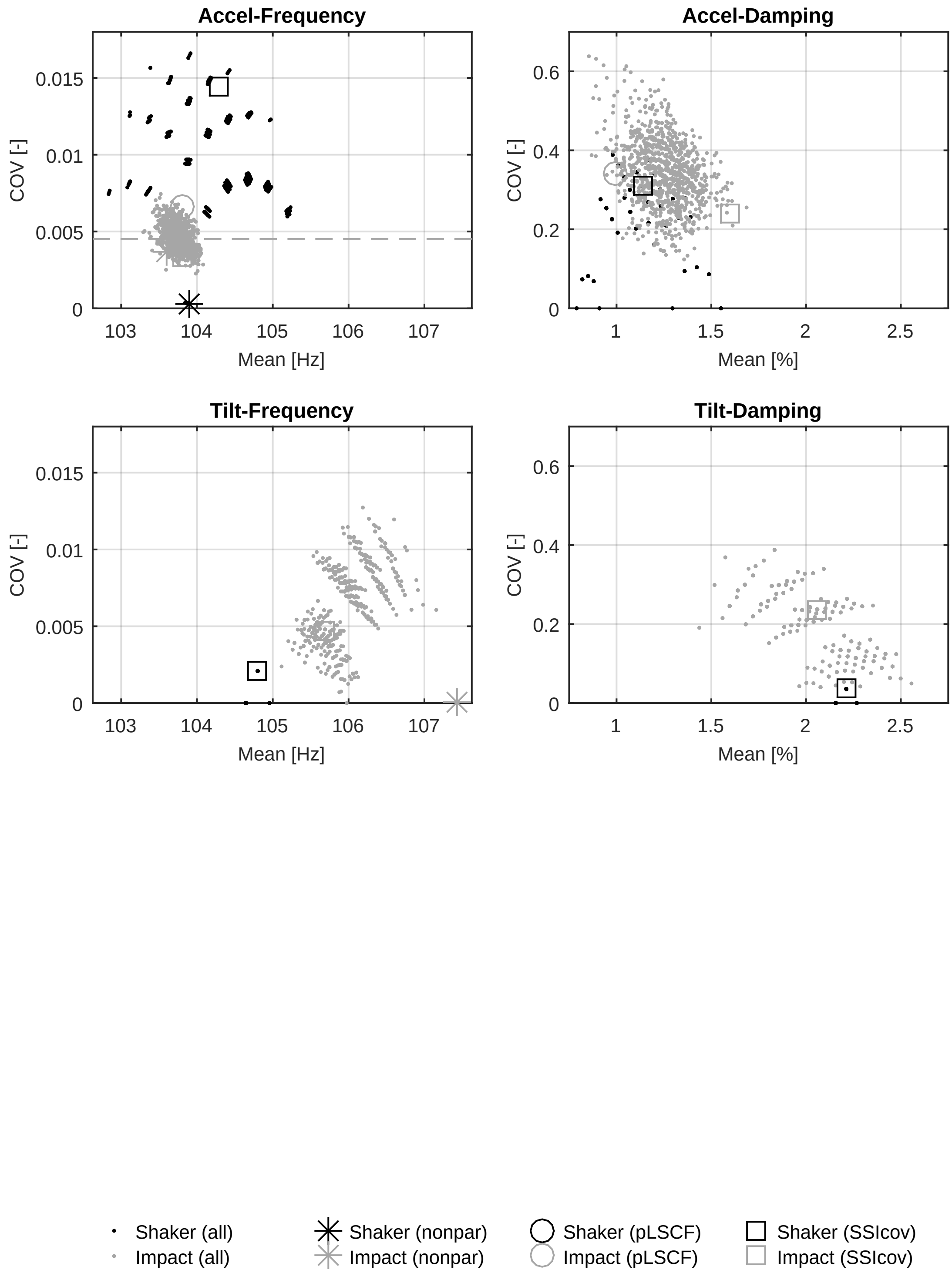


Sensor	$\text{MAC}_{\text{quality}}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.79	6	10	7
Tilt	0.87	1	-	7
FBG	-	-	-	-



System 1 - Mode 11

Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	-	10	10	7
Tilt	-	2	1	5
FBG	0.71	1	-	6



System 2

Tab. 5.4: System 2 - Acceleration results

Mode No.	f_{mean} [Hz]	f_{COV} [-]	ξ_{mean} [%]	ξ_{COV} [-]	$\text{MAC}_{\text{quality}}$	N_{samples}
1	8.54	0.005	1.56	0.147	0.97	22
2	36.53	0.021	2.20	0.585	0.89	21
3	42.05	0.003	1.38	0.229	0.97	14
4	56.32	0.003	1.40	0.139	0.97	17
5	68.75	0.022	1.90	0.312	0.91	13
6	92.45	0.004	0.87	0.214	0.91	24
7	96.68	0.002	0.89	0.260	0.87	19
8	103.57	0.002	1.14	0.231	0.91	27

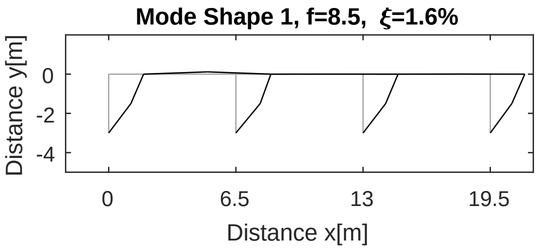
Tab. 5.5: System 2 - Tilt results

Mode No.	f_{mean} [Hz]	f_{COV} [-]	ξ_{mean} [%]	ξ_{COV} [-]	$\text{MAC}_{\text{quality}}$	N_{samples}
1	8.57	0.007	1.93	0.306	0.99	31
2	36.28	0.017	2.88	0.664	0.88	17
3	41.15	0.010	1.96	0.154	0.93	12
4	56.30	0.003	1.16	0.205	0.94	13
6	91.65	0.012	1.44	0.491	0.88	40
8	103.19	0.003	1.23	0.266	0.96	8
9	155.54	0.004	1.17	0.203	0.94	17

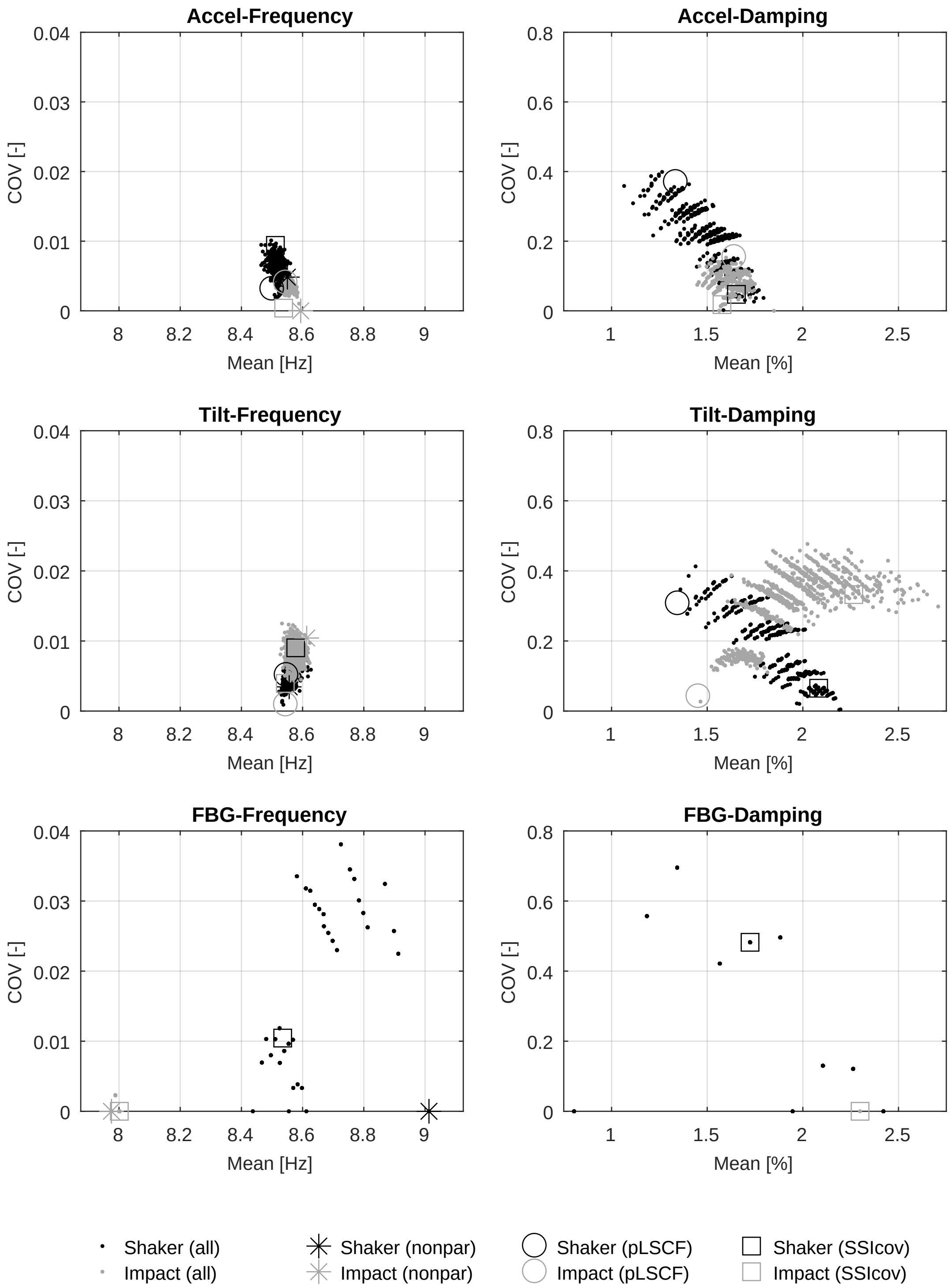
Tab. 5.6: System 2 - FBG results

Mode No.	f_{mean} [Hz]	f_{COV} [-]	ξ_{mean} [%]	ξ_{COV} [-]	$\text{MAC}_{\text{quality}}$	N_{samples}
1	8.43	0.041	1.88	0.307	0.76	6
2	36.33	0.015	2.12	0.495	0.88	13
3	40.42	0.019	2.23	0.787	0.83	11
5	72.49	0.014	1.30	0.657	0.71	7
6	92.52	0.001	1.48	0.109	0.83	6

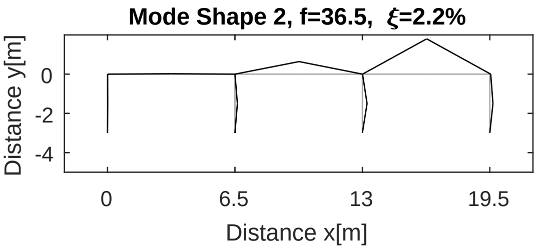
System 2 - Mode 1



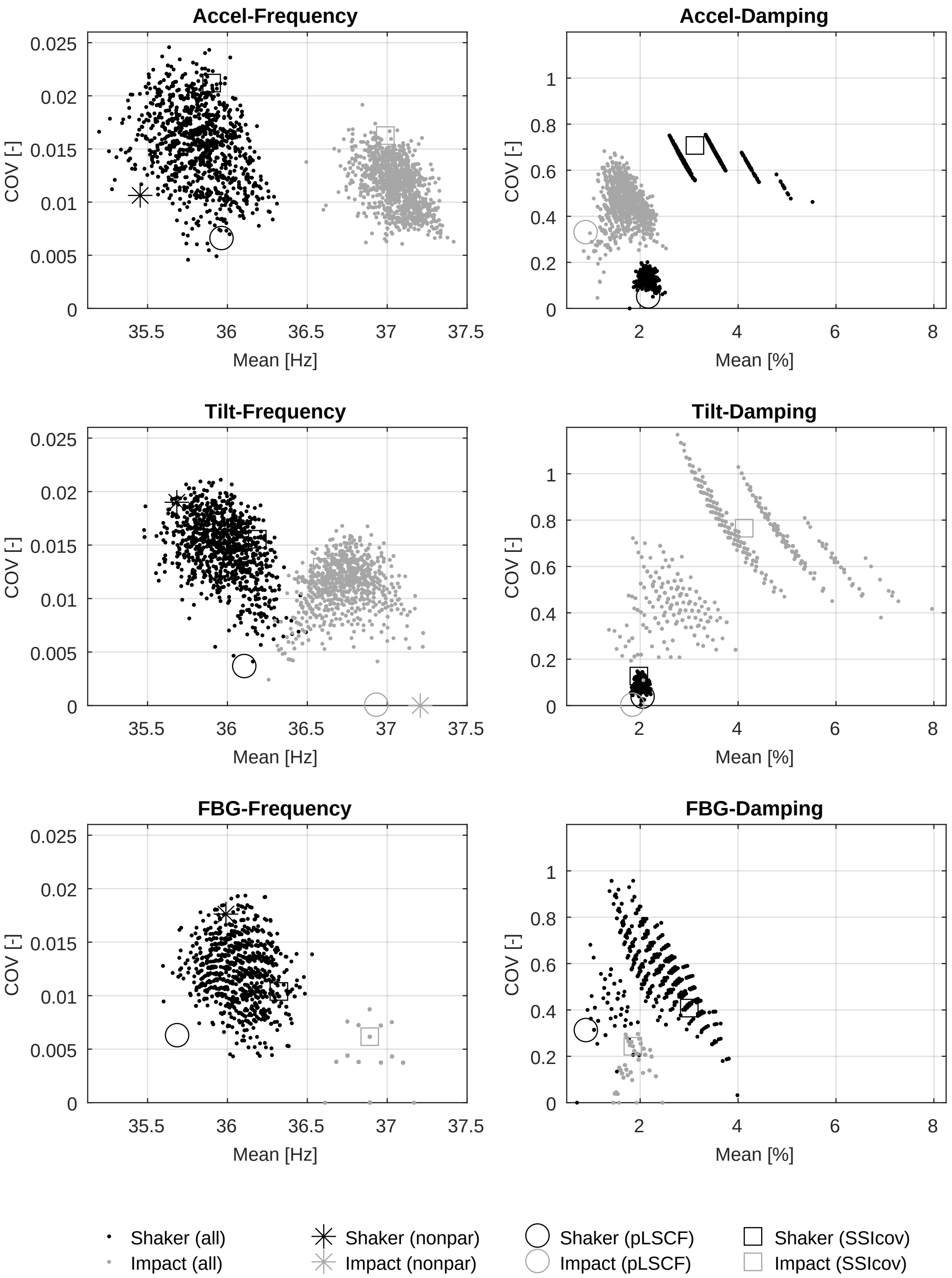
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.97	8	6	8
Tilt	0.99	14	6	11
FBG	0.76	2	-	4



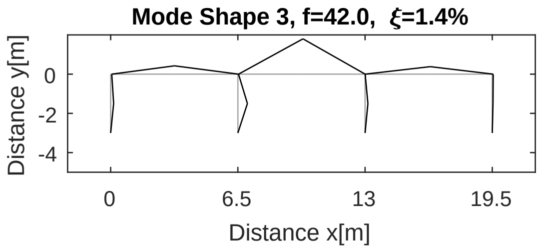
System 2 - Mode 2



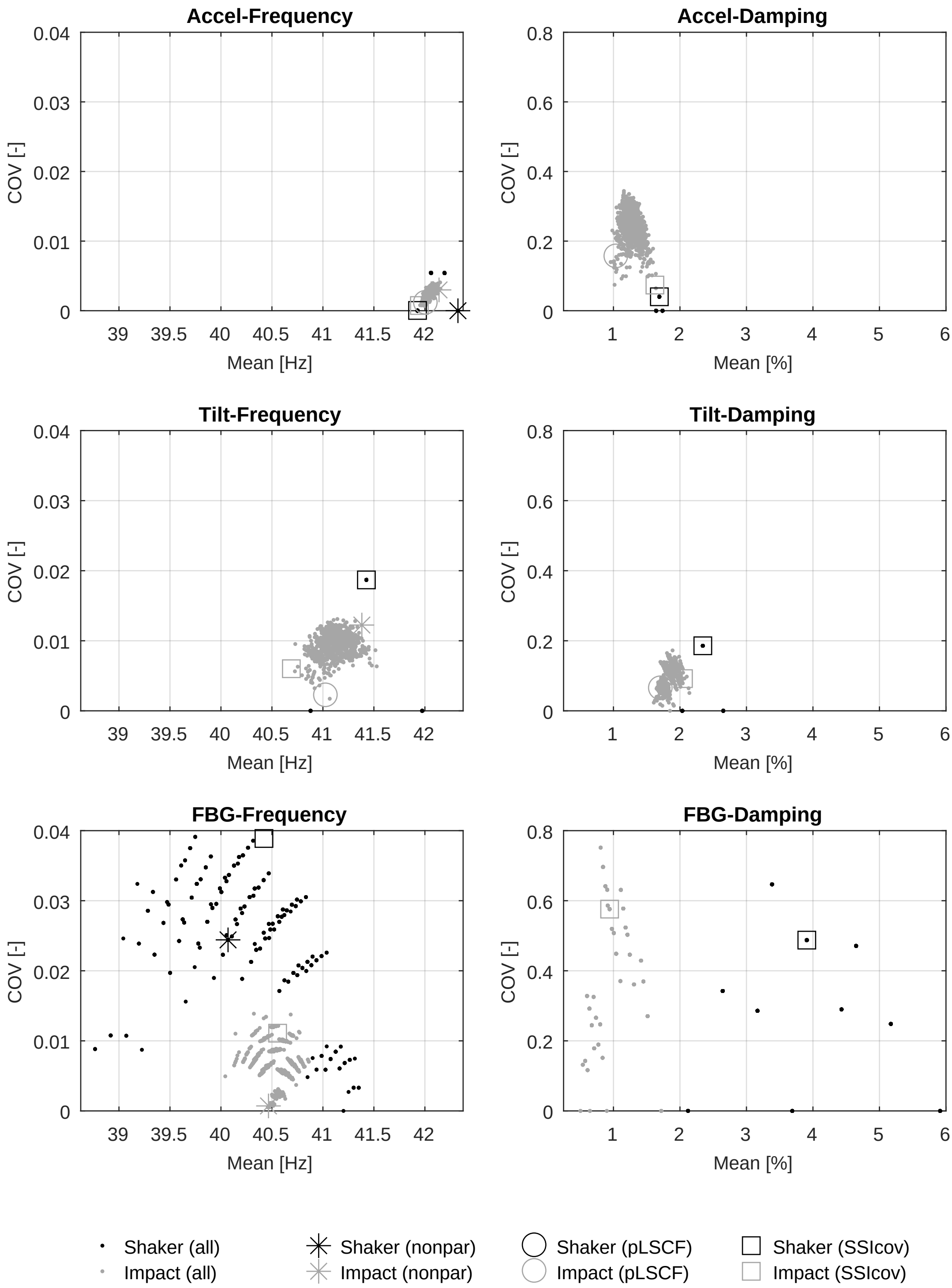
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.89	6	4	11
Tilt	0.88	5	3	9
FBG	0.88	3	2	8



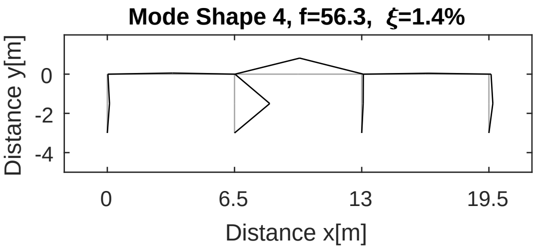
System 2 - Mode 3



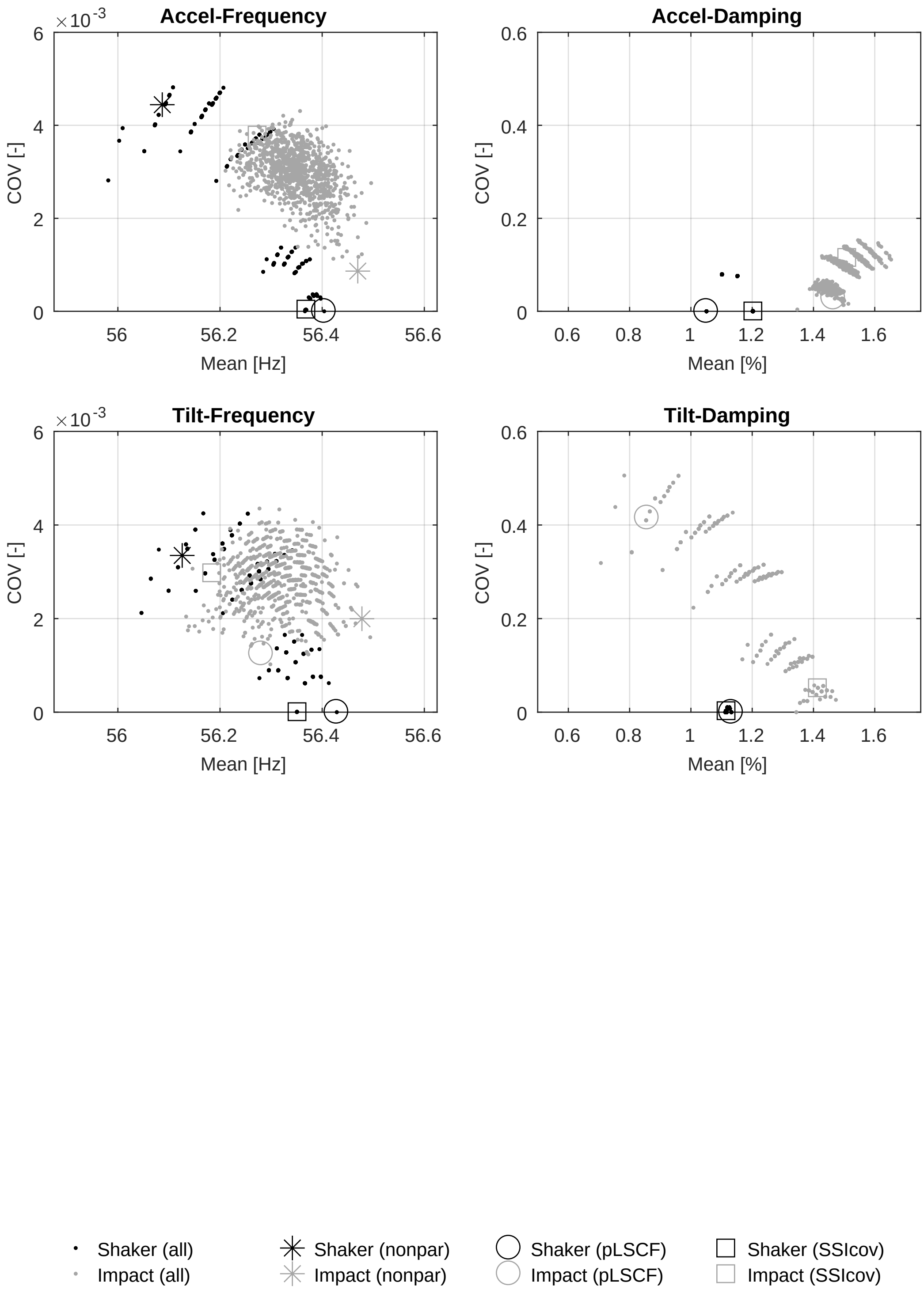
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.97	5	4	5
Tilt	0.93	4	4	4
FBG	0.83	4	-	7



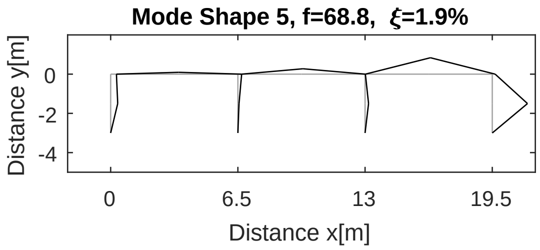
System 2 - Mode 4



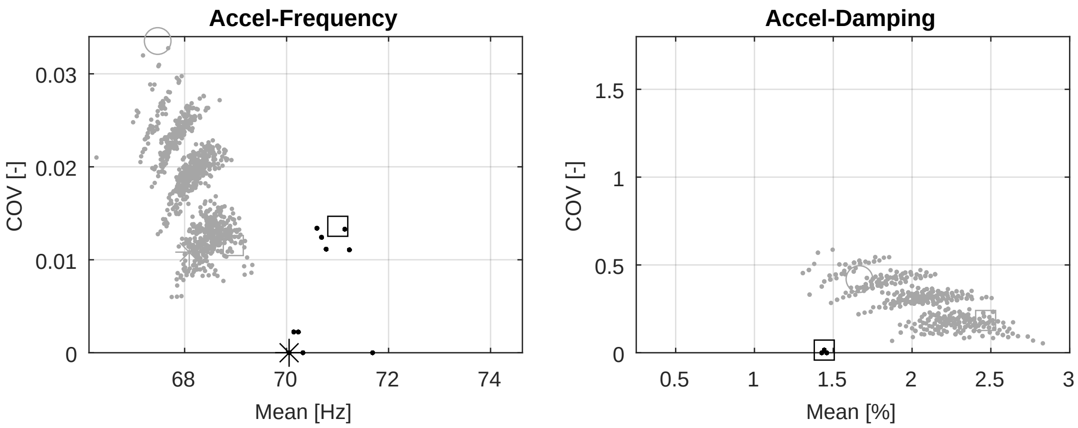
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.97	6	3	8
Tilt	0.94	5	3	5
FBG	-	-	-	-

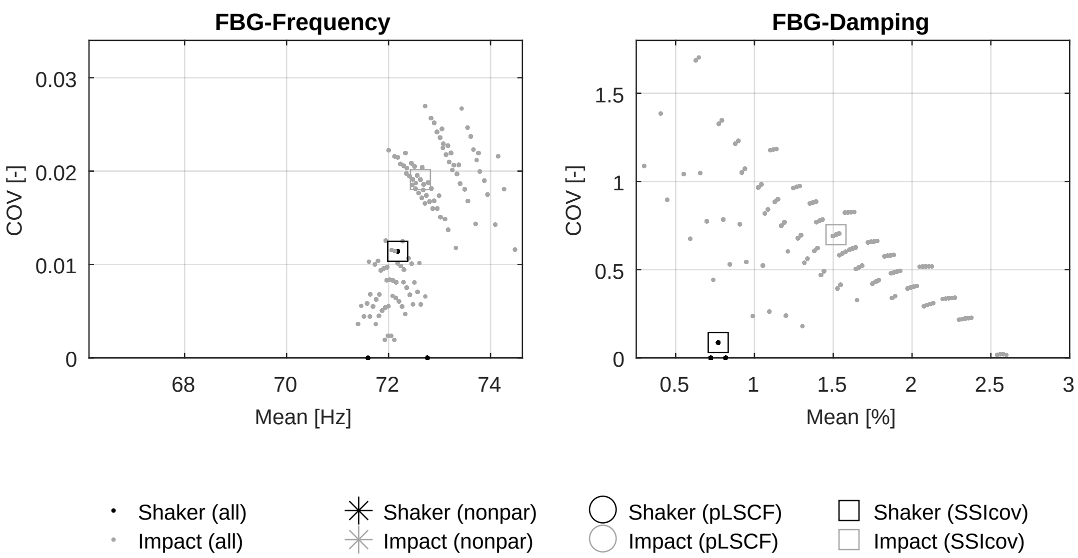


System 2 - Mode 5

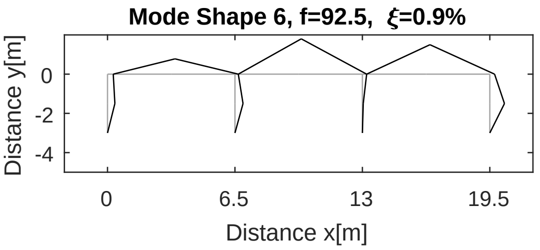


Sensor	$\text{MAC}_{\text{quality}}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.91	5	3	5
Tilt	-	-	-	-
FBG	0.71	-	-	7

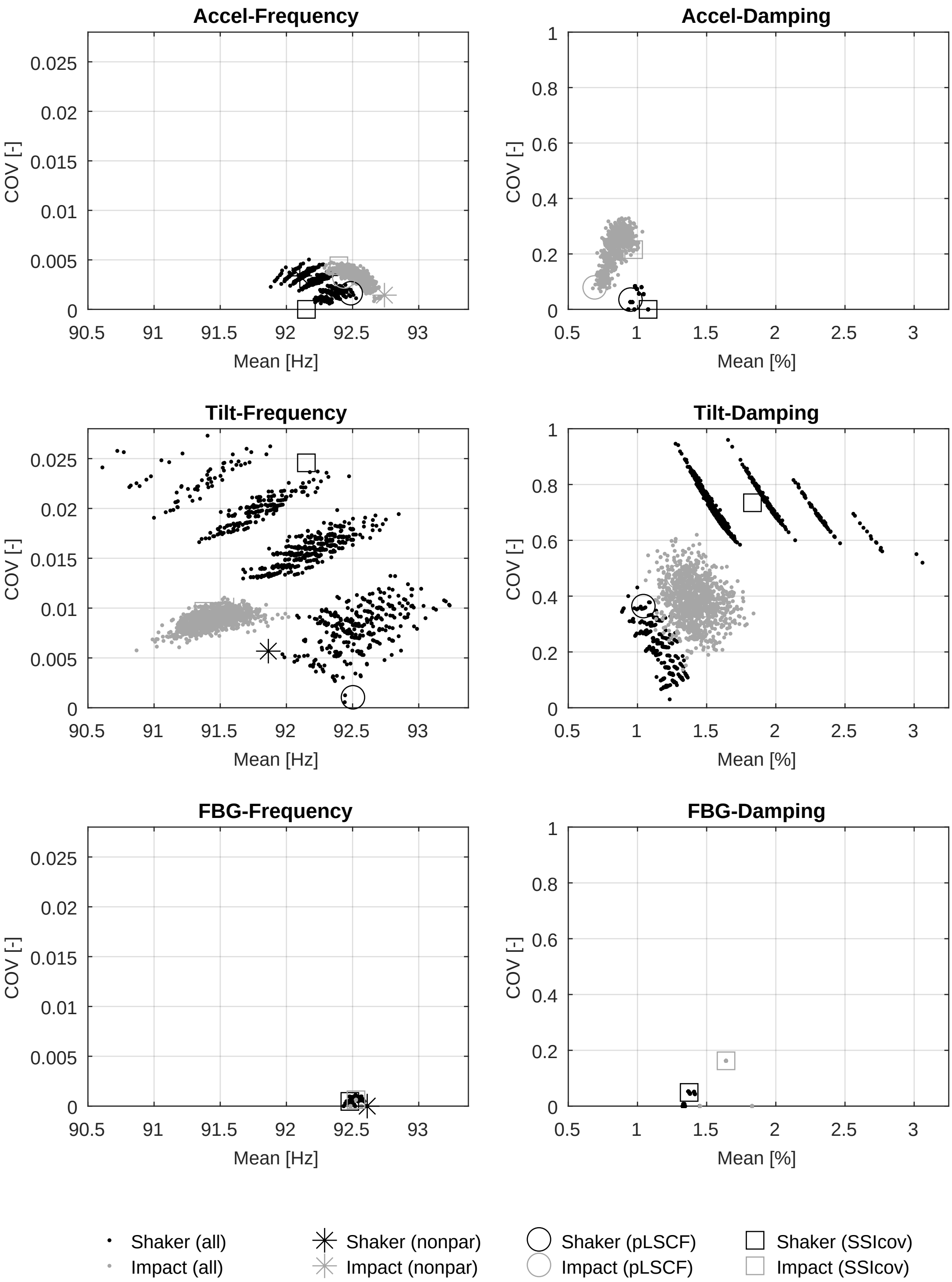




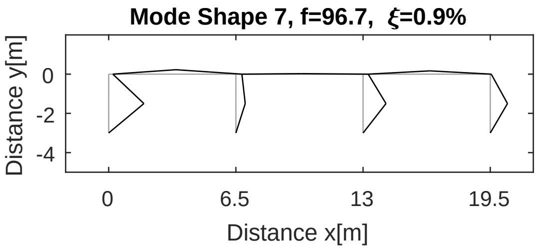
System 2 - Mode 6



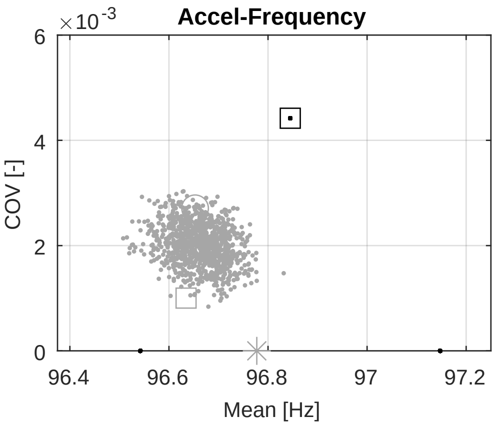
Sensor	$\text{MAC}_{\text{quality}}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.91	9	8	7
Tilt	0.88	13	12	15
FBG	0.86	1	-	5

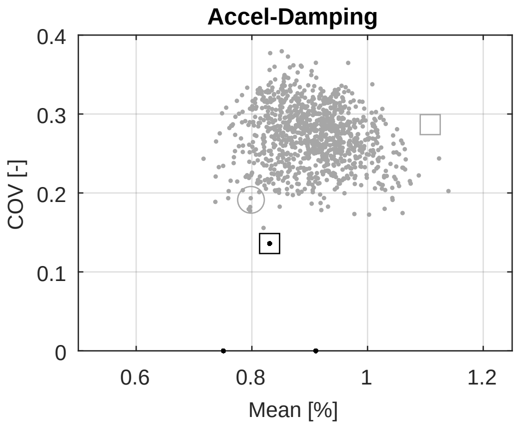


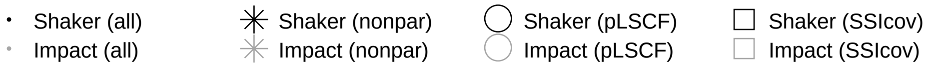
System 2 - Mode 7



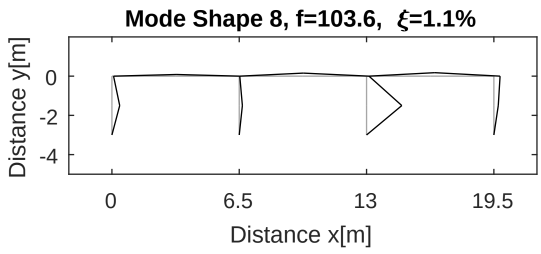
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.87	2	10	7
Tilt	-	-	-	-
FBG	-	-	-	-



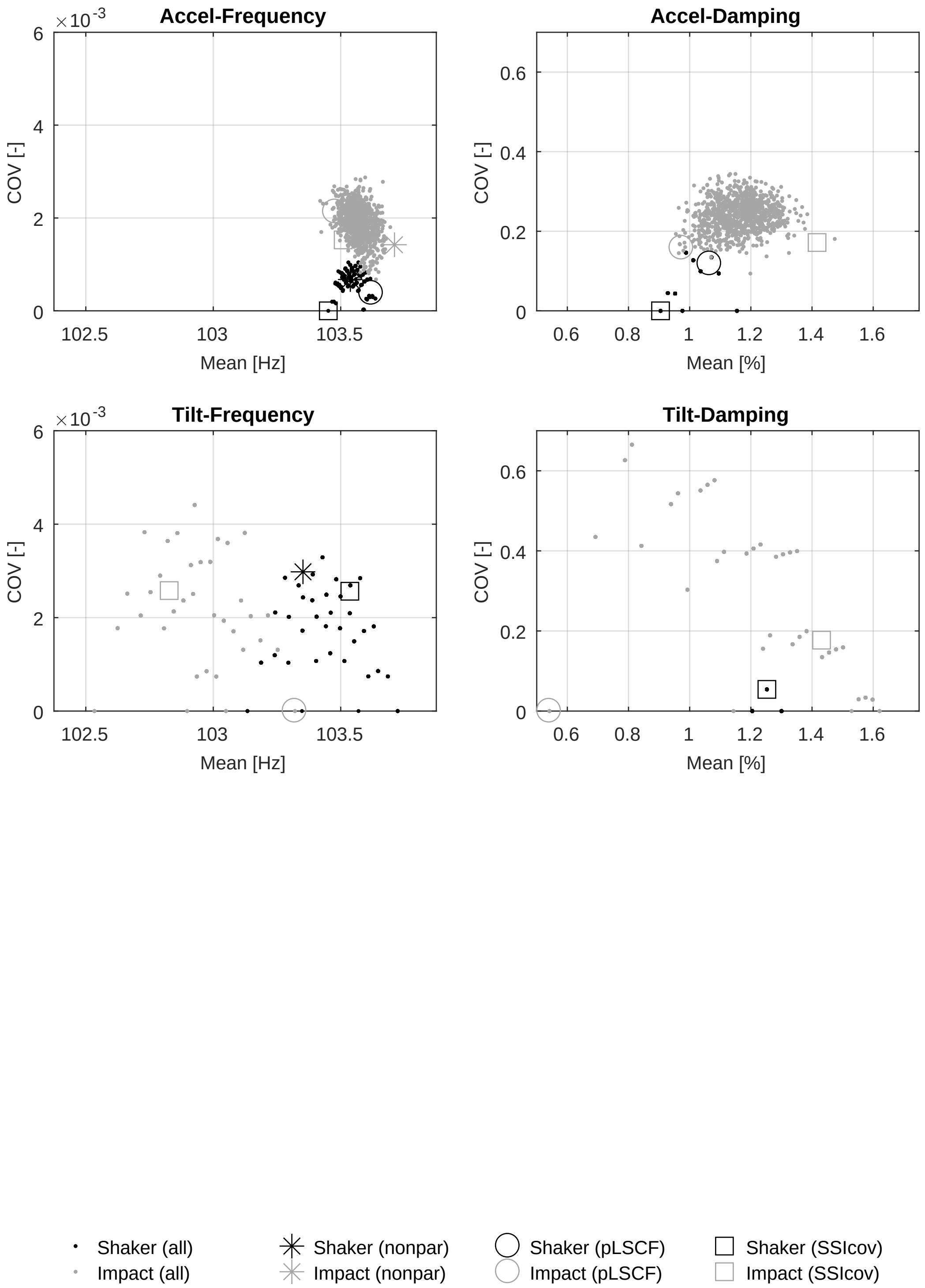




System 2 - Mode 8

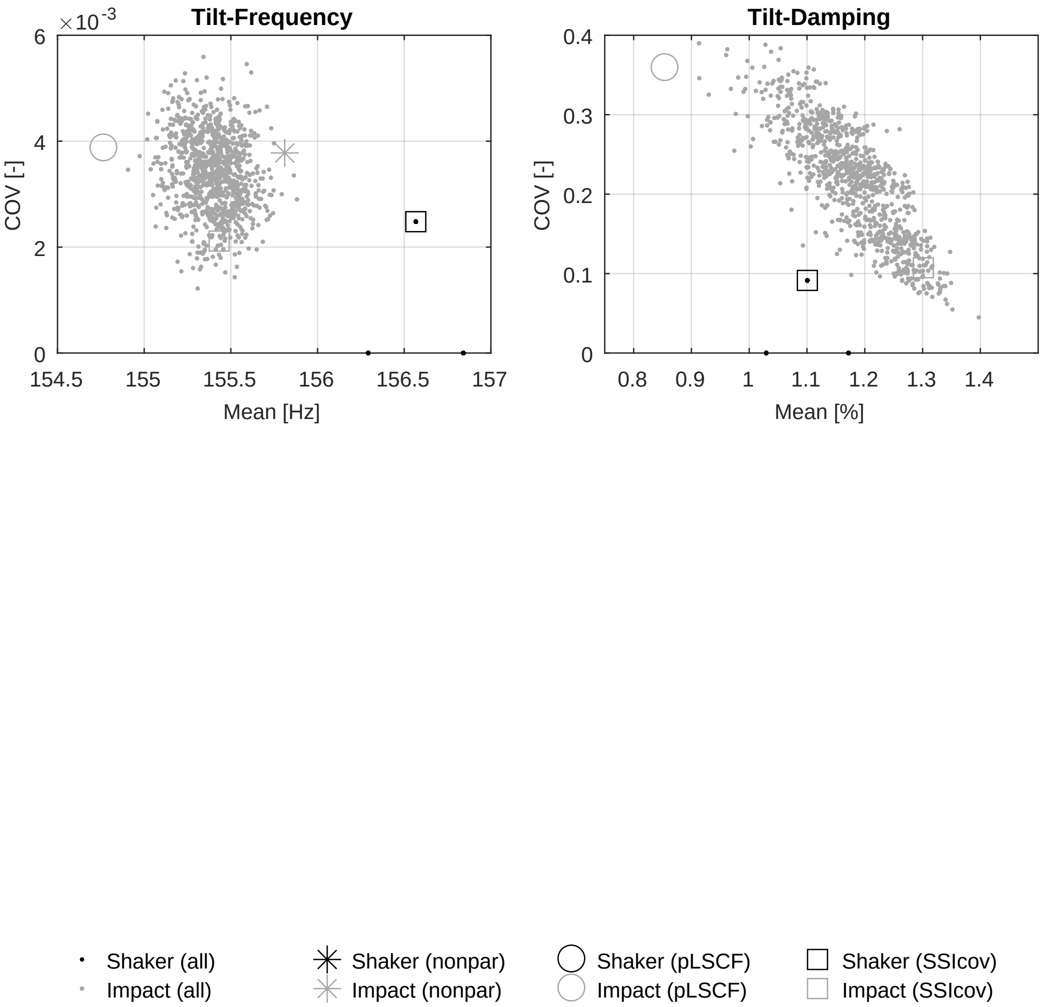


Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.91	10	10	7
Tilt	0.96	2	1	5
FBG	-	-	-	-



System 2 - Mode 9

Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	-	-	-	-
Tilt	0.94	4	3	10
FBG	-	-	-	-



System 3

Tab. 5.7: System 3 - Acceleration results

Mode No.	f_{mean} [Hz]	f_{COV} [-]	ξ_{mean} [%]	ξ_{COV} [-]	$MAC_{quality}$	$N_{samples}$
1	9.55	0.006	1.55	0.341	0.99	23
2	39.18	0.009	2.00	0.332	0.83	16
3	44.98	0.011	2.25	0.727	0.95	13
4	74.47	0.005	0.88	0.284	0.85	9
5	89.62	0.003	1.13	0.217	0.92	20
6	103.45	0.006	1.29	0.339	0.82	22

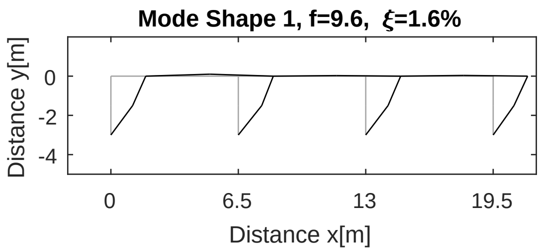
Tab. 5.8: System 3 - Tilt results

Mode No.	f_{mean} [Hz]	f_{COV} [-]	ξ_{mean} [%]	ξ_{COV} [-]	$MAC_{quality}$	$N_{samples}$
1	9.57	0.009	2.29	0.453	0.99	30
2	39.22	0.011	2.09	0.172	0.85	27
4	74.25	0.019	1.38	0.082	0.85	6
5	91.32	0.034	1.19	0.388	0.87	46
6	104.35	0.009	1.81	0.319	0.94	9
7	157.56	0.003	1.69	0.209	0.95	15

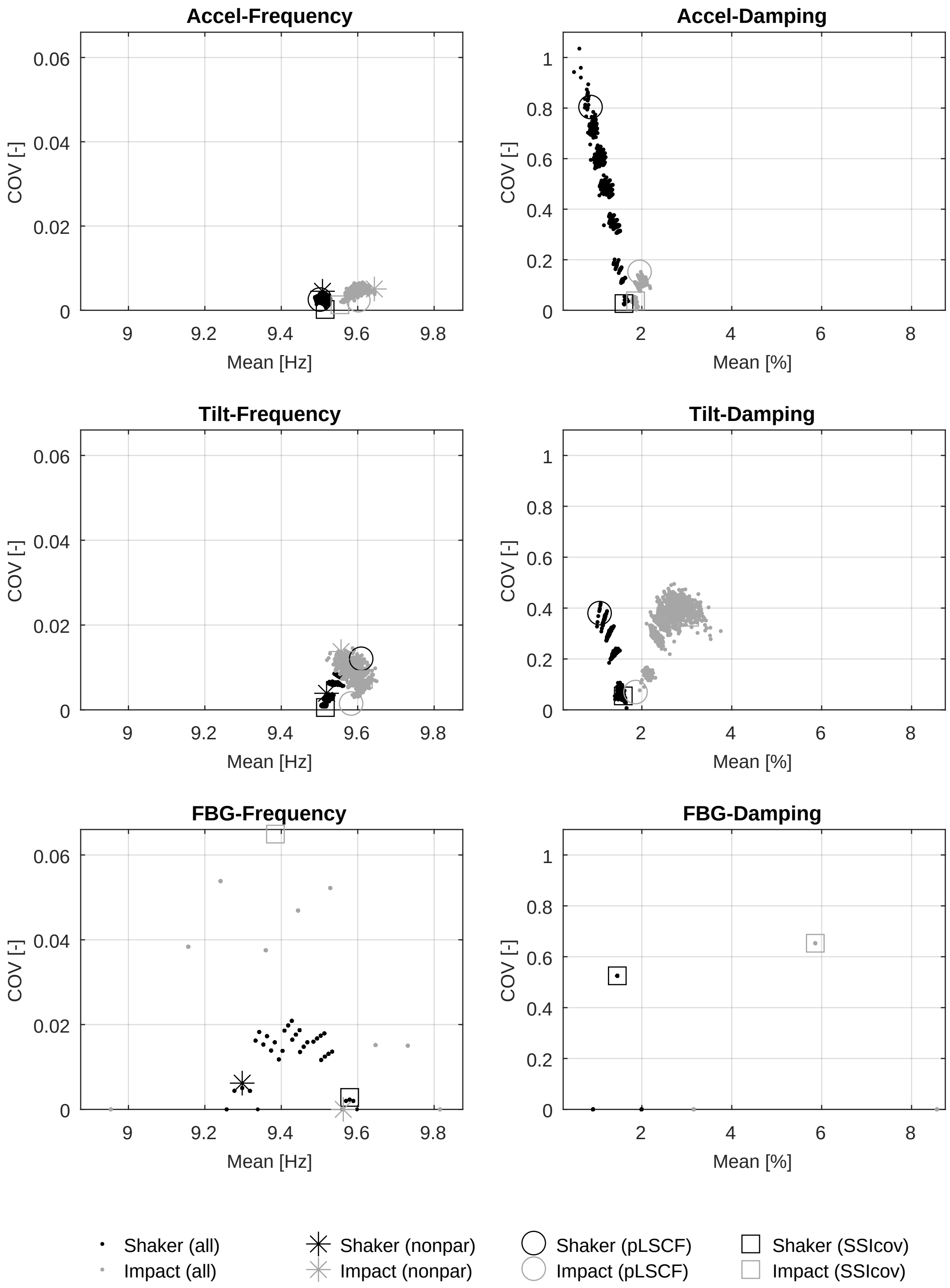
Tab. 5.9: System 3 - FBG results

Mode No.	f_{mean} [Hz]	f_{COV} [-]	ξ_{mean} [%]	ξ_{COV} [-]	$MAC_{quality}$	$N_{samples}$
1	9.44	0.026	3.69	0.733	0.89	7
2	38.95	0.020	3.76	0.712	0.86	16
5	93.87	0.028	2.25	0.554	0.82	6

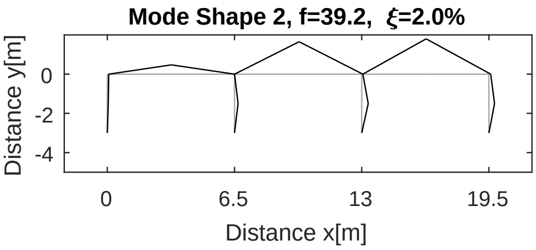
System 3 - Mode 1



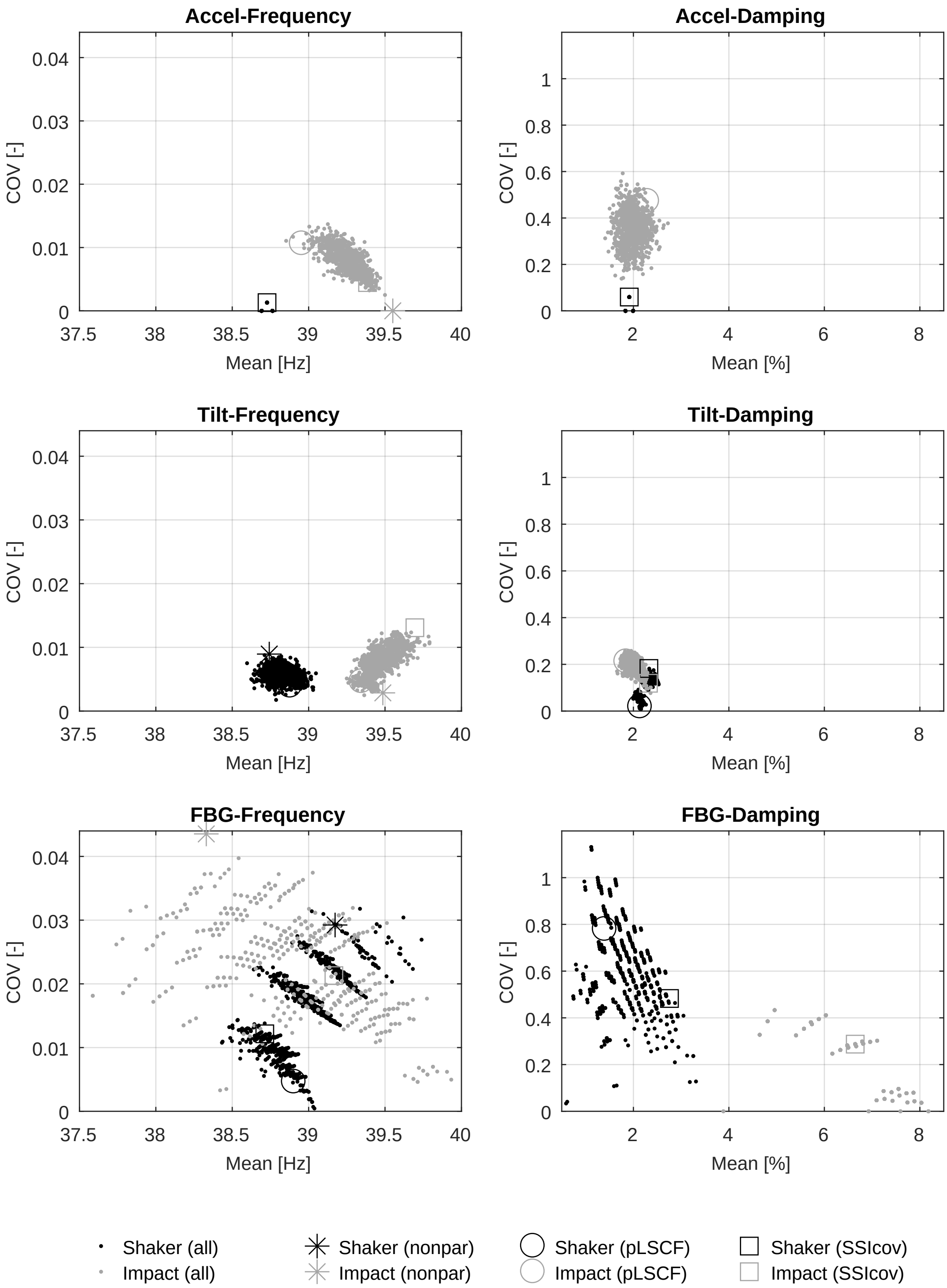
Sensor	$\mathrm{MAC}_{\mathrm{quality}}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.99	8	7	8
Tilt	0.99	11	6	13
FBG	0.89	3	-	4



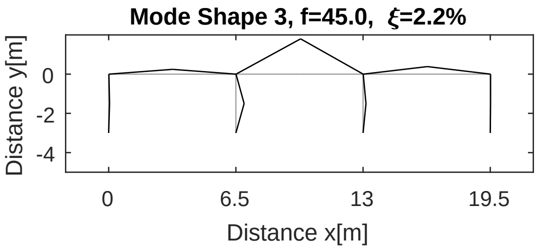
System 3 - Mode 2



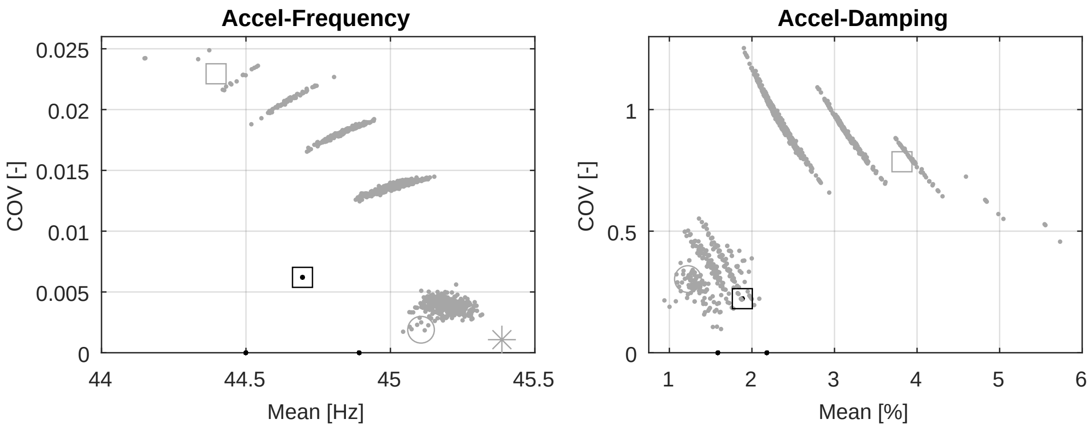
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.83	1	5	10
Tilt	0.85	7	12	8
FBG	0.86	6	4	6

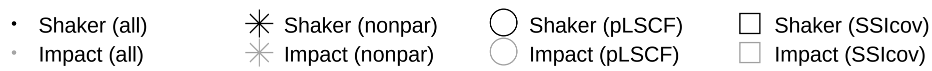


System 3 - Mode 3

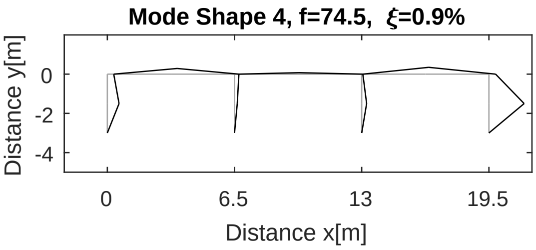


Sensor	$\text{MAC}_{\text{quality}}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.95	4	4	5
Tilt	-	-	-	-
FBG	-	-	-	-

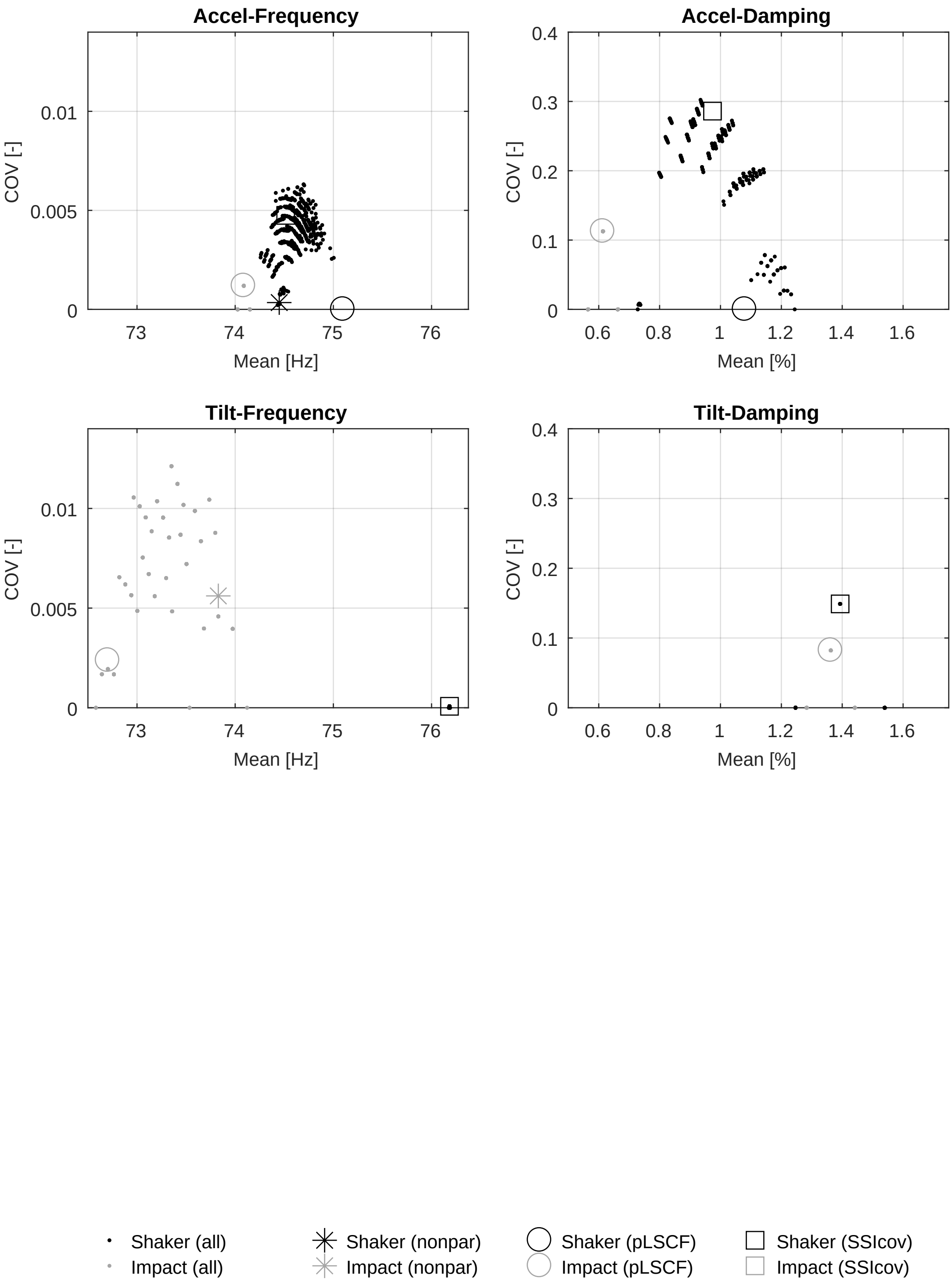




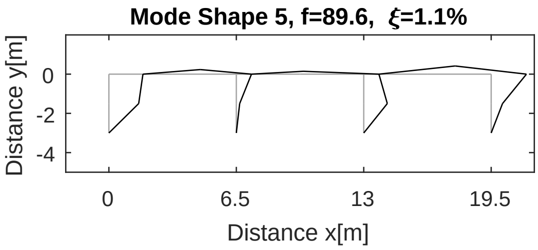
System 3 - Mode 4



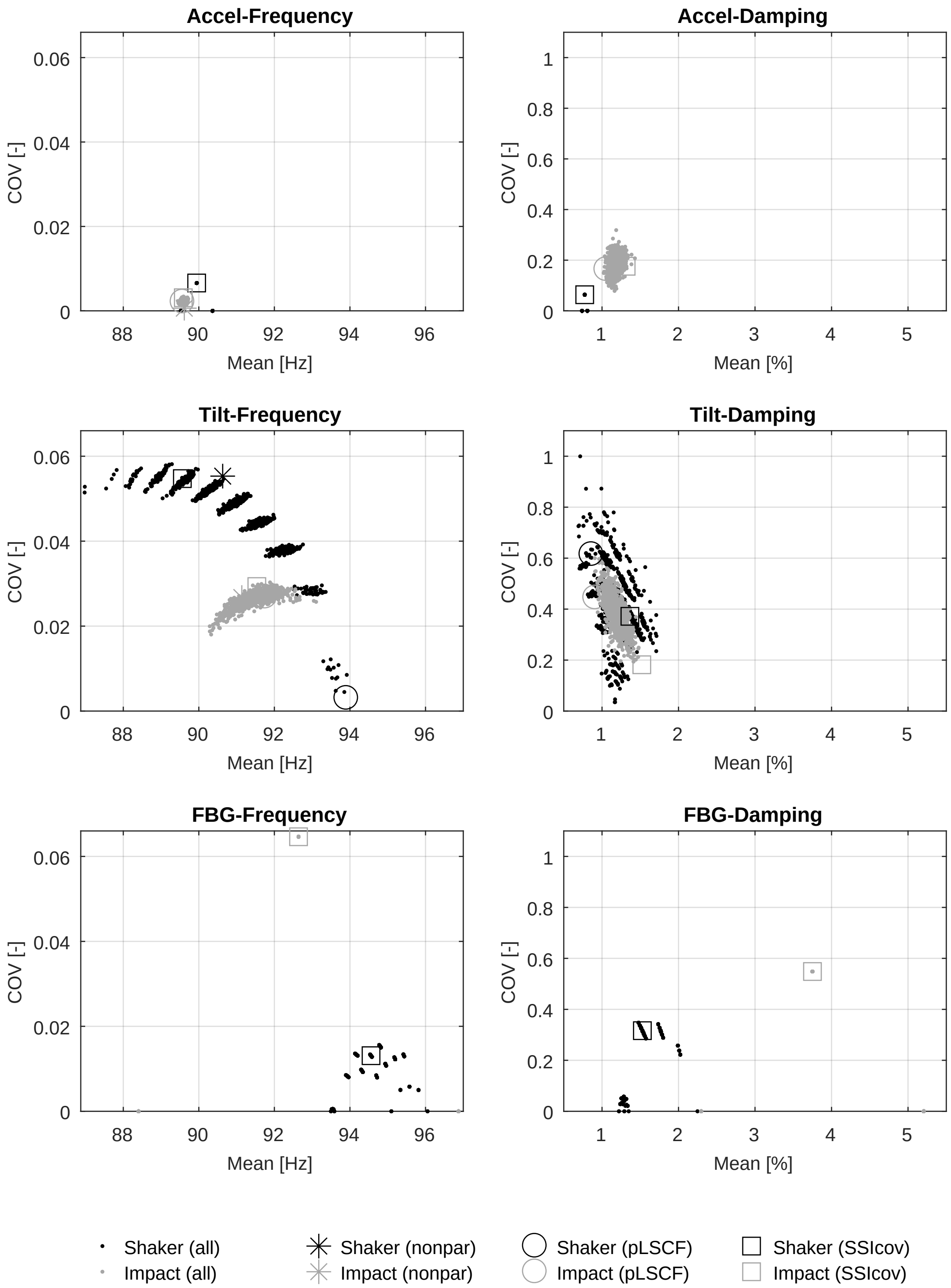
Sensor	$\mathrm{MAC}_{\mathrm{quality}}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.85	2	3	4
Tilt	0.85	2	2	2
FBG	-	-	-	-



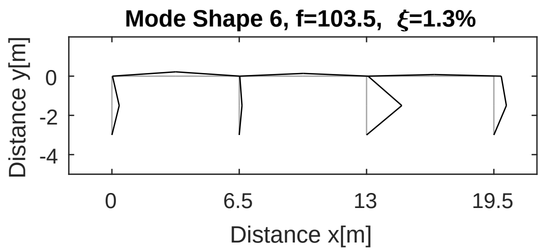
System 3 - Mode 5



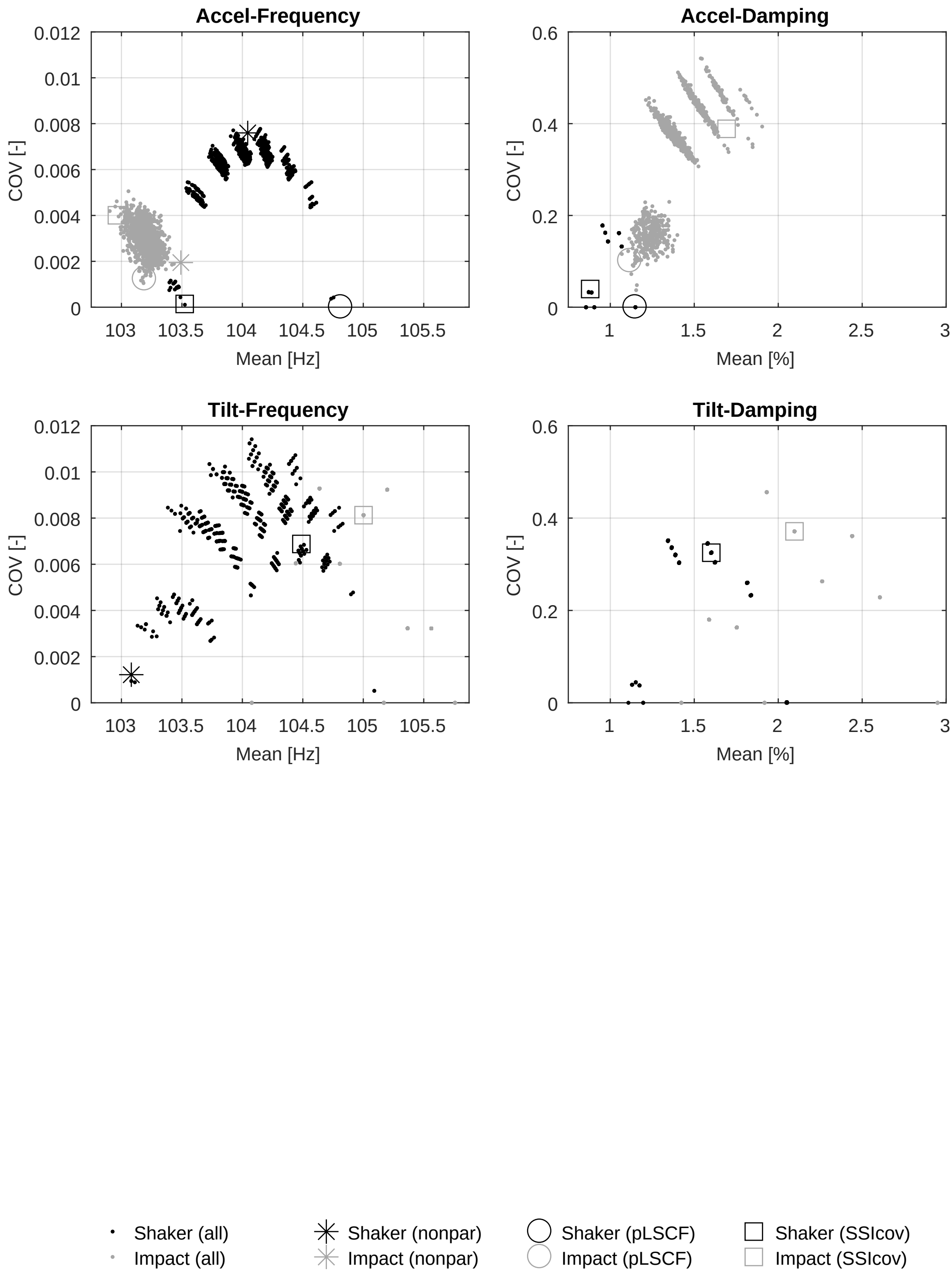
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.92	3	8	9
Tilt	0.87	18	14	14
FBG	0.82	-	-	6



System 3 - Mode 6

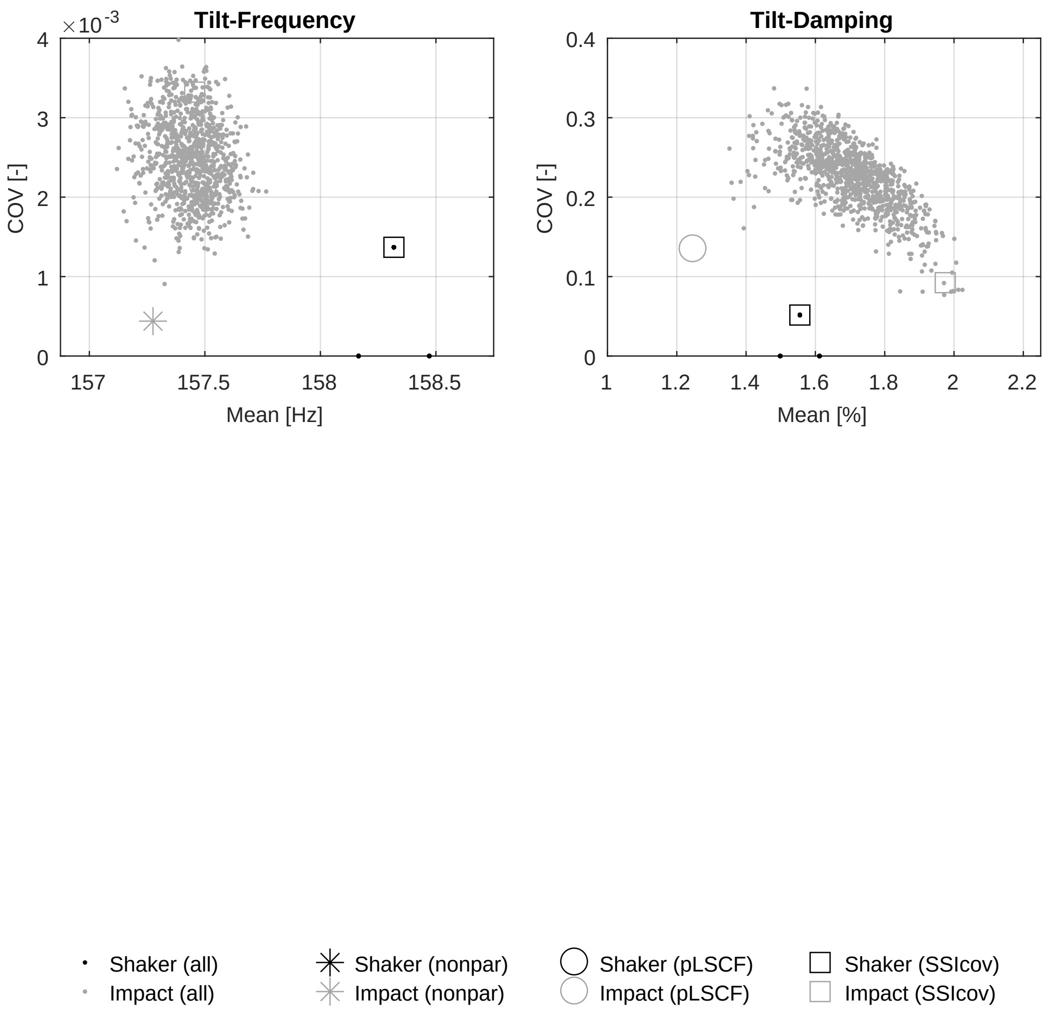


Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.82	8	7	7
Tilt	0.94	2	-	7
FBG	-	-	-	-



System 3 - Mode 7

Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	-	-	-	-
Tilt	0.95	2	4	9
FBG	-	-	-	-



System 4

Tab. 5.10: System 4 - Acceleration results

Mode No.	f_{mean} [Hz]	f_{COV} [-]	ξ_{mean} [%]	ξ_{COV} [-]	$\text{MAC}_{\text{quality}}$	N_{samples}
1	8.58	0.003	1.45	0.238	0.99	21
2	36.33	0.021	2.60	0.325	0.93	11
3	40.00	0.014	2.17	0.441	0.81	16
4	48.56	0.004	2.08	0.209	0.95	8
5	56.94	0.006	1.40	0.221	0.95	20
6	69.79	0.010	1.38	0.236	0.87	12
7	93.42	0.003	0.76	0.212	0.85	27
8	103.96	0.002	1.03	0.208	0.93	30

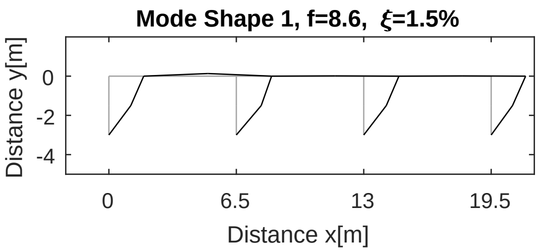
Tab. 5.11: System 4 - Tilt results

Mode No.	f_{mean} [Hz]	f_{COV} [-]	ξ_{mean} [%]	ξ_{COV} [-]	$\text{MAC}_{\text{quality}}$	N_{samples}
1	8.61	0.005	1.81	0.348	0.99	29
2	36.18	0.015	2.55	0.204	0.87	12
3	39.59	0.017	1.61	0.515	0.87	10
4	48.27	0.009	3.12	0.126	0.99	6
5	56.89	0.005	1.67	0.158	0.93	12
7	92.81	0.014	1.26	0.501	0.86	44
8	103.86	0.004	0.98	0.532	0.91	25
9	156.42	0.002	1.35	0.178	0.97	18

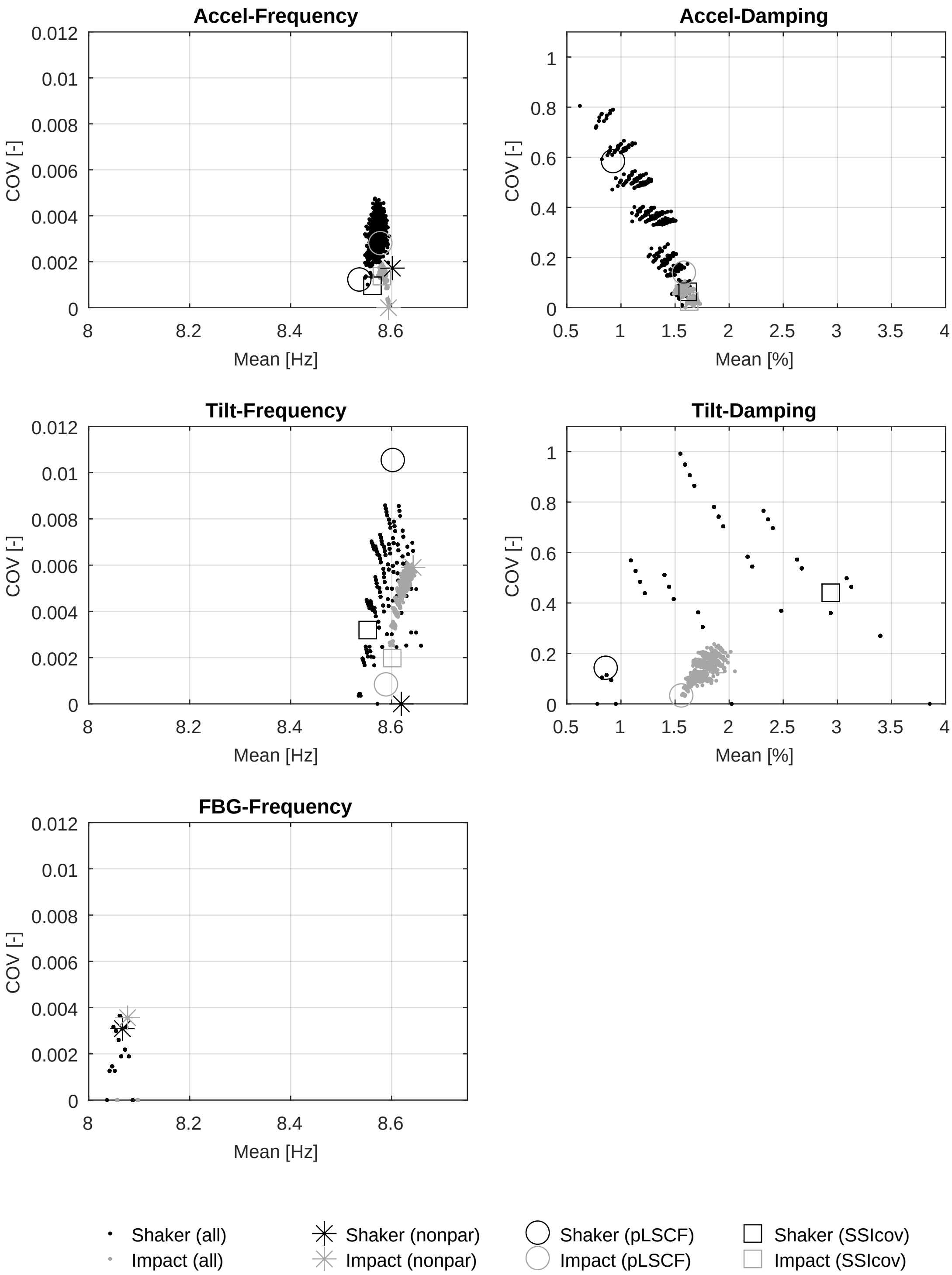
Tab. 5.12: System 4 - FBG results

Mode No.	f_{mean} [Hz]	f_{COV} [-]	ξ_{mean} [%]	ξ_{COV} [-]	$\text{MAC}_{\text{quality}}$	N_{samples}
1	8.07	0.003	-	-	0.84	6
2	36.46	0.021	3.15	0.490	0.88	9
7	93.53	0.008	0.95	0.639	0.86	12

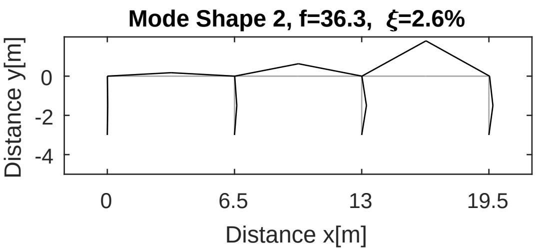
System 4 - Mode 1



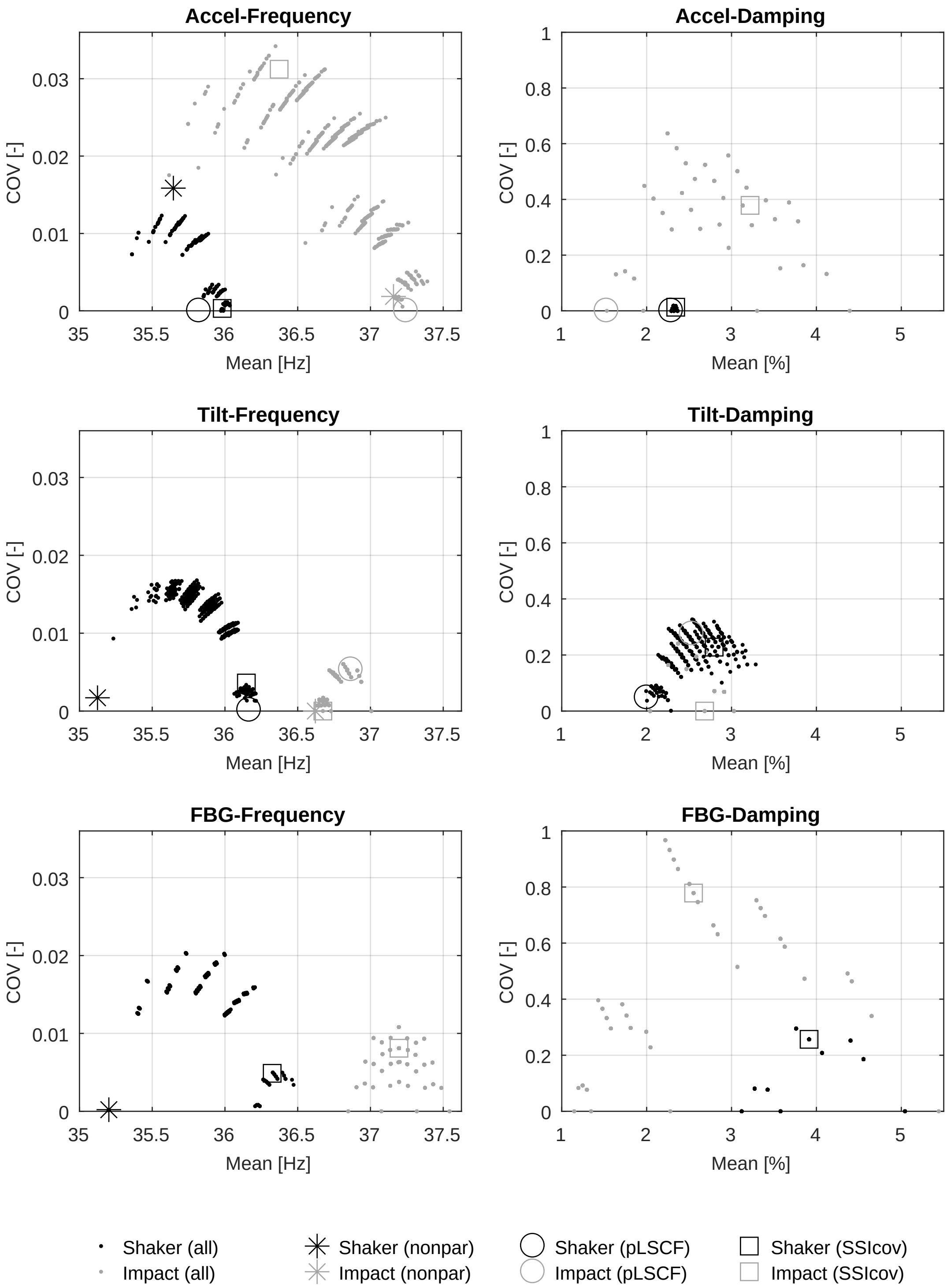
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.99	8	5	8
Tilt	0.99	13	6	10
FBG	0.84	6	-	-



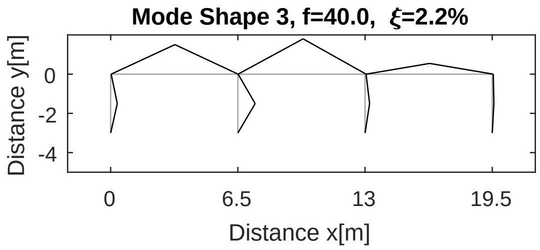
System 4 - Mode 2



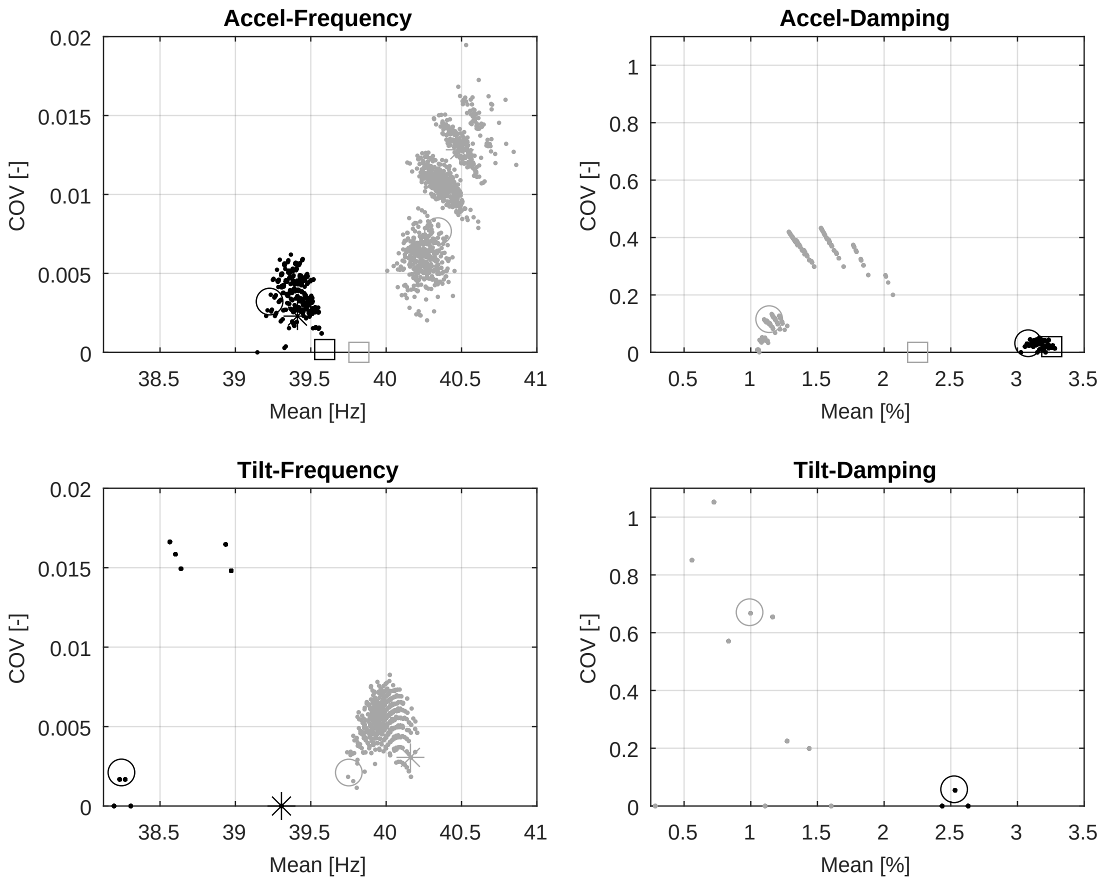
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.93	4	2	5
Tilt	0.87	3	4	5
FBG	0.88	2	-	7

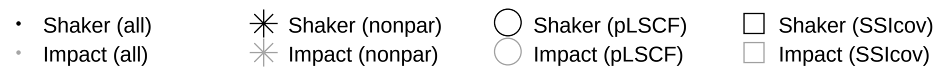


System 4 - Mode 3

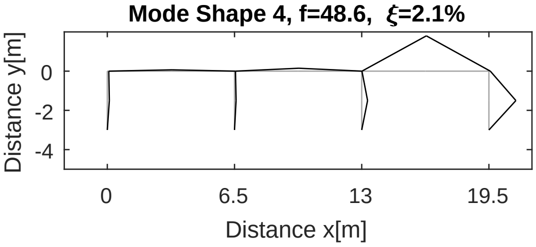


Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.81	7	6	3
Tilt	0.87	5	5	-
FBG	-	-	-	-

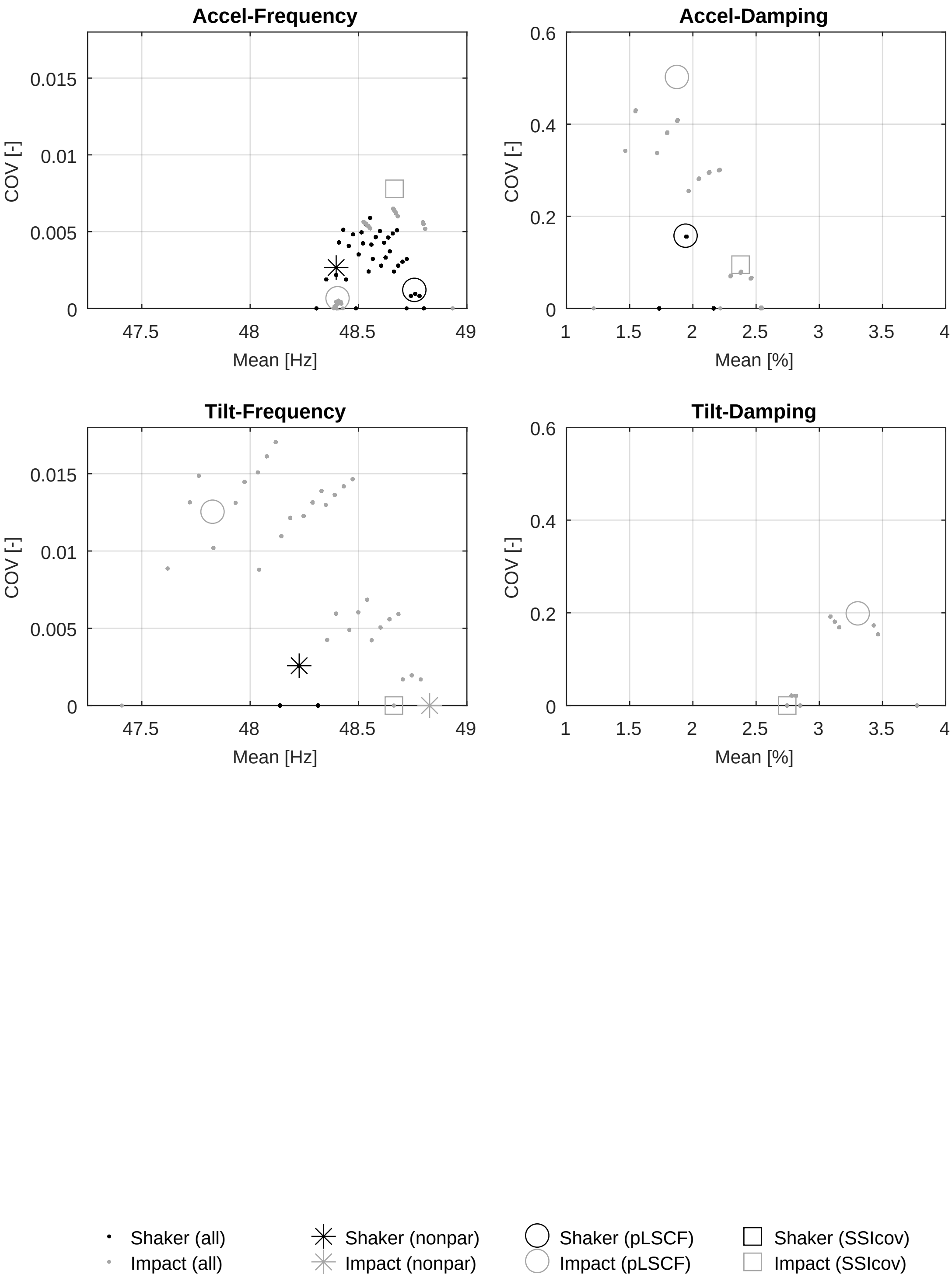




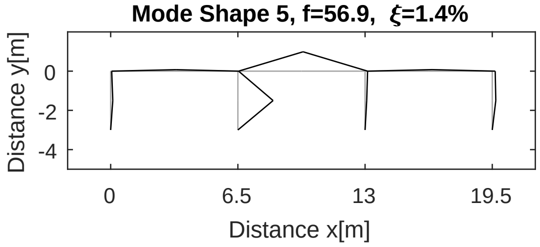
System 4 - Mode 4



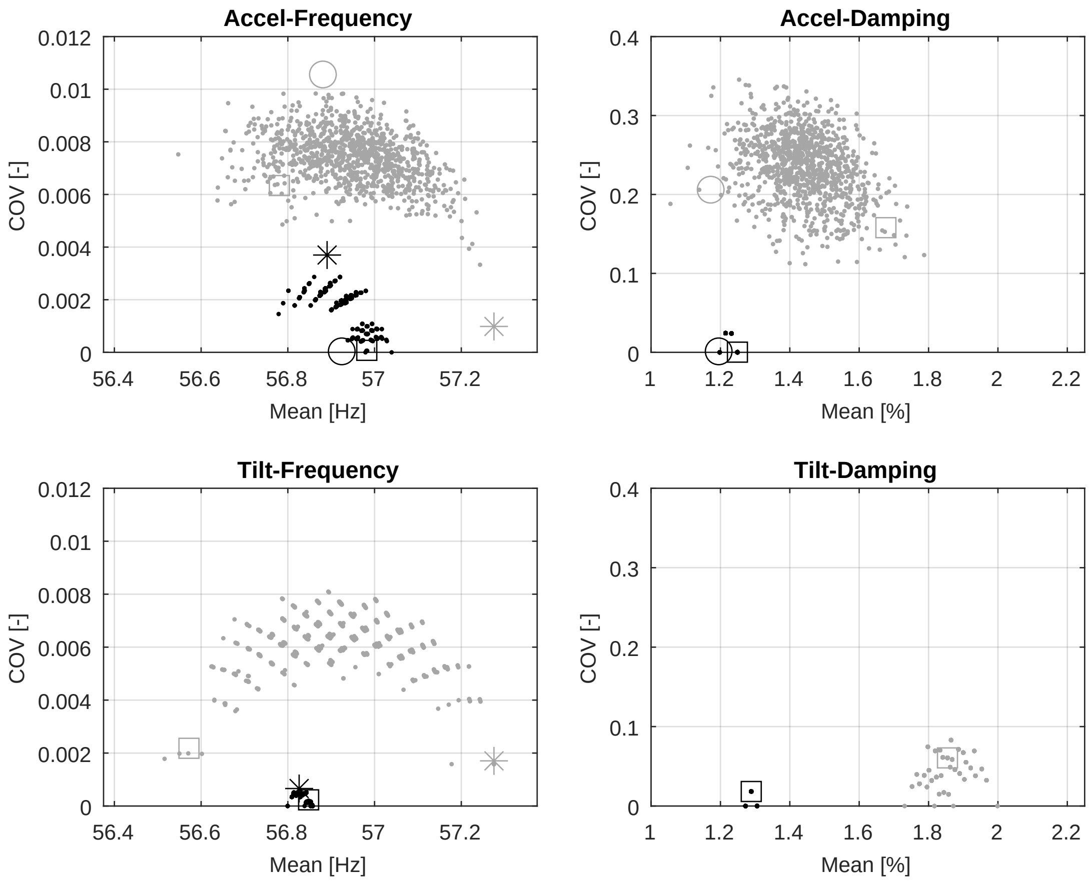
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.95	2	4	2
Tilt	0.99	3	2	1
FBG	-	-	-	-

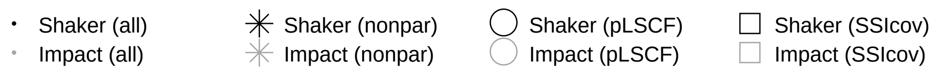


System 4 - Mode 5

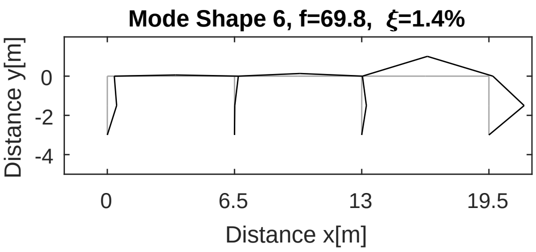


Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.95	6	6	8
Tilt	0.93	6	-	6
FBG	-	-	-	-

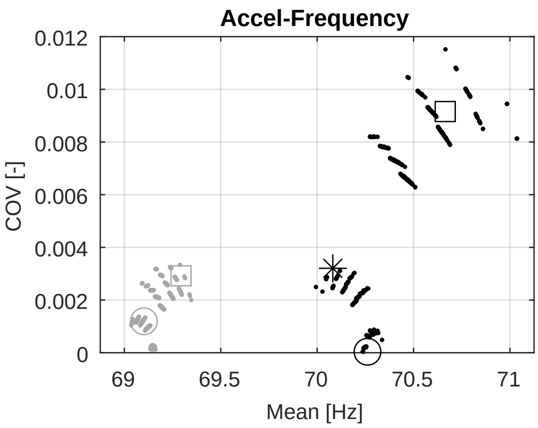


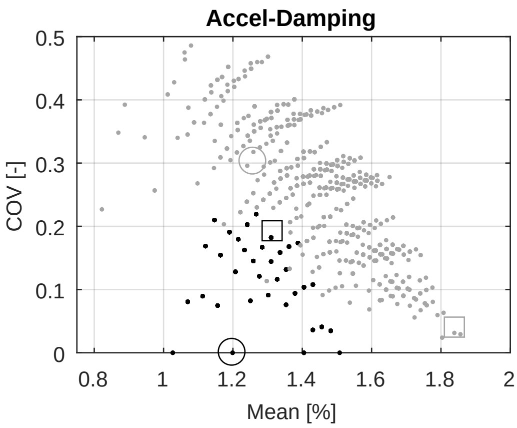


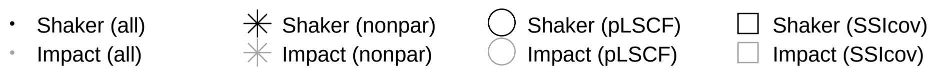
System 4 - Mode 6



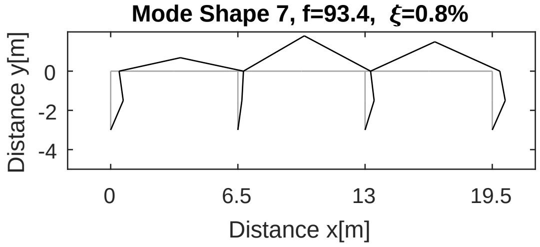
Sensor	$\text{MAC}_{\text{quality}}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.87	2	5	5
Tilt	-	-	-	-
FBG	-	-	-	-



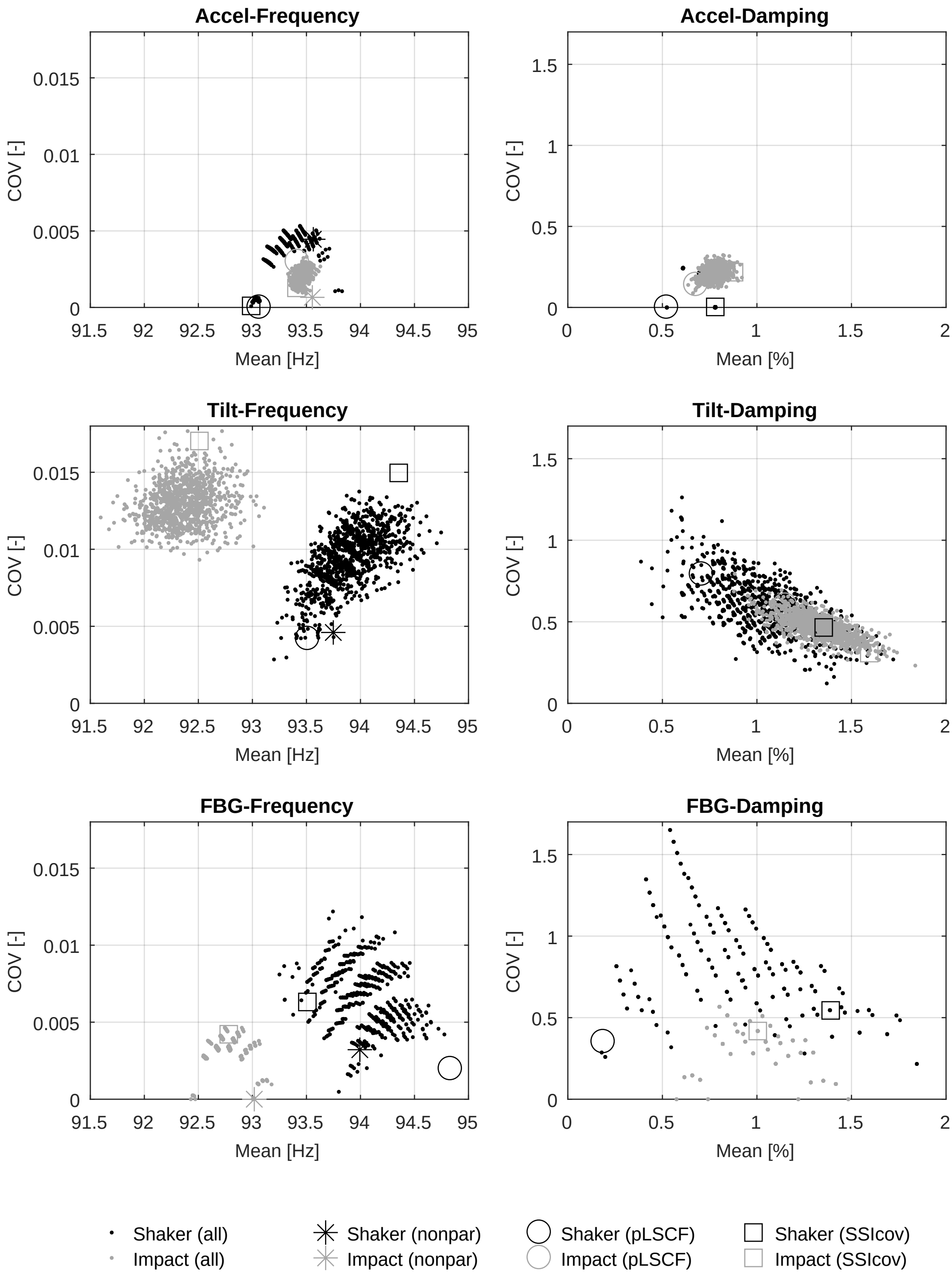




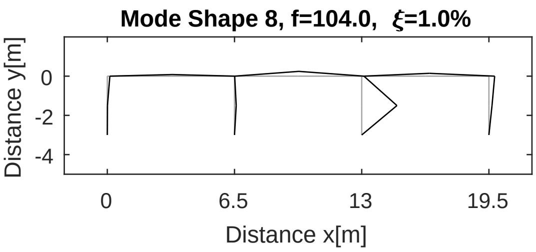
System 4 - Mode 7



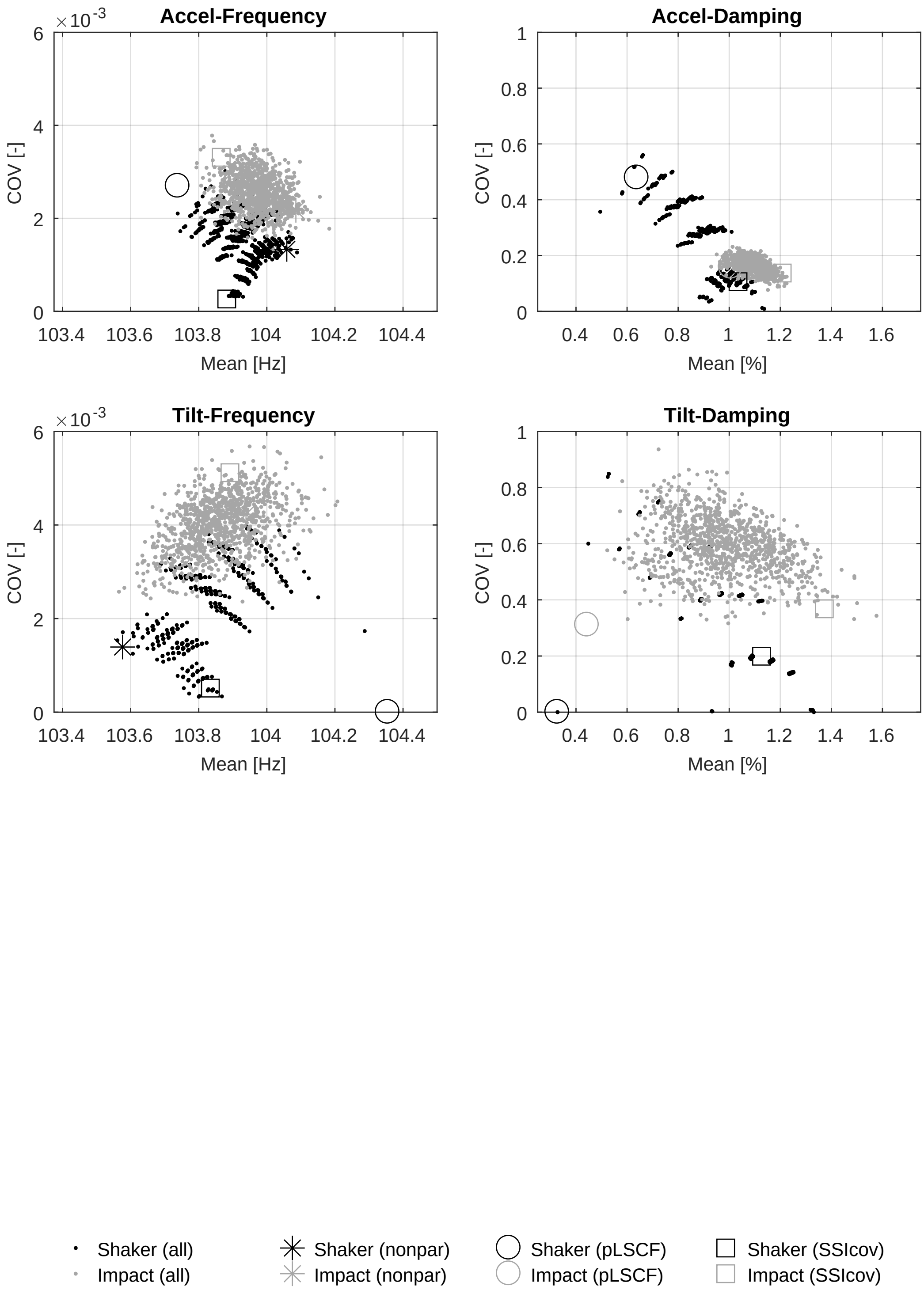
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.85	9	9	9
Tilt	0.86	16	15	13
FBG	0.86	3	2	7



System 4 - Mode 8

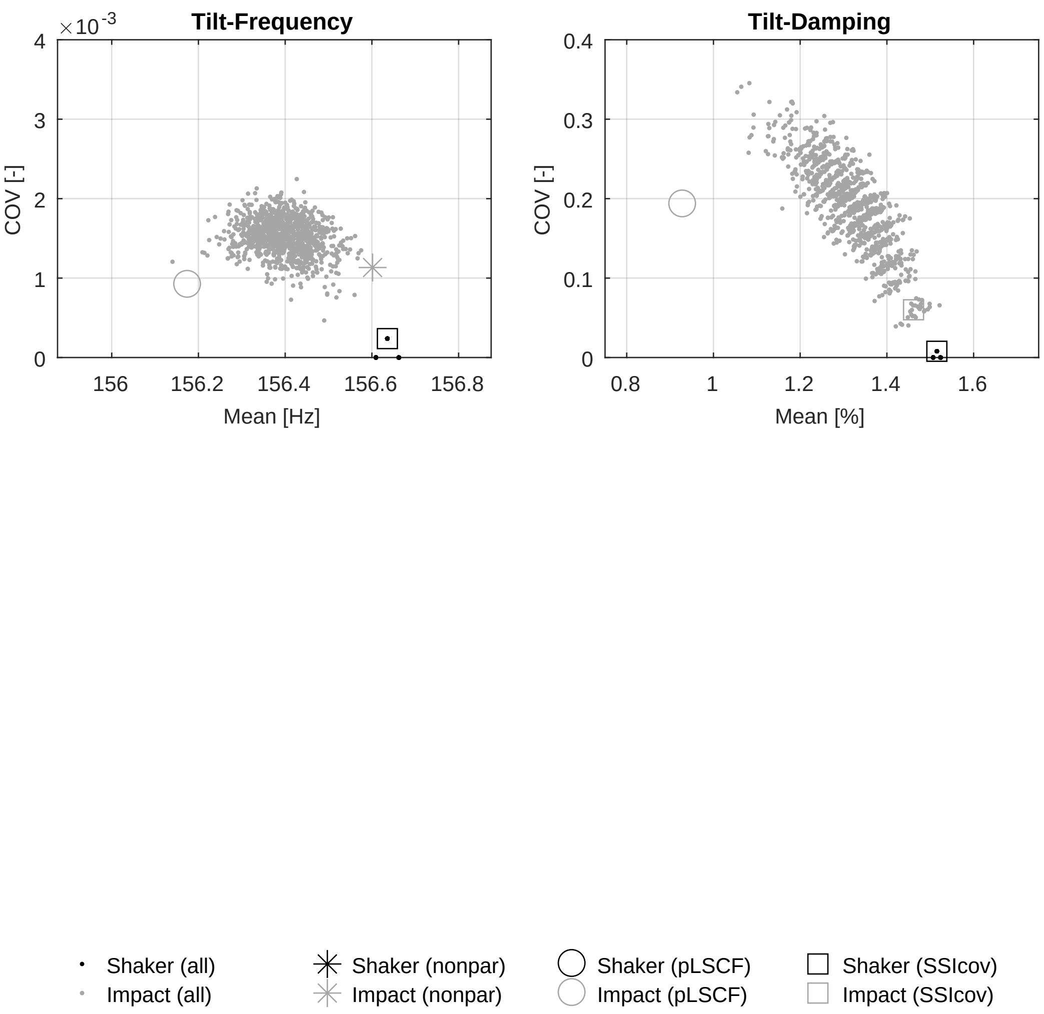


Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.93	10	10	10
Tilt	0.91	8	6	11
FBG	-	-	-	-



System 4 - Mode 9

Sensor	$\text{MAC}_{\text{quality}}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	-	-	-	-
Tilt	0.97	5	3	10
FBG	-	-	-	-



System 5

Tab. 5.13: System 5 - Acceleration results

Mode No.	f_{mean} [Hz]	f_{COV} [-]	ξ_{mean} [%]	ξ_{COV} [-]	$\text{MAC}_{\text{quality}}$	N_{samples}
1	9.49	0.003	1.61	0.229	0.99	19
2	38.57	0.014	2.24	0.532	0.79	17
3	43.23	0.014	1.77	0.216	0.95	16
4	53.05	0.023	1.40	0.116	0.94	13
5	63.62	0.014	1.65	0.489	0.85	10
6	72.75	0.015	1.15	0.188	0.86	18
8	96.27	0.003	1.34	0.305	0.84	20
9	103.98	0.004	1.11	0.271	0.86	20

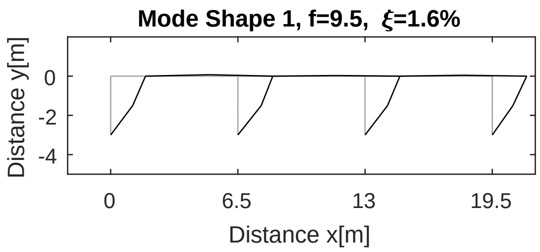
Tab. 5.14: System 5 - Tilt results

Mode No.	f_{mean} [Hz]	f_{COV} [-]	ξ_{mean} [%]	ξ_{COV} [-]	$\text{MAC}_{\text{quality}}$	N_{samples}
1	9.50	0.005	1.78	0.395	0.99	25
2	38.51	0.015	2.48	0.534	0.84	20
3	42.45	0.013	2.72	0.036	0.86	6
7	90.39	0.021	1.90	0.319	0.92	22
9	104.55	0.006	1.66	0.402	0.92	10

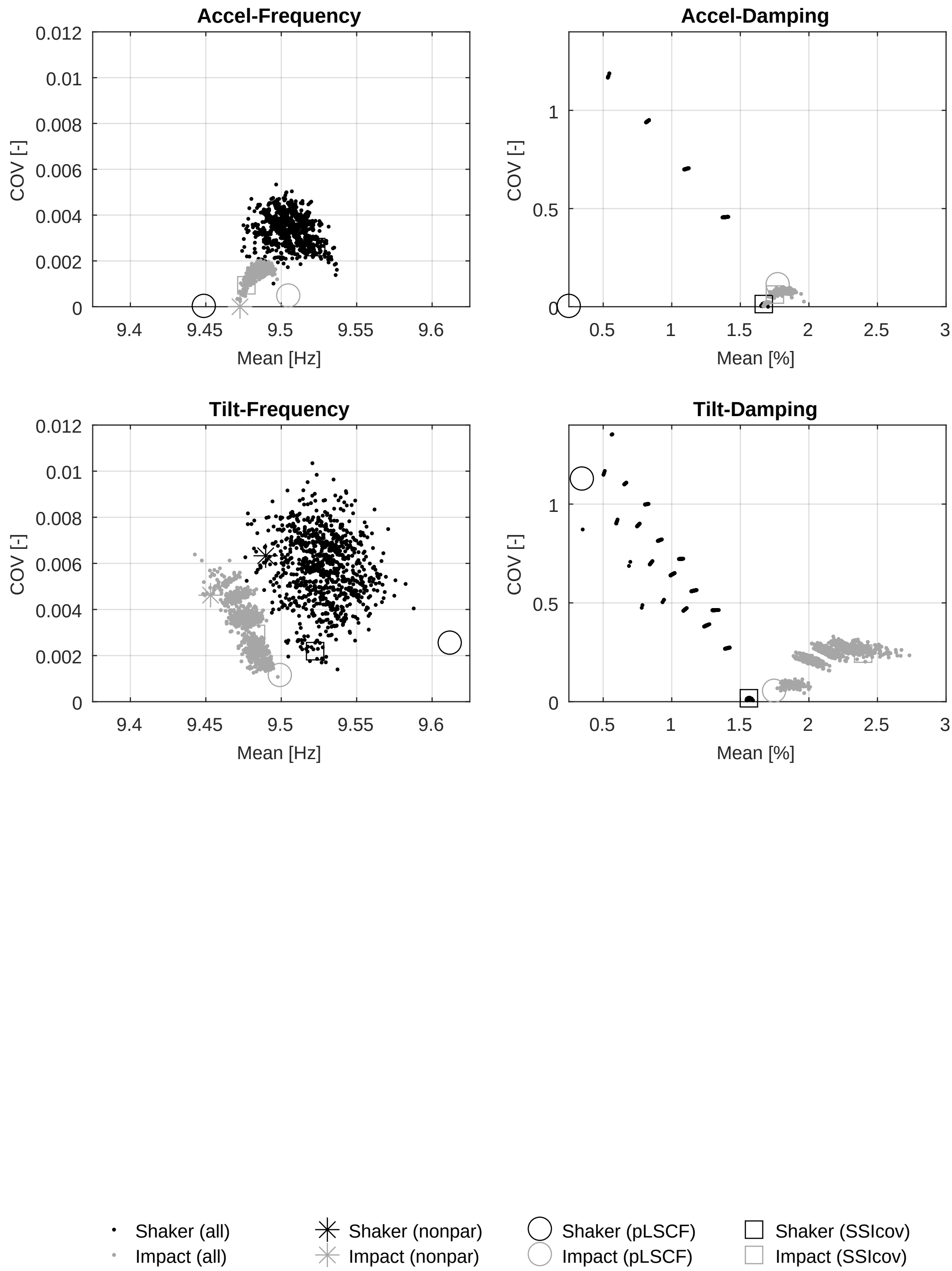
Tab. 5.15: System 5 - FBG results

Mode No.	f_{mean} [Hz]	f_{COV} [-]	ξ_{mean} [%]	ξ_{COV} [-]	$\text{MAC}_{\text{quality}}$	N_{samples}
2	38.22	0.017	5.73	0.588	0.84	12
3	41.43	0.013	1.37	0.503	0.84	9
10	135.60	0.031	6.28	0.333	0.75	9

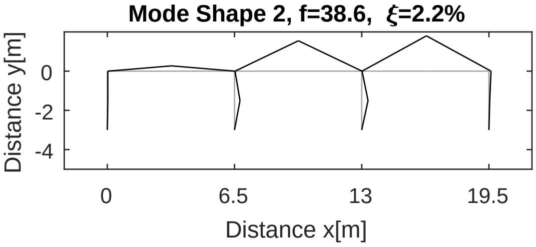
System 5 - Mode 1



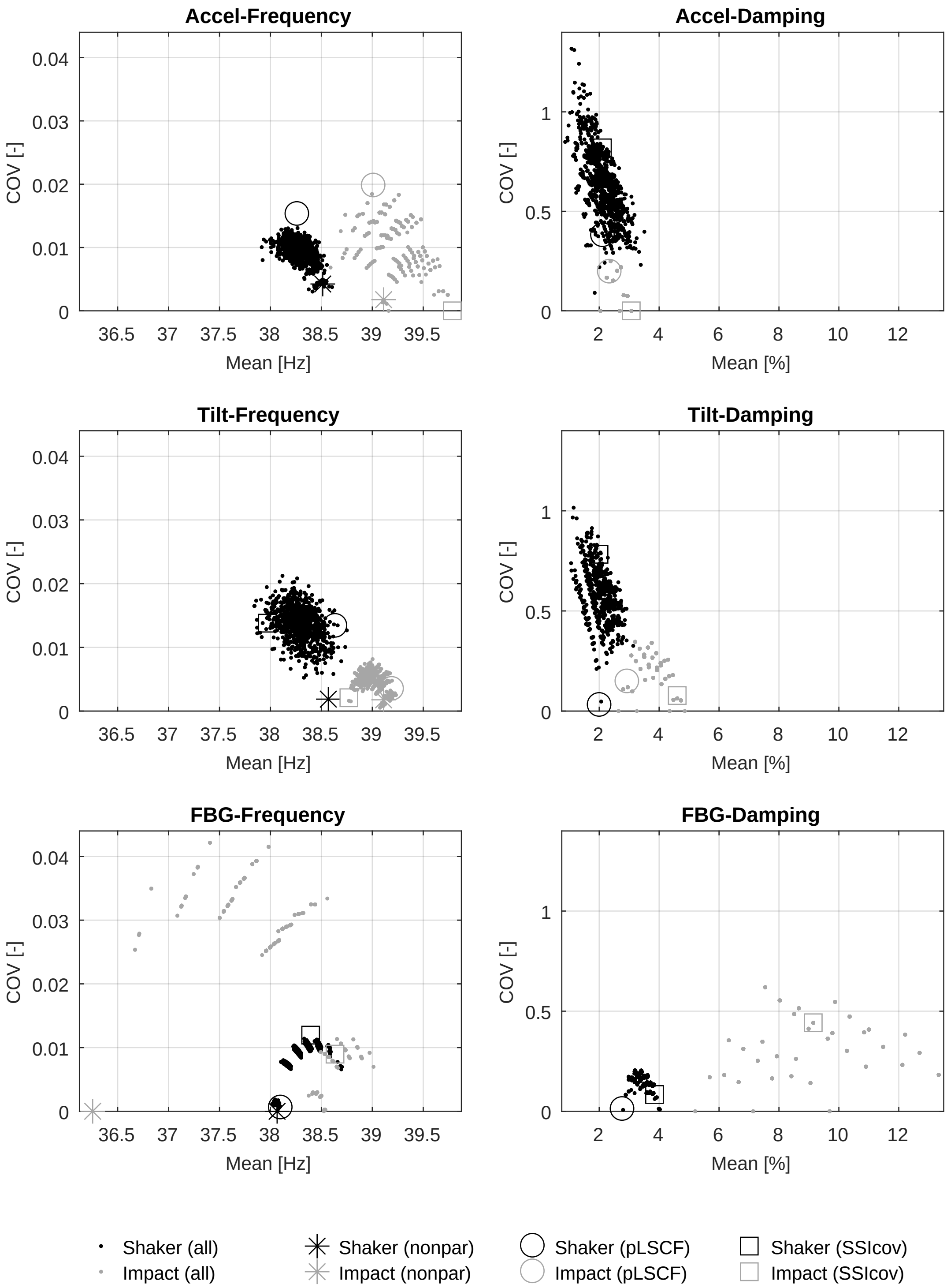
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.99	7	4	8
Tilt	0.99	9	6	10
FBG	-	-	-	-



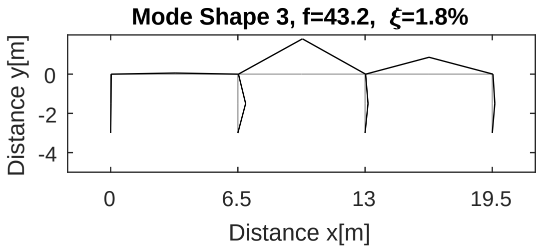
System 5 - Mode 2



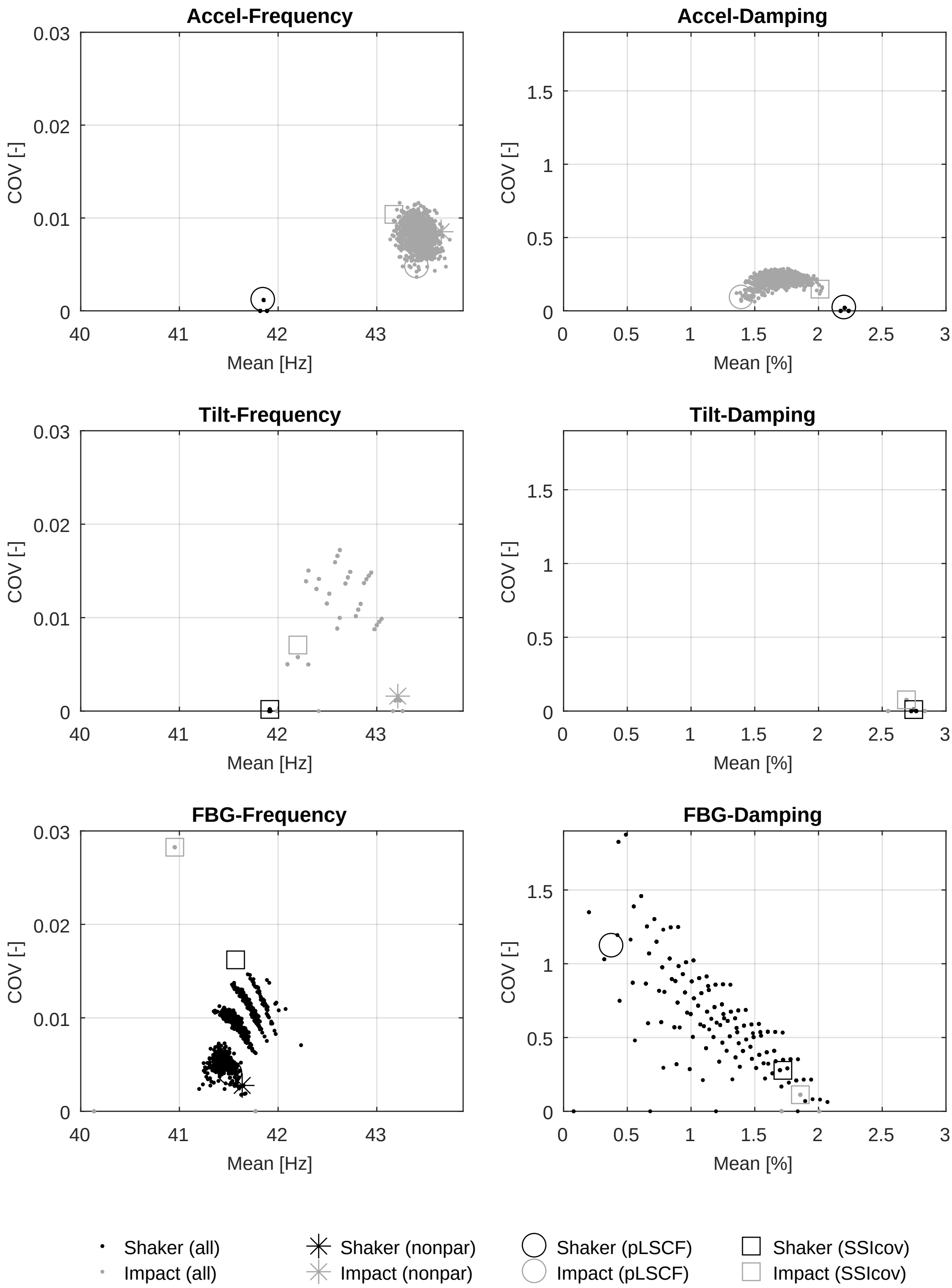
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.79	5	5	7
Tilt	0.84	5	6	9
FBG	0.84	2	2	8



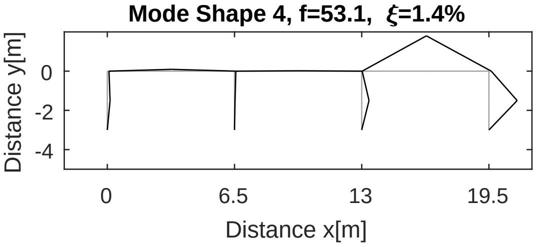
System 5 - Mode 3



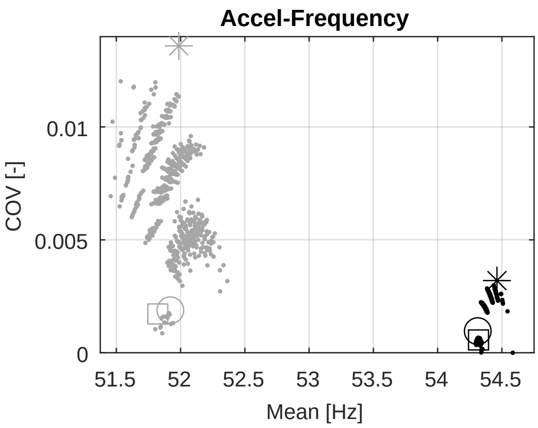
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.95	5	7	4
Tilt	0.86	2	-	4
FBG	0.84	2	2	5

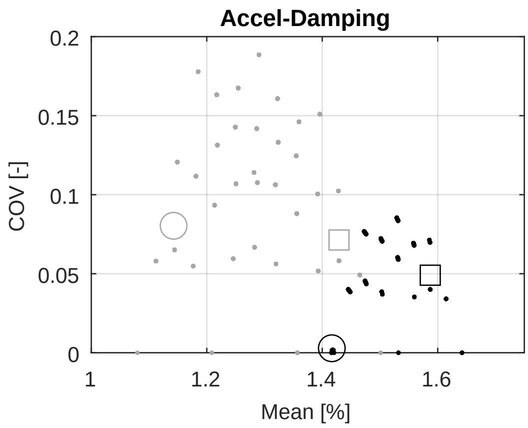


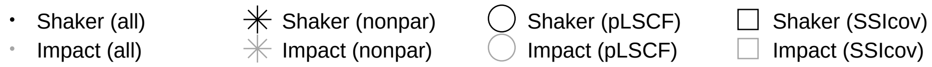
System 5 - Mode 4



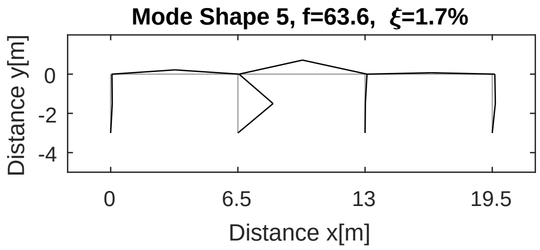
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.94	5	4	4
Tilt	-	-	-	-
FBG	-	-	-	-



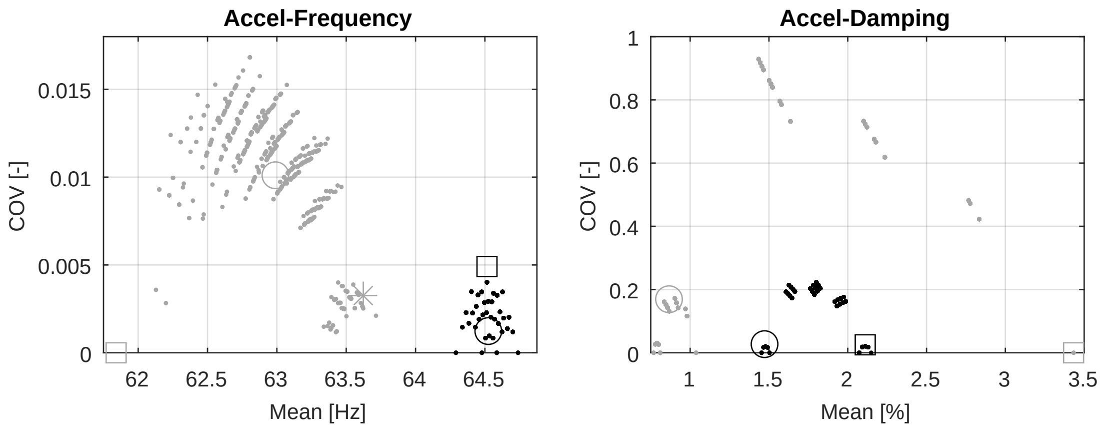


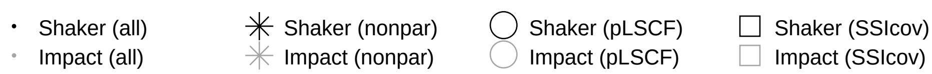


System 5 - Mode 5

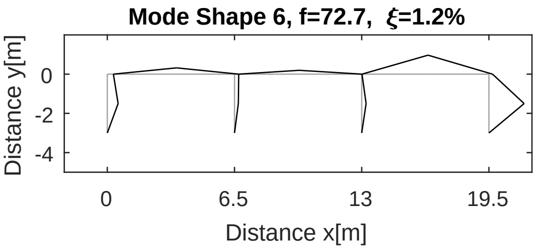


Sensor	$\mathrm{MAC}_{\mathrm{quality}}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.85	2	5	3
Tilt	-	-	-	-
FBG	-	-	-	-

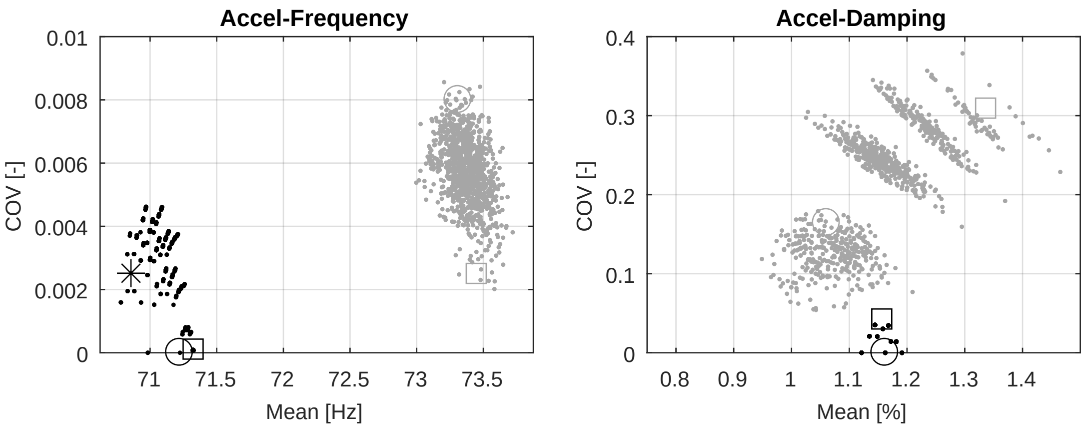


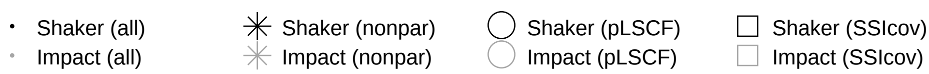


System 5 - Mode 6



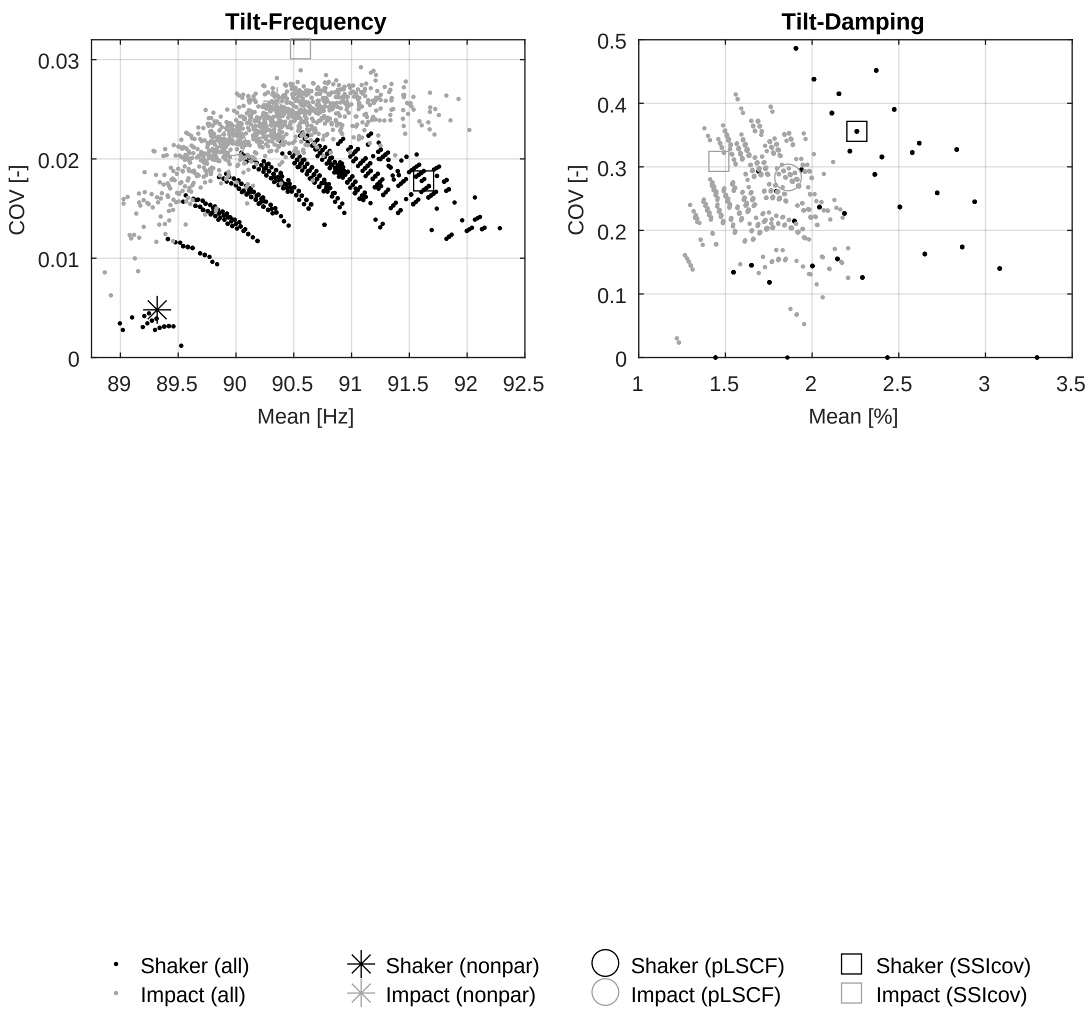
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.86	6	7	5
Tilt	-	-	-	-
FBG	-	-	-	-



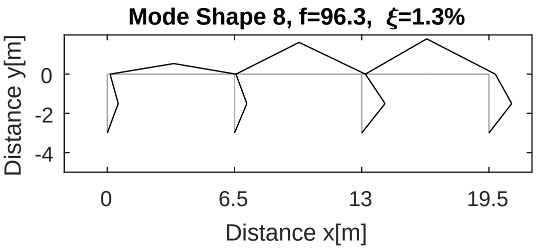


System 5 - Mode 7

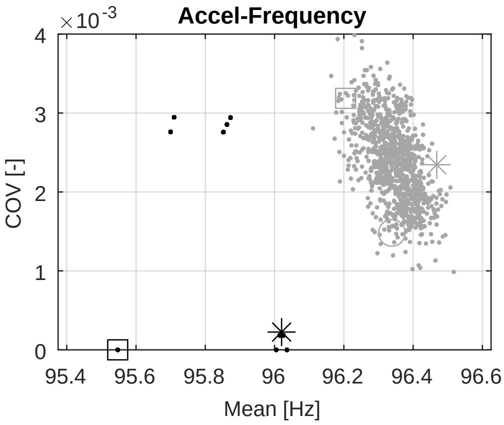
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	-	-	-	-
Tilt	0.92	11	4	7
FBG	-	-	-	-

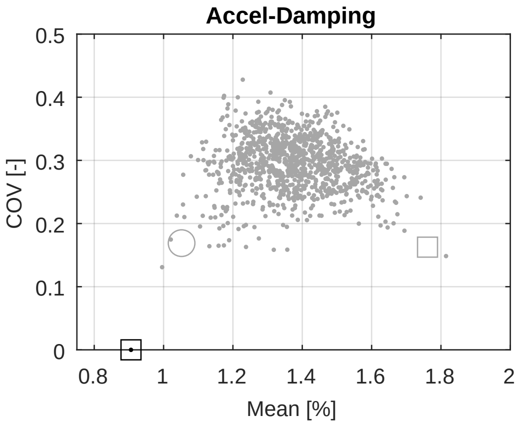


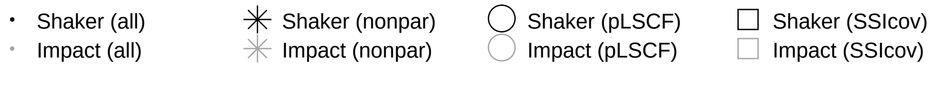
System 5 - Mode 8



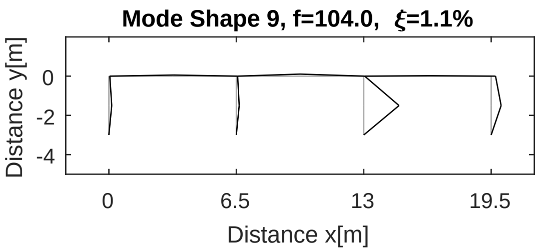
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.84	8	6	6
Tilt	-	-	-	-
FBG	-	-	-	-



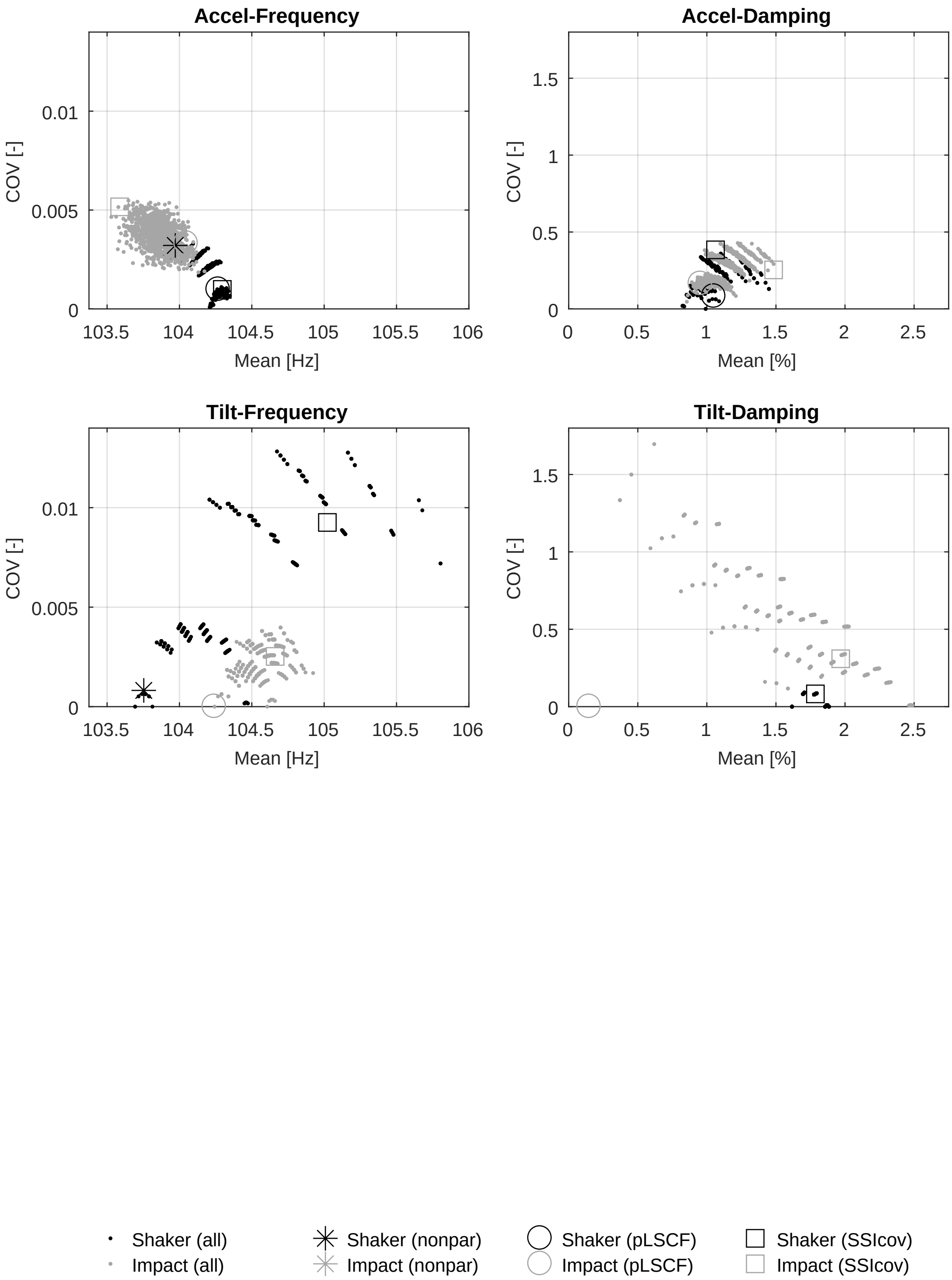




System 5 - Mode 9

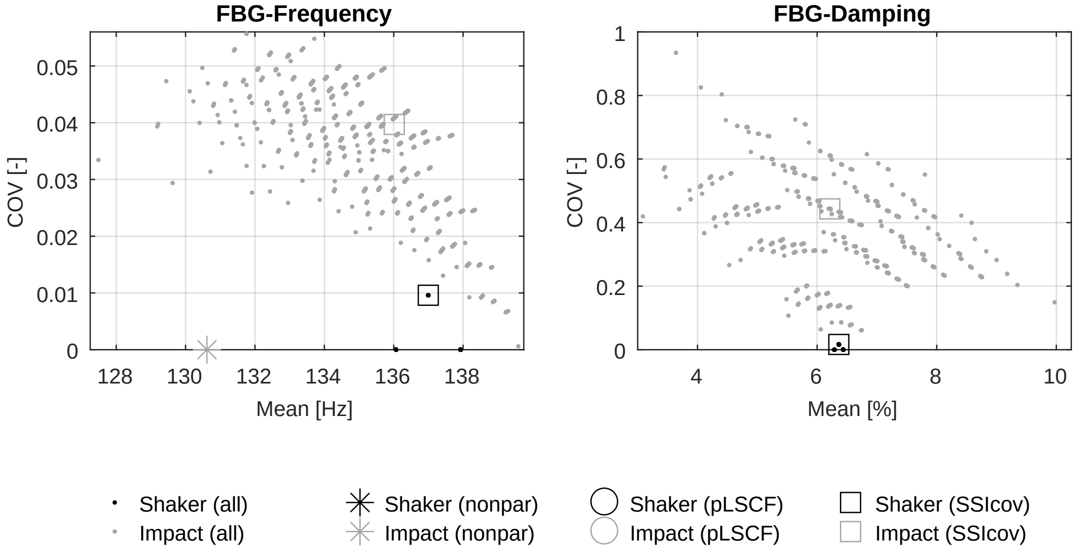


Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.86	6	8	6
Tilt	0.92	2	1	7
FBG	-	-	-	-



System 5 - Mode 10

Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	-	-	-	-
Tilt	-	-	-	-
FBG	0.75	1	-	8



System 6

Tab. 5.16: System 6 - Acceleration results

Mode No.	f_{mean} [Hz]	f_{COV} [-]	ξ_{mean} [%]	ξ_{COV} [-]	$\text{MAC}_{\text{quality}}$	N_{samples}
1	8.58	0.003	1.31	0.326	0.99	20
2	33.96	0.026	4.77	0.831	0.95	13
3	39.25	0.009	3.40	0.393	0.89	12
4	48.49	0.006	2.32	0.216	0.97	14
5	57.12	0.006	1.50	0.302	0.95	23
6	67.43	0.018	1.70	0.523	0.78	17
8	82.11	0.014	1.25	0.353	0.84	14
9	94.28	0.007	0.98	0.193	0.86	29
10	104.73	0.002	1.06	0.174	0.94	38

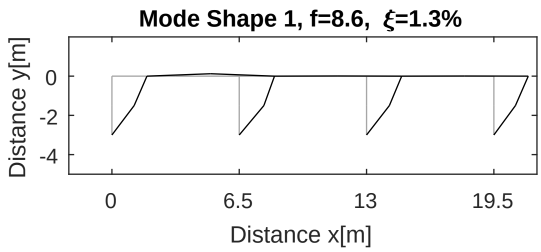
Tab. 5.17: System 6 - Tilt results

Mode No.	f_{mean} [Hz]	f_{COV} [-]	ξ_{mean} [%]	ξ_{COV} [-]	$\text{MAC}_{\text{quality}}$	N_{samples}
1	8.62	0.007	1.99	0.460	0.99	36
3	38.83	0.007	3.22	0.442	0.90	11
4	48.23	0.008	2.81	0.218	0.99	15
5	57.06	0.008	1.78	0.264	0.92	15
6	65.83	0.027	3.04	0.458	0.88	8
7	71.78	0.043	3.08	0.344	0.88	7
8	82.62	0.010	1.74	0.277	0.93	10
9	93.90	0.010	1.37	0.573	0.94	37
10	104.68	0.003	1.02	0.259	0.93	26

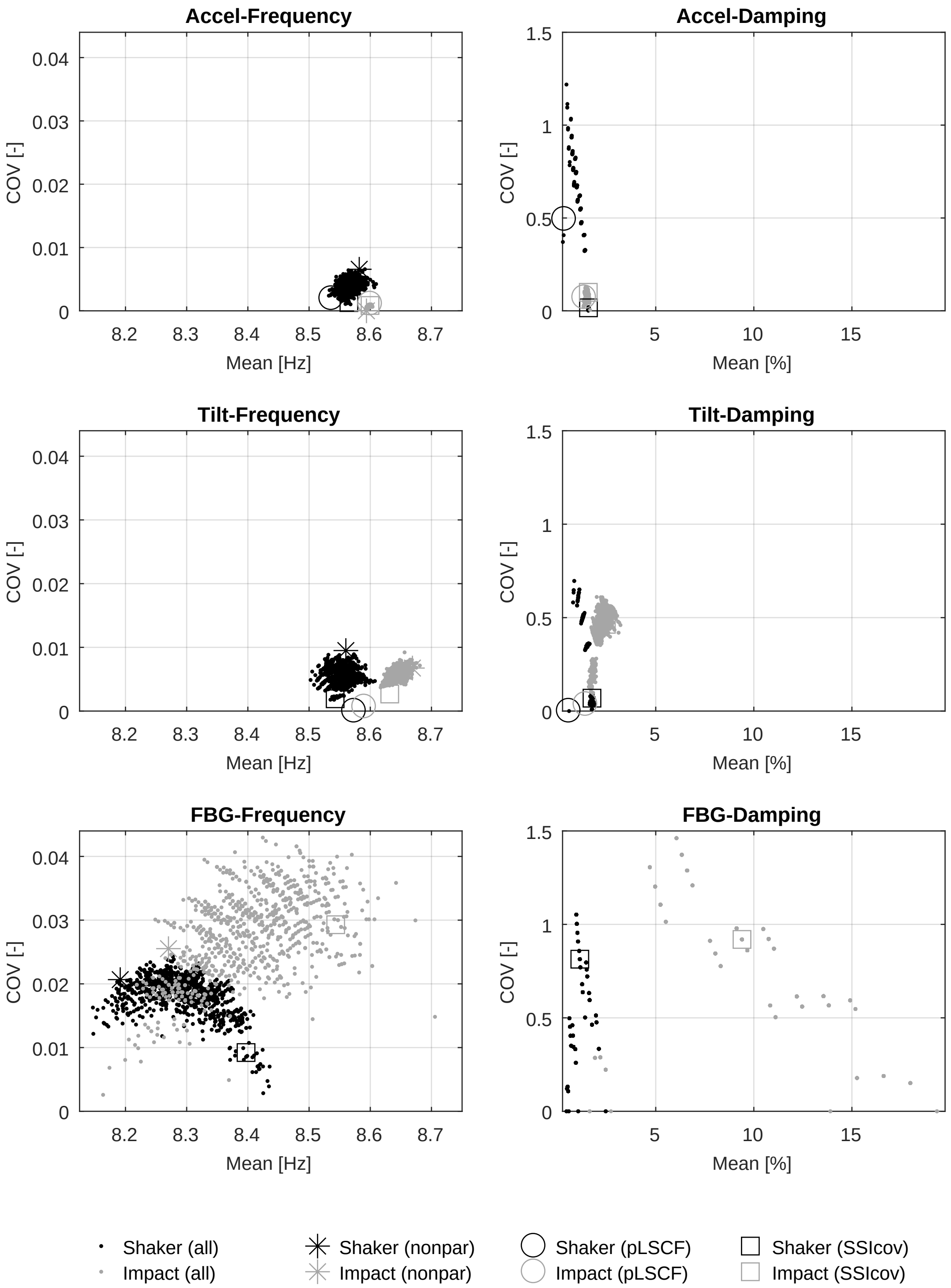
Tab. 5.18: System 6 - FBG results

Mode No.	f_{mean} [Hz]	f_{COV} [-]	ξ_{mean} [%]	ξ_{COV} [-]	$\text{MAC}_{\text{quality}}$	N_{samples}
1	8.35	0.025	5.20	1.211	0.81	16
3	41.14	0.016	2.03	0.689	0.82	10
4	47.90	0.009	3.56	0.772	0.90	8
9	93.74	0.007	2.18	0.270	0.79	7

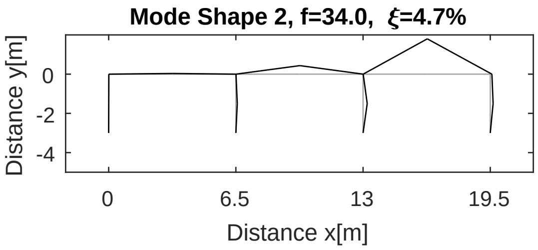
System 6 - Mode 1



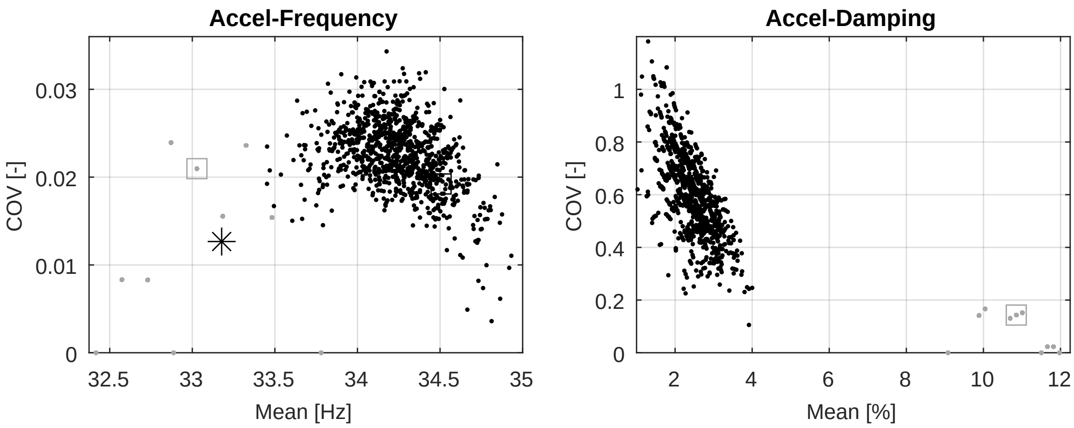
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.99	8	5	7
Tilt	0.99	17	5	14
FBG	0.81	8	-	8

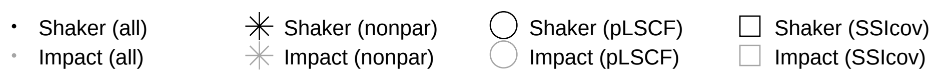


System 6 - Mode 2

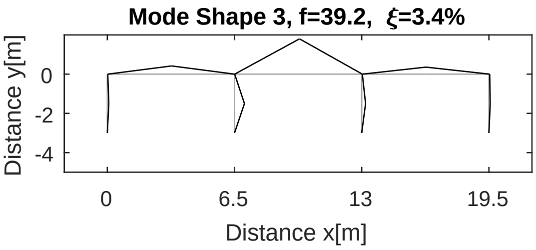


Sensor	$\text{MAC}_{\text{quality}}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.95	2	-	11
Tilt	-	-	-	-
FBG	-	-	-	-

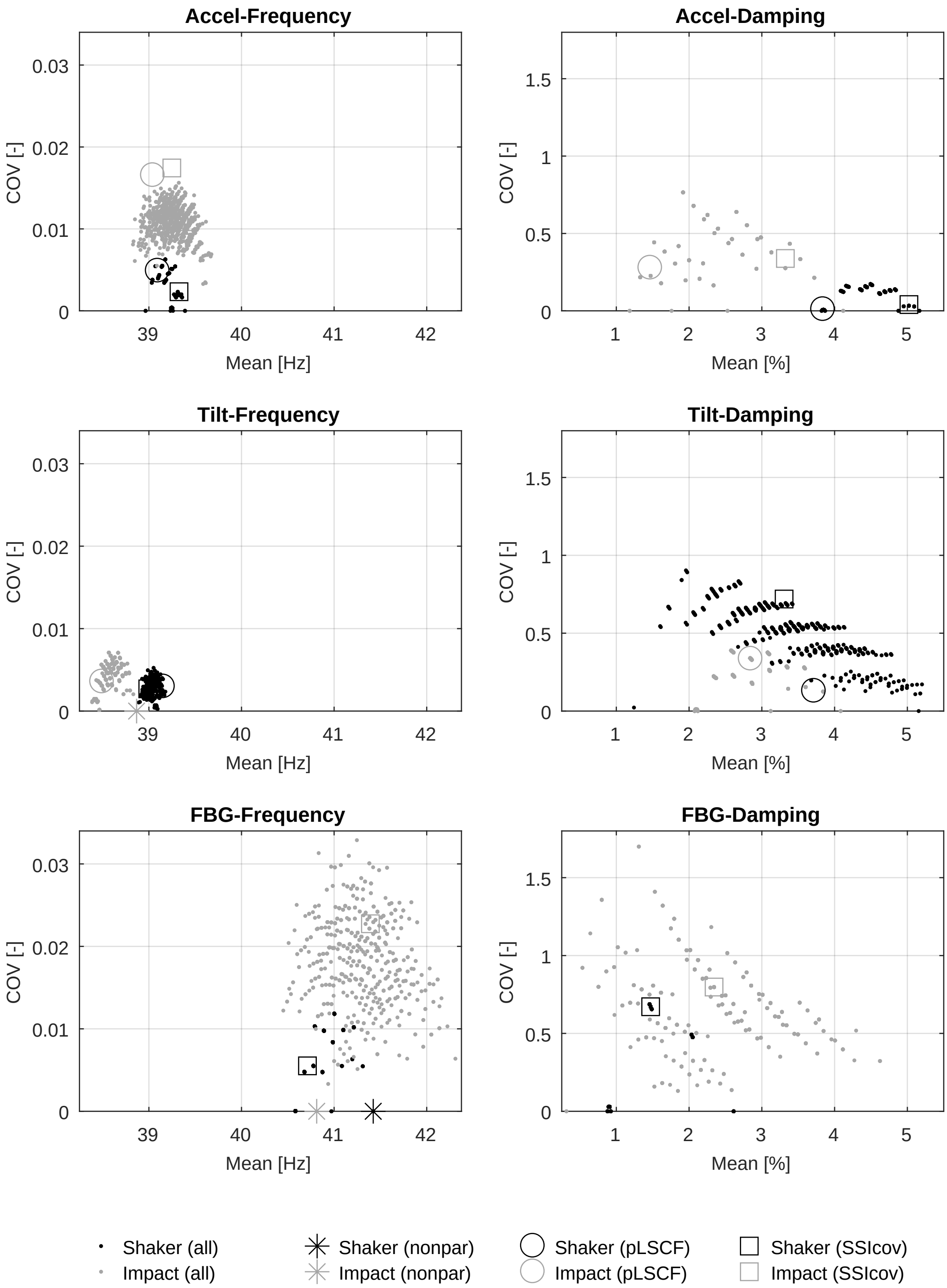




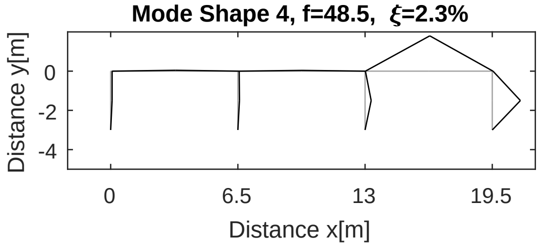
System 6 - Mode 3



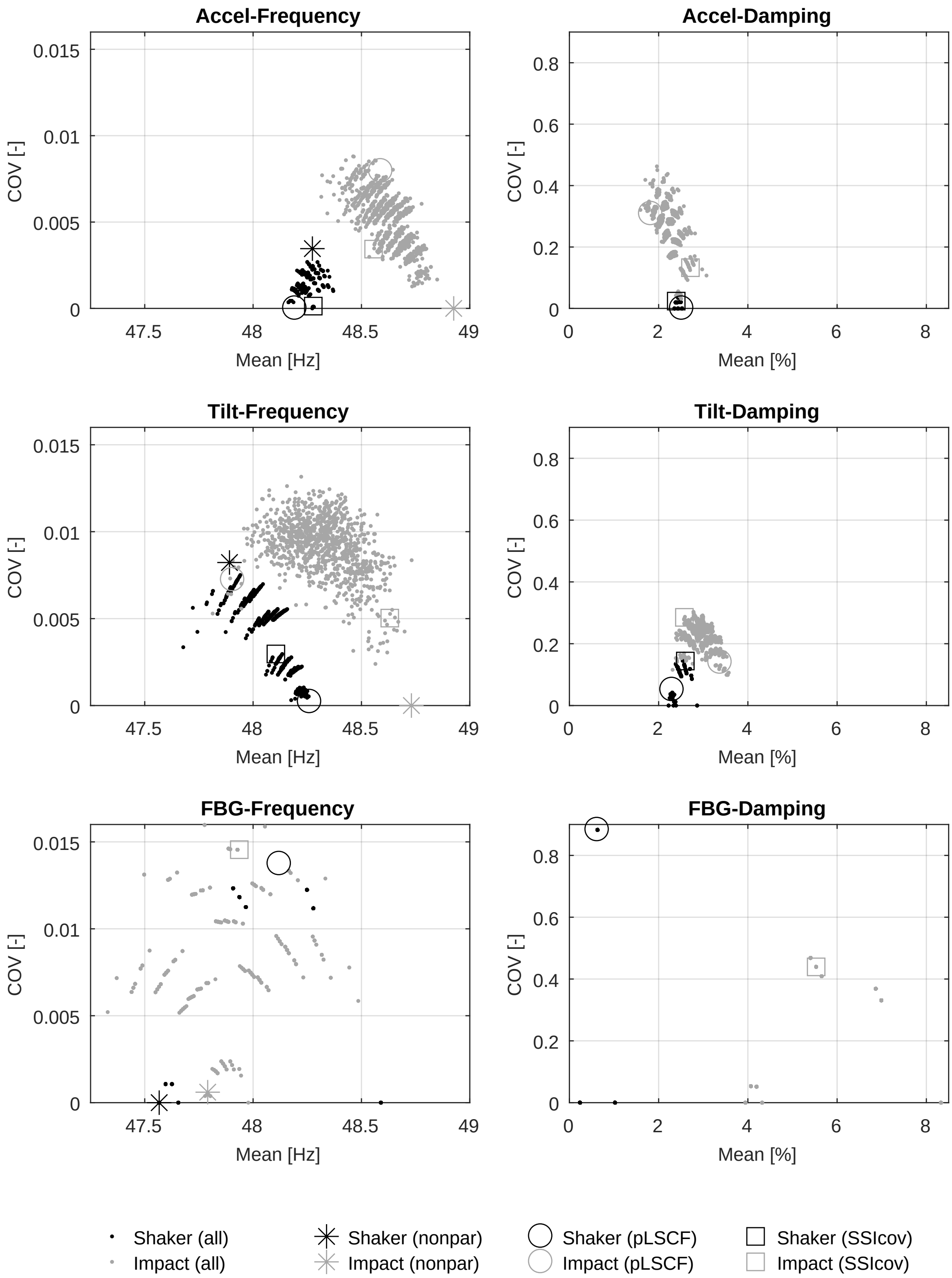
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.89	4	4	4
Tilt	0.90	1	6	4
FBG	0.82	2	-	8



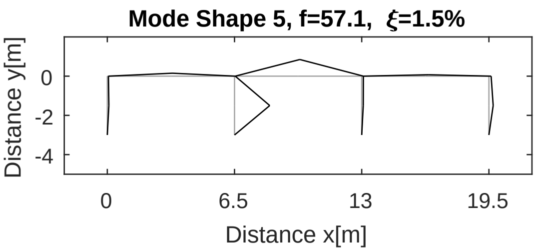
System 6 - Mode 4



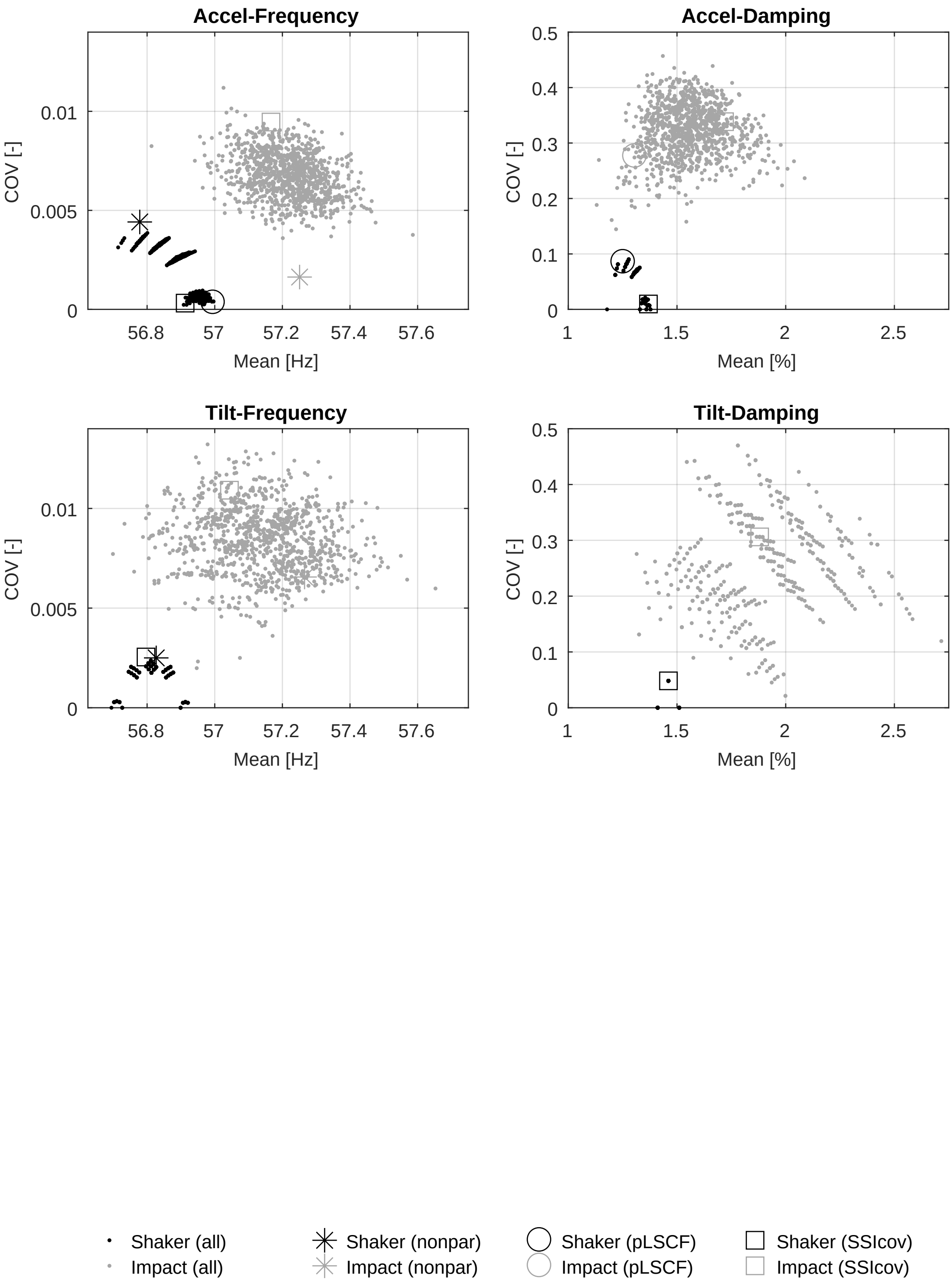
Sensor	MAC$_{\text{quality}}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.97	3	5	6
Tilt	0.99	3	6	6
FBG	0.90	3	2	3



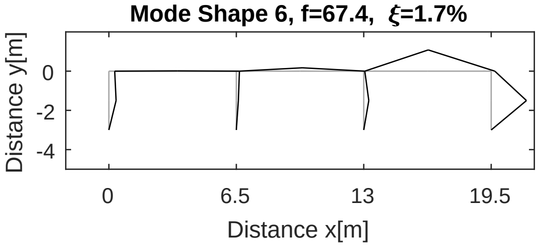
System 6 - Mode 5



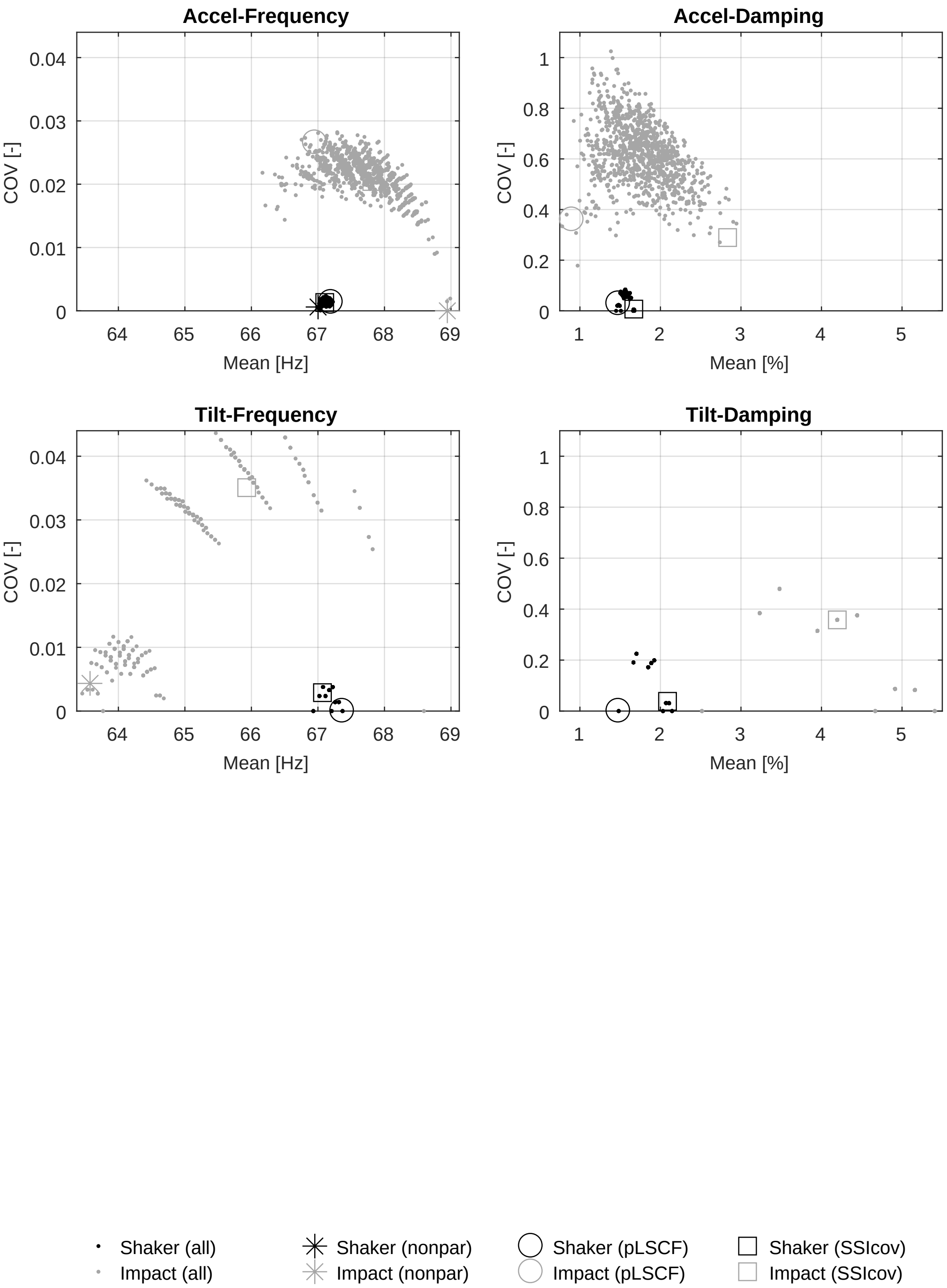
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.95	6	7	10
Tilt	0.92	7	-	8
FBG	-	-	-	-



System 6 - Mode 6

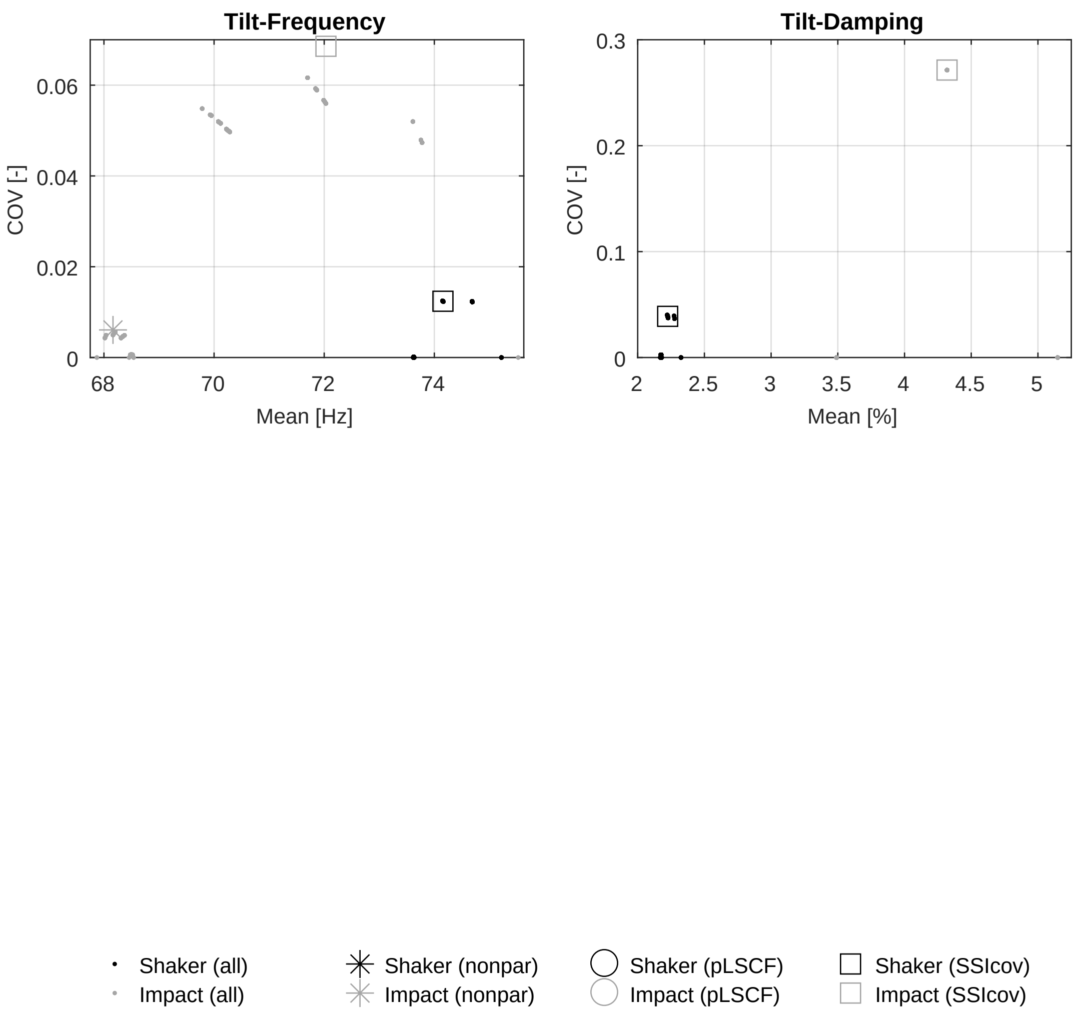


Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.78	4	7	6
Tilt	0.88	2	1	5
FBG	-	-	-	-

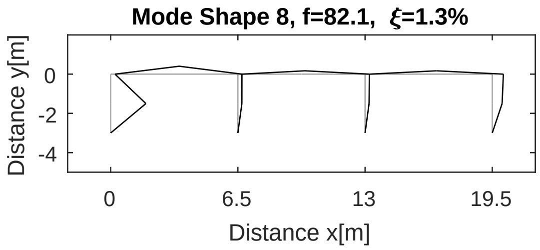


System 6 - Mode 7

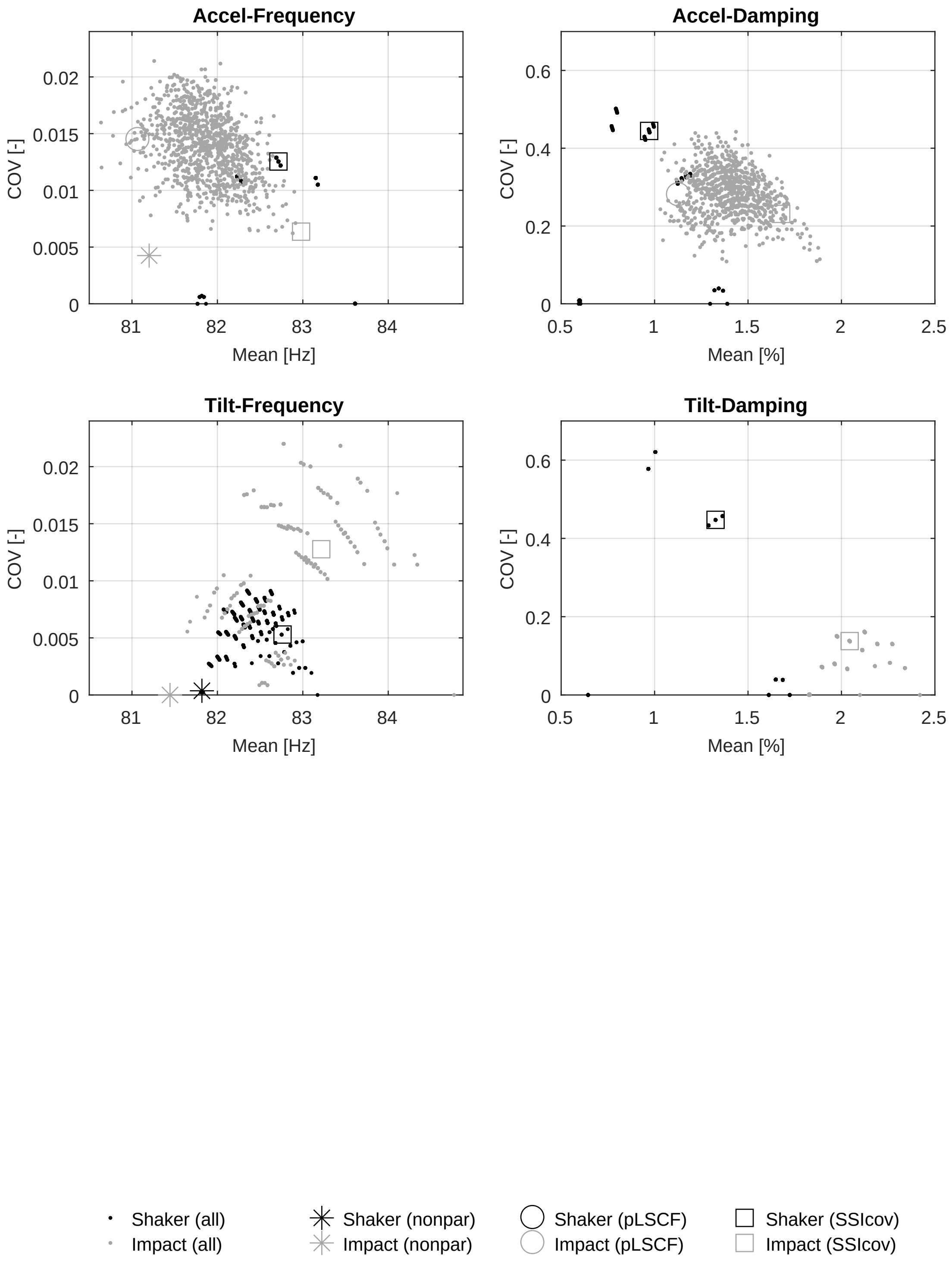
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	-	-	-	-
Tilt	0.88	2	-	5
FBG	-	-	-	-



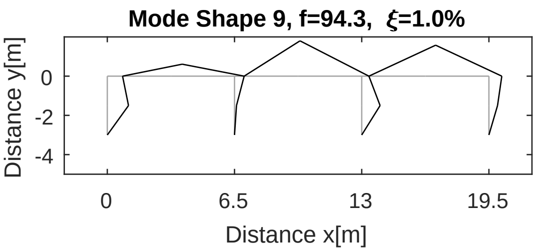
System 6 - Mode 8



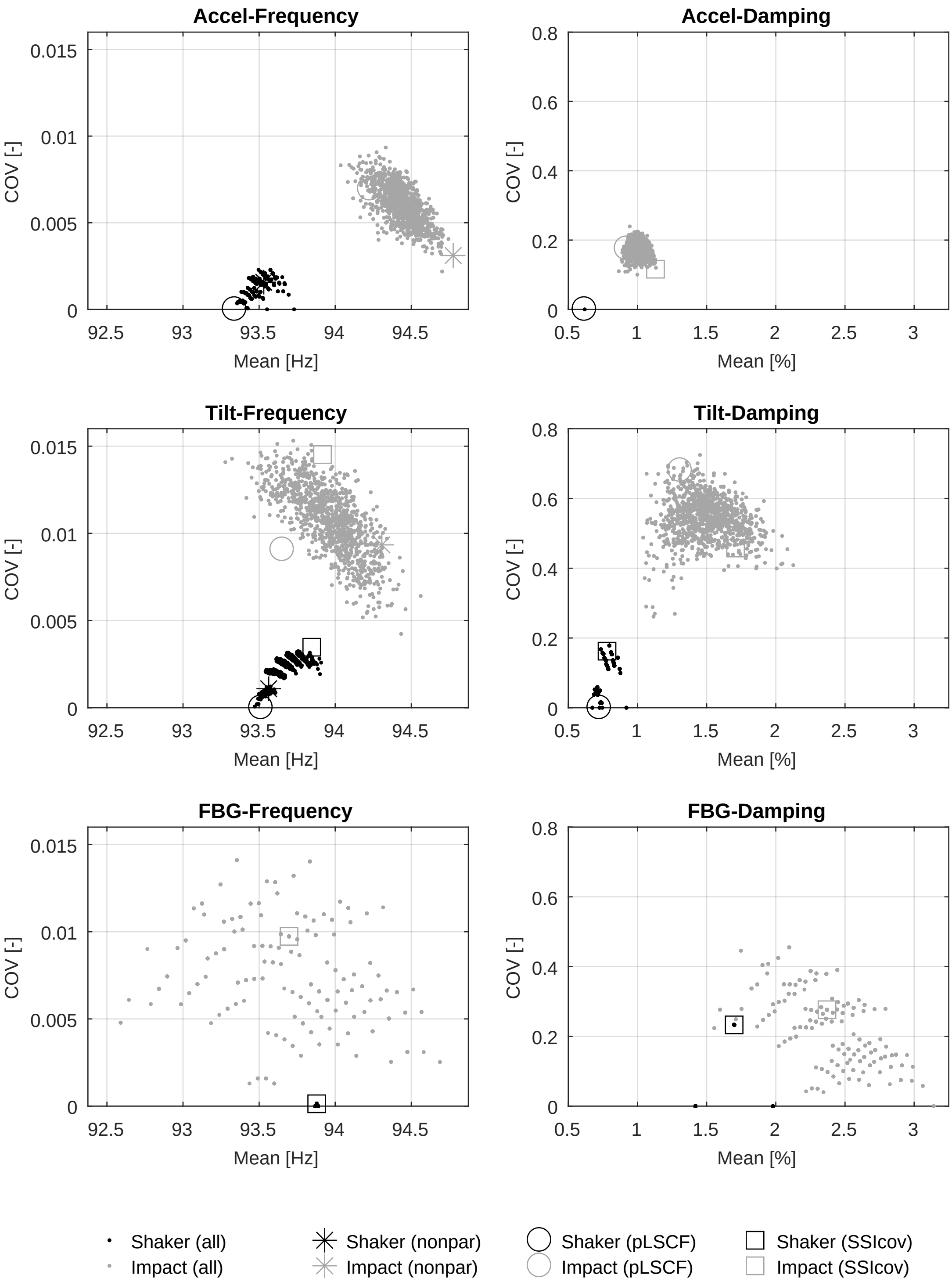
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.84	2	4	8
Tilt	0.93	3	-	7
FBG	-	-	-	-



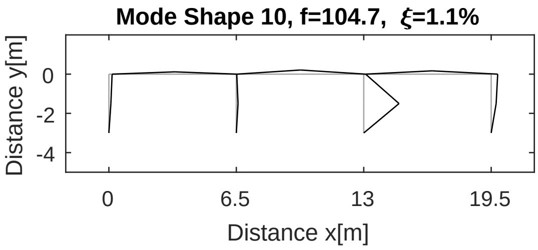
System 6 - Mode 9



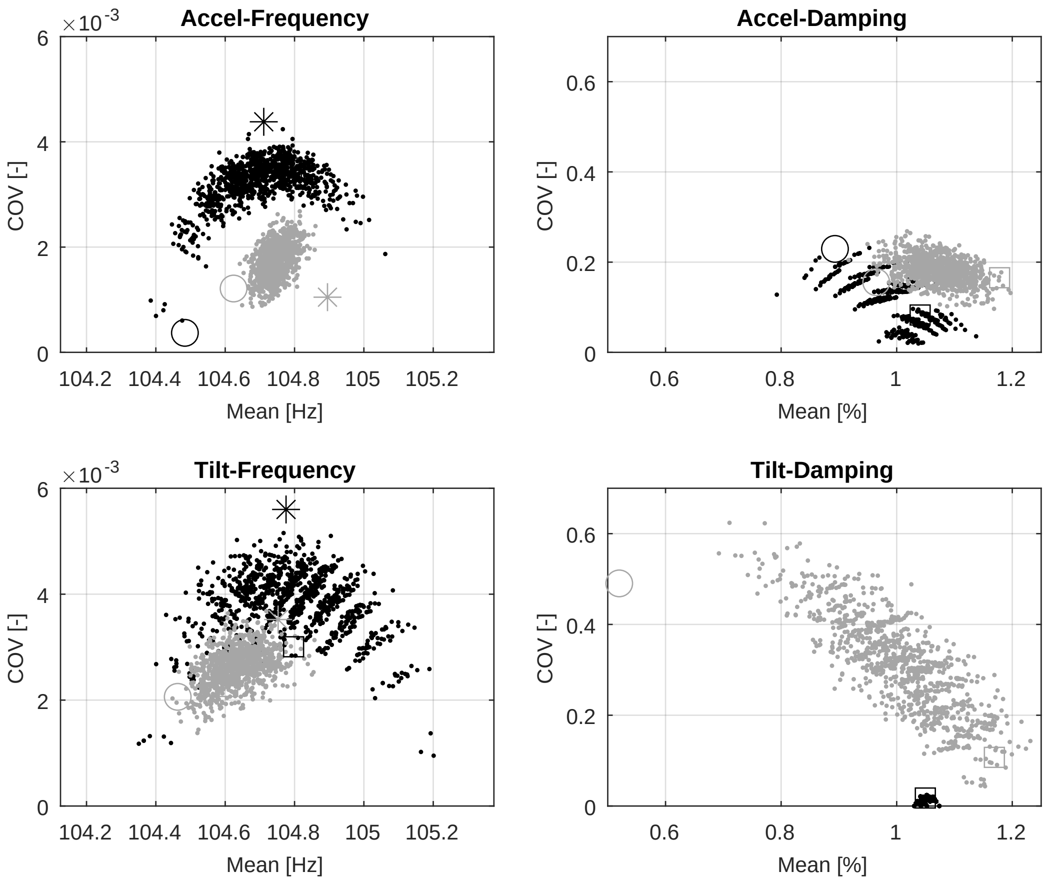
Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.86	10	12	7
Tilt	0.94	14	11	12
FBG	0.79	-	-	7

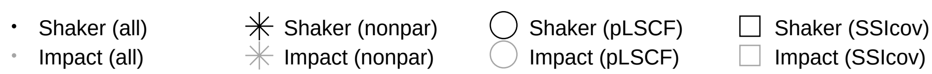


System 6 - Mode 10



Sensor	$MAC_{quality}$	N_{nonpar}	N_{pLSCF}	N_{SSIcov}
Accel.	0.94	12	12	14
Tilt	0.93	10	3	13
FBG	-	-	-	-





5.2.4 QDeadalus - single test results

QDeadalus Impact 1

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
1	P2 (exterior column (top))	h	200		x

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	9.11	0.77	1.00	0.18	9.12±0.09	1.13±1.15	1.00	0.59
2	9.16	1.00	-	-	-	-	-	-	-	-

QDeadalus Impact 2

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
2	P2 (exterior column (top))	h	200		x

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	3.74	0.84	0.99	0.72	-	-	-	-
2	-	-	6.81	1.18	1.00	-0.21	-	-	-	-
3	-	-	9.09	0.92	1.00	-0.21	6.80±0.09	1.50±0.89	1.00	-0.11
4	9.16	1.00	-	-	-	-	-	-	-	-

QDeadalus Impact 3

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
3	P2 (exterior column (top))	h	200		x

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	9.08	1.10	1.00	-0.01	6.75±0.89	1.42±16.08	1.00	0.07
2	9.16	1.00	-	-	-	-	-	-	-	-

QDeadalus Shaker 4

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	fixed
4	P7 (midspan of exterior beam)	h	200		x

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.06	1.00	9.08	1.24	1.00	0.29	9.09±0.86	1.36±10.43	1.00	0.40
2	-	-	-	-	-	-	16.44±0.07	0.05±0.35	0.74	-7.29

QDeadalus Shaker 5

Test	Position	Orientation	P_0	Columns	
No.		vert/hor	[kN]	pinned	fixed
5	P7 (midspan of exterior beam)	h	200		x

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.33	1.00	9.32	0.25	1.00	-0.00	9.29±0.02	0.76±0.15	1.00	0.49
2	-	-	-	-	-	-	16.43±0.74	0.02±5.85	0.59	-6.45
3	-	-	-	-	-	-	17.39±1.77	1.34±13.02	1.00	0.52

QDeadalus Shaker 6

Test	Position	Orientation	P_0	Columns	
No.		vert/hor	[kN]	pinned	fixed
6	P7 (midspan of exterior beam)	h	200		x

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	9.00	0.23	1.00	-0.09	9.01±0.08	1.25±0.55	1.00	0.47
2	9.14	1.00	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	16.45±0.21	0.06±0.79	0.90	-4.64
4	-	-	-	-	-	-	17.35±0.88	0.97±3.02	0.96	4.84
5	-	-	-	-	-	-	23.88±4.97	0.58±10.99	0.72	12.53

QDeadalus Shaker 7

Test	Position	Orientation	P_0	Columns	
No.		vert/hor	[kN]	pinned	fixed
7	P7 (midspan of exterior beam)	h	200		x

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	9.22	1.00	9.30	0.89	1.00	-0.09	9.26±1.53	0.50±38.14	1.00	0.40

QDeadalus Shaker 8

Test	Position	Orientation	P_0	Columns	
No.		vert/hor	[kN]	pinned	fixed
8	P7 (midspan of exterior beam)	h	600	x	

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	-	-	10.63	1.47	1.00	-0.02	8.48±0.04	1.07±0.61	1.00	0.57
2	8.48	1.00	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	17.19±2.27	0.29±15.47	0.15	-30.29

QDeadalus Shaker 9

Test	Position	Orientation	P_0	Columns	
No.		vert/hor	[kN]	pinned	fixed
9	P7 (midspan of exterior beam)	h	600	x	

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.46	1.00	8.43	1.03	1.00	0.35	9.04±0.67	0.46±5.57	1.00	0.68

QDeadalus Shaker 10

Test	Position	Orientation	P_0	Columns	
No.		vert/hor	[kN]	pinned	fixed
10	P7 (midspan of exterior beam)	h	600	x	

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.46	1.00	8.46	1.04	1.00	0.61	8.50±0.12	1.09±1.65	1.00	0.63
2	-	-	-	-	-	-	9.03±0.52	0.49±5.24	0.45	-16.04
3	-	-	-	-	-	-	17.18±1.87	0.65±13.12	0.87	-4.60

QDeadalus Shaker 11

Test	Position	Orientation	P_0	Columns	
No.		vert/hor	[kN]	pinned	fixed
11	P7 (midspan of exterior beam)	h	600	x	

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.47	1.00	8.45	1.04	1.00	0.58	9.40±0.21	1.98±3.03	1.00	0.88
2	-	-	-	-	-	-	9.03±0.22	0.41±2.56	1.00	1.25

QDeadalus Shaker 12

Test	Position	Orientation	P_0	Columns	
No.		vert/hor	[kN]	pinned	fixed
12	P7 (midspan of exterior beam)	h	600	x	

Mode No.	FDD f [Hz]	FDD MPC [-]	pLSCF f [Hz]	pLSCF ξ [%]	pLSCF MPC [-]	pLSCF MP [°]	SSIcov $f \pm 2\sigma$ [Hz]	SSIcov $\xi \pm 2\sigma$ [Hz]	SSIcov MPC [-]	SSIcov MP [°]
1	8.50	1.00	8.49	1.07	1.00	0.60	9.08±0.22	0.73±1.41	1.00	0.37
2	-	-	-	-	-	-	15.68±1.38	2.71±7.75	1.00	0.02

QDeadalus Shaker 13

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
13	P7 (midspan of exterior beam)	h	600	x	

Mode No.	FDD f [Hz]	FDD MPC [-]	pLSCF f [Hz]	pLSCF ξ [%]	pLSCF MPC [-]	pLSCF MP [°]	SSIcov $f \pm 2\sigma$ [Hz]	SSIcov $\xi \pm 2\sigma$ [Hz]	SSIcov MPC [-]	SSIcov MP [°]
1	8.50	1.00	8.48	1.13	1.00	0.67	9.06±0.20	0.50±1.56	1.00	-0.21
2	-	-	-	-	-	-	16.59±1.19	3.13±5.78	0.95	-2.36

QDeadalus Shaker 14

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
14	P7 (midspan of exterior beam)	h	600	x	

Mode No.	FDD f [Hz]	FDD MPC [-]	pLSCF f [Hz]	pLSCF ξ [%]	pLSCF MPC [-]	pLSCF MP [°]	SSIcov $f \pm 2\sigma$ [Hz]	SSIcov $\xi \pm 2\sigma$ [Hz]	SSIcov MPC [-]	SSIcov MP [°]
1	8.51	1.00	8.51	1.06	1.00	0.55	9.79±1.47	1.07±17.56	1.00	0.55

QDeadalus Shaker 15

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
15	P7 (midspan of exterior beam)	h	600	x	

Mode No.	FDD f [Hz]	FDD MPC [-]	pLSCF f [Hz]	pLSCF ξ [%]	pLSCF MPC [-]	pLSCF MP [°]	SSIcov $f \pm 2\sigma$ [Hz]	SSIcov $\xi \pm 2\sigma$ [Hz]	SSIcov MPC [-]	SSIcov MP [°]
1	8.54	1.00	8.53	1.08	1.00	0.80	8.56±0.03	1.07±0.33	1.00	0.78
2	-	-	-	-	-	-	16.94±1.77	4.25±11.23	0.99	-0.85
3	-	-	-	-	-	-	17.11±0.86	1.08±5.28	0.85	-8.68
4	-	-	-	-	-	-	22.27±1.90	2.86±8.13	0.87	-1.49

QDeadalus Shaker 16

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed
16	P7 (midspan of exterior beam)	h	600	x	

Mode	FDD		pLSCF				SSIcov			
No.	f [Hz]	MPC [-]	f [Hz]	ξ [%]	MPC [-]	MP [°]	$f \pm 2\sigma$ [Hz]	$\xi \pm 2\sigma$ [Hz]	MPC [-]	MP [°]
1	8.54	1.00	8.53	1.05	1.00	0.77	8.54±0.03	1.16±0.34	1.00	0.78
2	-	-	-	-	-	-	16.27±7.43	5.20±32.04	0.96	-1.24
3	-	-	-	-	-	-	17.14±2.03	1.33±11.71	0.73	15.42
4	-	-	-	-	-	-	24.45±0.90	0.47±4.71	0.87	2.32

Chapter 6

Discussion

6.1 Pushover tests

6.1.1 Rotations in the connection area

The rotations measured at the connections are displayed in Figure 6.1 (grey lines) together with the analytical solution (black lines). The analytical solution is not derived herein but can be found in [39].

The rotations for the inner column are plotted in Figures 6.1(a), 6.1(c) and 6.1(e) (figures on the left), whereas the rotations of the outer column are plotted on the right-side (Figures 6.1(b), 6.1(d) and 6.1(f)). The analytical prediction for the rotations of the inner columns (with two adjacent beams) fits the test data well for both for the total rotations θ_{tot} and the rotations due to shear θ_{GA}. The analytical predictions for the rotations at the outer column, with only one adjacent beam, however, are less accurate. The total rotation is under-predicted by the analytical model, whereas the rotations due to shear are over-predicted.

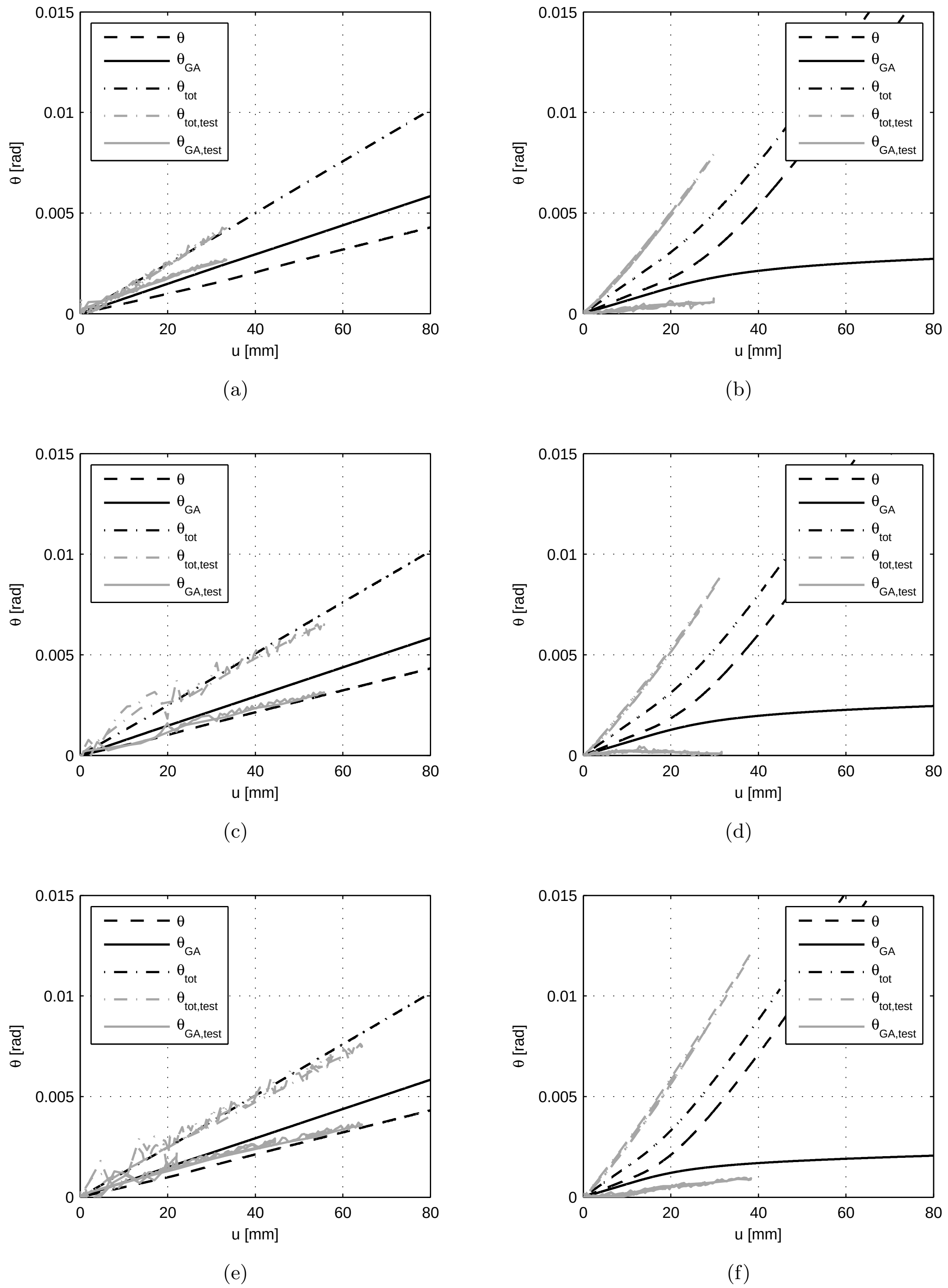


Fig. 6.1: Rotations from tests (grey) and the analytical model (black); Total rotations θ_{tot}, rotations due to shear θ_{GA} and rotations due to the moment θ for different tendon forces P 6.1(a): Inner column P=600 kN 6.1(b): Outer column P=600 kN 6.1(c): Inner column P=500 kN 6.1(d): Outer column P=500 kN 6.1(e): Inner column P=400 kN 6.1(f): Outer column P=400 kN

6.1.2 Pushover-curves

The pushover-curves for all tests are presented in Figure 6.2 together with the analytical solution, which is independent of the tendon force. The analytical solution matches the results for the tests with a tendon force of 600 kN and 500 kN, respectively. The higher the tendon force is, the better the match between the analytical model and the test results.

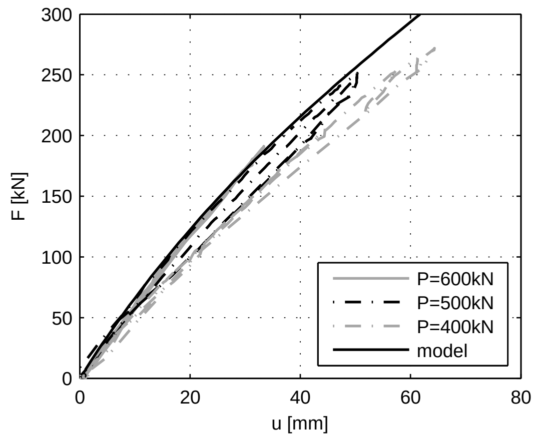


Fig. 6.2: Pushover-curves for a tendon force of 600 kN, 500 kN and 400 kN including the pushover-curve obtained from the analytical solution

The results of the experimental analysis show the favourable structural behaviour of the developed post-tensioned timber frame. The frame can deform under horizontal loads and re-centre itself if the load is reduced. Nearly no damage occurred during the tests and only minor residual deformations were observed. The three test series with tendon forces of 600 kN, 500 kN and 400 kN showed that a loss of 30% tendon force only leads to a minor decrease in horizontal stiffness. A decrease in stiffness of 20% can be observed at a horizontal load of 150 kN by comparing the curves for a tendon force of 600 kN and 400 kN, which corresponds to an increase in lateral displacement of 7 mm.

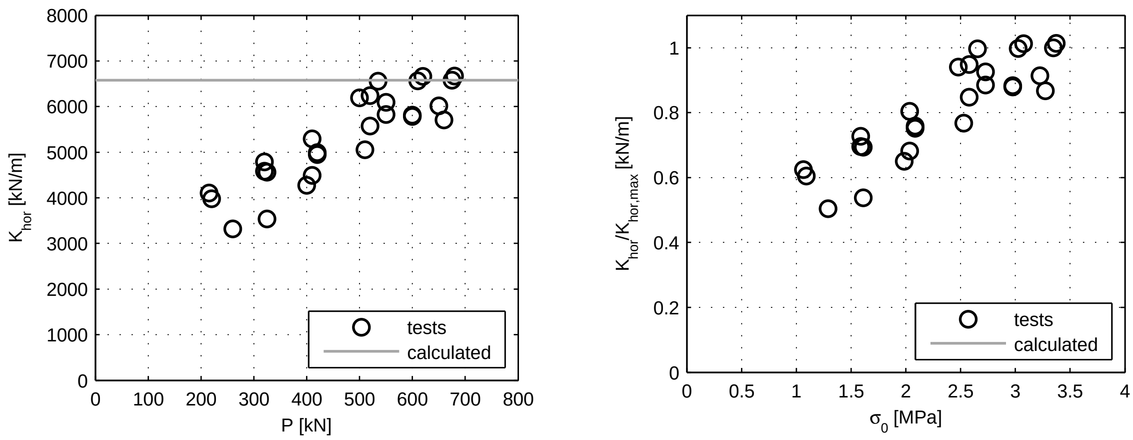
The theoretical horizontal stiffness of a frame with pinned column bases up to the moment of decompression can be calculated with Equations (6.1)-(6.2):

$$K_{tot} = 2 \cdot K_o + 2 \cdot K_i = 136'800\text{kNm/rad} \tag{6.1}$$

and therefore:

$$K_{hor,max} = \frac{F}{u} = \left(\frac{h_c^3}{4 \cdot 3 \cdot E_c \cdot I_c} + \frac{h_c}{4 \cdot G_c \cdot A_c} + \frac{h_c^2}{K_{tot}} \right)^{-1} = 6580\text{kN/m} \tag{6.2}$$

The initial stiffness of the frame is measured for each test and is illustrated in Figure 6.3(a). It can be noted, that the tests match the calculated stiffness for higher tendon forces, whereas the system behaves softer than predicted for lower tendon forces. This was already the case for the model predictions with the post-tensioned timber joint described in [19]. Moreover, a scatter within the tests of equal tendon force is noticeable. This might be due to the low humidity in the test environment, which led to several shrinkage cracks in the specimen (especially in the columns made of ash). Figure 6.3(b) displays the actual stiffness normalized with the theoretical stiffness in function of the initial compressive stress. It is recommended to apply a tendon force that guarantees an initial compressive stress of 2.5 MPa at all times to obtain at least 80% of the analytically calculated stiffness.



(a) (b)

Fig. 6.3: Measured and calculated initial horizontal stiffness for the post-tensioned timber frame specimen 6.3(a): Stiffness versus tendon force 6.3(b): Stiffness normalized with theoretical stiffness versus initial compressive stress

The pushover-curves for a test with fixed and pinned column bases are shown in Figure 6.4 for a tendon force of 500 kN. The fixed column bases reduce the lateral deformations especially for higher lateral loads.

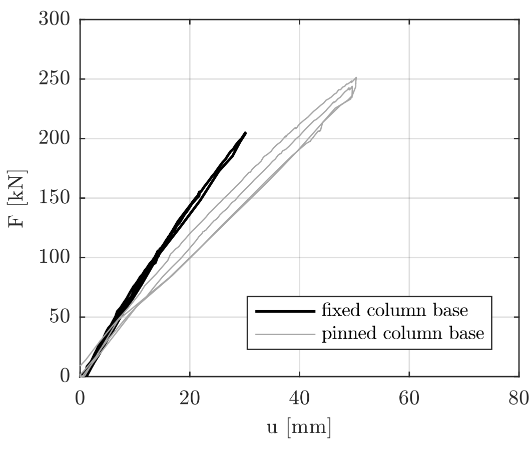


Fig. 6.4: Pushover-curves for a tendon force of 500 kN with fixed and pinned column connections

6.2 Dynamic tests

The results of single impact hammer tests and shaker tests are presented in the previous chapter, along with results from tests using the QDeadalus measurement system. The following discussion focuses on the main 70 impact hammer tests and 48 shaker tests and the results obtained for the accelerometers, tiltmeters, and FBG sensors. In addition, three different evaluation methods were implemented (nonpar, pLSCF, SSIcov). The effect of excitation technique, sensor type and evaluation method on the results will be discussed in the following paragraphs. Furthermore, a comparison of the six structural systems, based on the acceleration data, will be presented.

In general it can be noted, that the coefficient of variation for the frequency results is in the magnitude of 1%, whereas the COV of damping ratio results is in the magnitude of 30%, i.e., the estimation of frequencies is quite consistent throughout the testing series, whereas the estimation of damping ratios presents a large variation. The COV is similar for low and high frequency modes, i.e., it is not frequency-dependent. The quality of the identified mode shapes (herein measured with the mean of the off-diagonal values of the MAC-matrix), however, decreases for higher modes. In all tests, the fundamental mode is the mode which is identified with the highest quality in terms of $MAC_{quality}$, MPC and MP values.

6.2.1 Influence of the excitation technique

There is a clear difference between the results from the impact hammer tests and the results from the shaker tests. First of all, significantly fewer modes were identified from the shaker test data.

For a large number of modes the frequencies obtained from the shaker data are slightly lower than those obtained from the impact data (by ca. $1-5\%$). The small difference in frequency might stem from the additional mass of the shaker on the structure. The dynamic mass of the timber frame is assumed as the weight of the three beams plus half of the weight of the columns (ca. 2300 kg). The shaker mass is 20 kg, which corresponds to 0.8% of the total mass. This percentage is very low, so it is questionable if this explains the difference in frequency. The shaker mass might however, locally affect modes (e.g. the beam bending mode, where the shaker is mounted). With respect to the mass of a single beam (ca. 620 kg), the shaker produces a 3.2% mass addition. Another explanation for the difference in frequency might be the different evaluation framework (input-output instead of output-only) for the shaker data. For the COV of the frequency results from different tests no clear difference is visible between both excitation techniques.

For the damping ratios, no clear difference between both excitation techniques is visible in terms of the absolute values. The COV, however, is often significantly lower for shaker data than for impact hammer data (especially for acceleration and tilt sensors). One explanation for this could be the longer data records of the shaker tests. Indeed, long data records favour the accurate estimation of damping ratios [40–42].

6.2.2 Influence of the sensor type

Accelerometers and tiltmeters deliver very similar results in terms of values and COV, for both damping ratios and frequencies. Furthermore, certain modes are only identified from tiltmeter data and others only from acceleration data. Especially, the highest mode (around 150 Hz) is only present in the results of the tiltmeter data. In the single test results, this mode is also present in the acceleration data, however, less often, and therefore it is removed in the "comparison between different systems" step of the automated evaluation framework.

The FBG sensor data presents a significantly lower number of identified modes. Furthermore, the COV of the identified modes is substantially higher than for the accelerometers and tiltmeters.

6.2.3 Influence of the evaluation method

Generally, all three evaluation methods deliver consistent results. The SSIcov method identifies the largest number of modes, whereas the nonpar method delivers the lowest number of modes. The COV of the three methods is very similar, especially compared to the influence of the sensor type (FBG) on the COV. For the nonpar method, the number of data points is sometimes extremely low, leading either to very low or very high COV values.

In terms of damping ratios, the damping ratios estimated with the SSIcov method can be twice as high as the damping ratios estimated from the pLSCF method. This discrepancy is partly responsible for the high COV values of damping ratios. The reason for this discrepancy might lie in the poor noise model of the pLSCF method (ARX model fitting).

6.2.4 Comparison of the 6 structural systems

In what follows, the effect of the bottom column connection (pinned or fixed) and the post-tensioning force (400 kN, 500 kN, 650 kN) on the dynamic characteristics of the structure will be studied. For the following explanations and figures, only the results from the acceleration sensors are utilized.

Figure 6.5 presents the MAC-matrices of the mode shapes obtained for all six systems. It can be noted that for each system the mode shapes are nearly perfectly orthogonal to each other (the mean of the off-diagonal elements is maximum 0.08).

In the next step, the seven modes, that appear in most of the six systems, are chosen for a comparison of the dynamic behaviour of the six structural systems. Figures 6.6 and 6.7 present the seven selected mode shapes and a comparison of their frequency values. For the first mode (pure translation mode), a clear influence of the column support is visible, whereas no clear influence of the post-tension force is identifiable. For the 2^{nd} and 3^{rd} mode (beam modes) an influence of the support is present (although less significant than for mode 1) and there seems to be a slight decrease in the mean of the frequency for higher post-tension forces. However, if the two times standard deviation confidence bounds are considered this effect is not noticeable. For modes 4, 5 and 6, the influence of the support is clearly visible as well. For mode 6, there is a clear influence of the post-tension force; an increase in post-tension force leads to a

higher frequency. For mode 7 (bending of 3rd column), no influence of the support nor of the post-tension force is present.
Overall, most modes present higher frequencies for the fixed bottom connection, whereas the increase in post-tension force only has a significant effect on mode 6.
Another observation can be made based on the mode shapes. Mode shapes 2 and 3 are very similar; however, a different beam exhibits the highest amount of bending. This indicates that the stiffness and mass of the three beams is presumably not identical. Indeed, most probably this is applicable to the columns as well and explains the appearance of local modes, such as modes 4, 5 and 7.

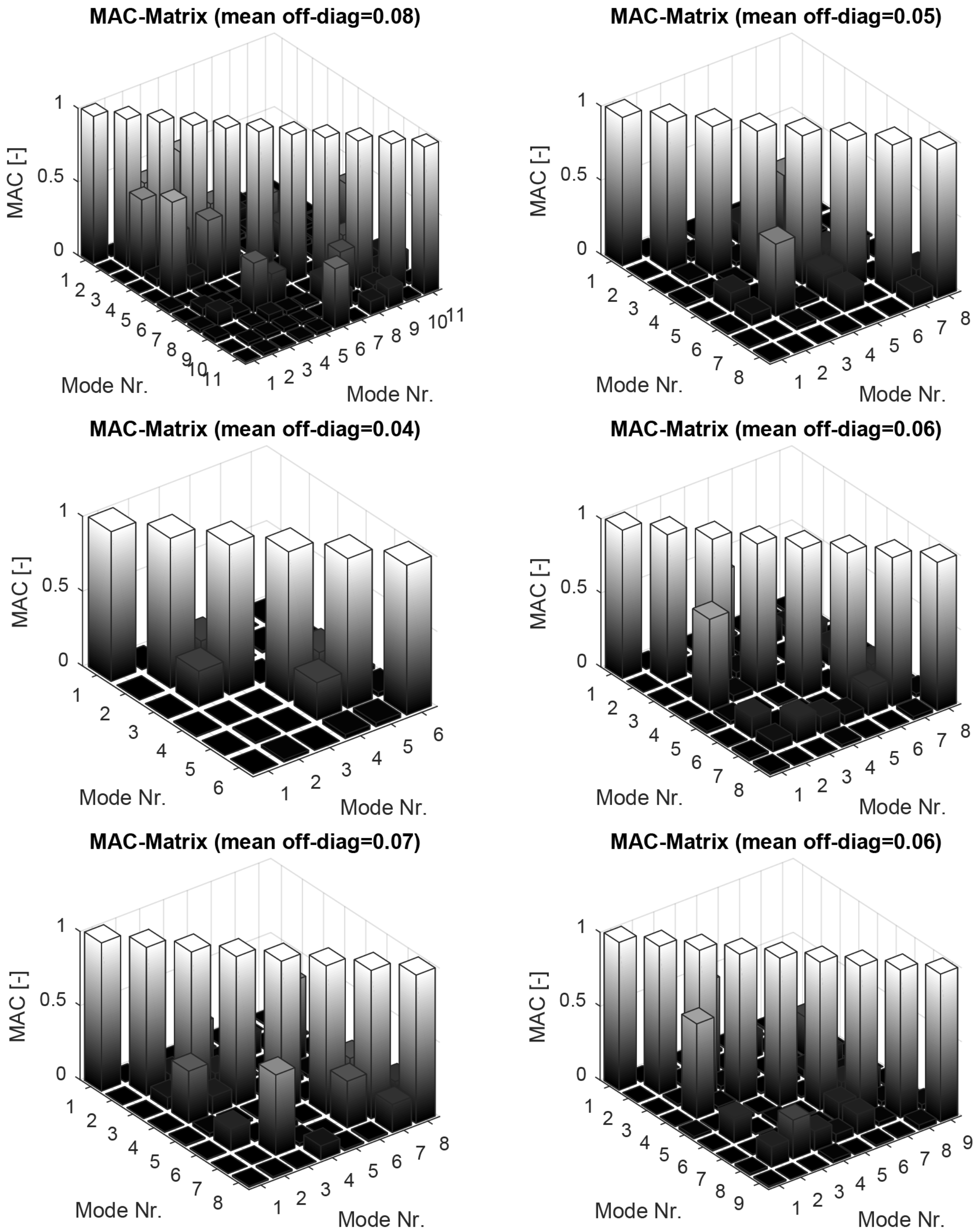


Fig. 6.5: MAC-matrices of the six systems

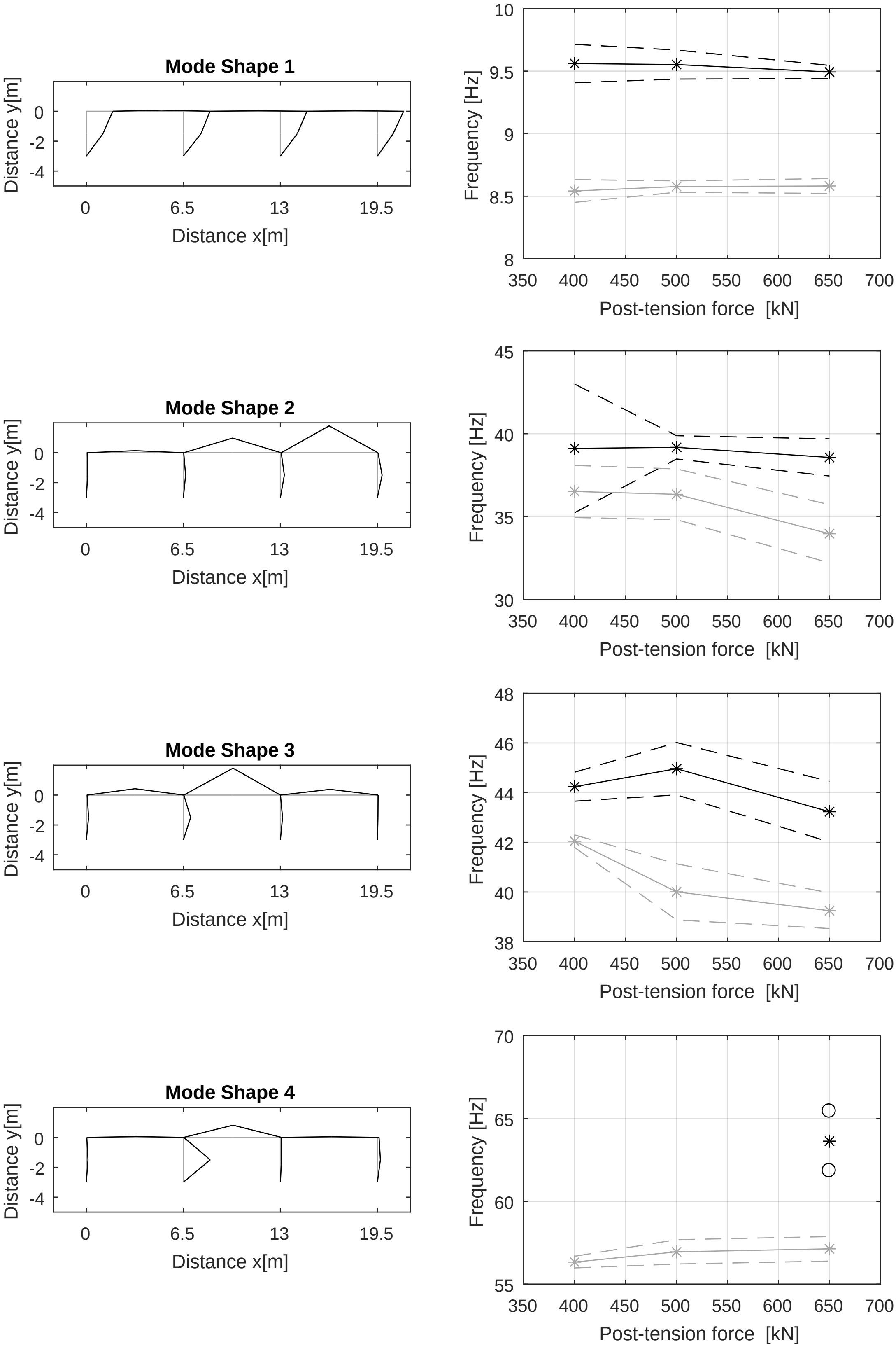


Fig. 6.6: Comparison of the main frequencies 1-4 from the 6 systems (acceleration sensors) (black: semi-rigid bottom connection, grey: pinned bottom connection; continuous line: mean-values, dashed lines: $\pm 2 \cdot \sigma$ confidence bound)

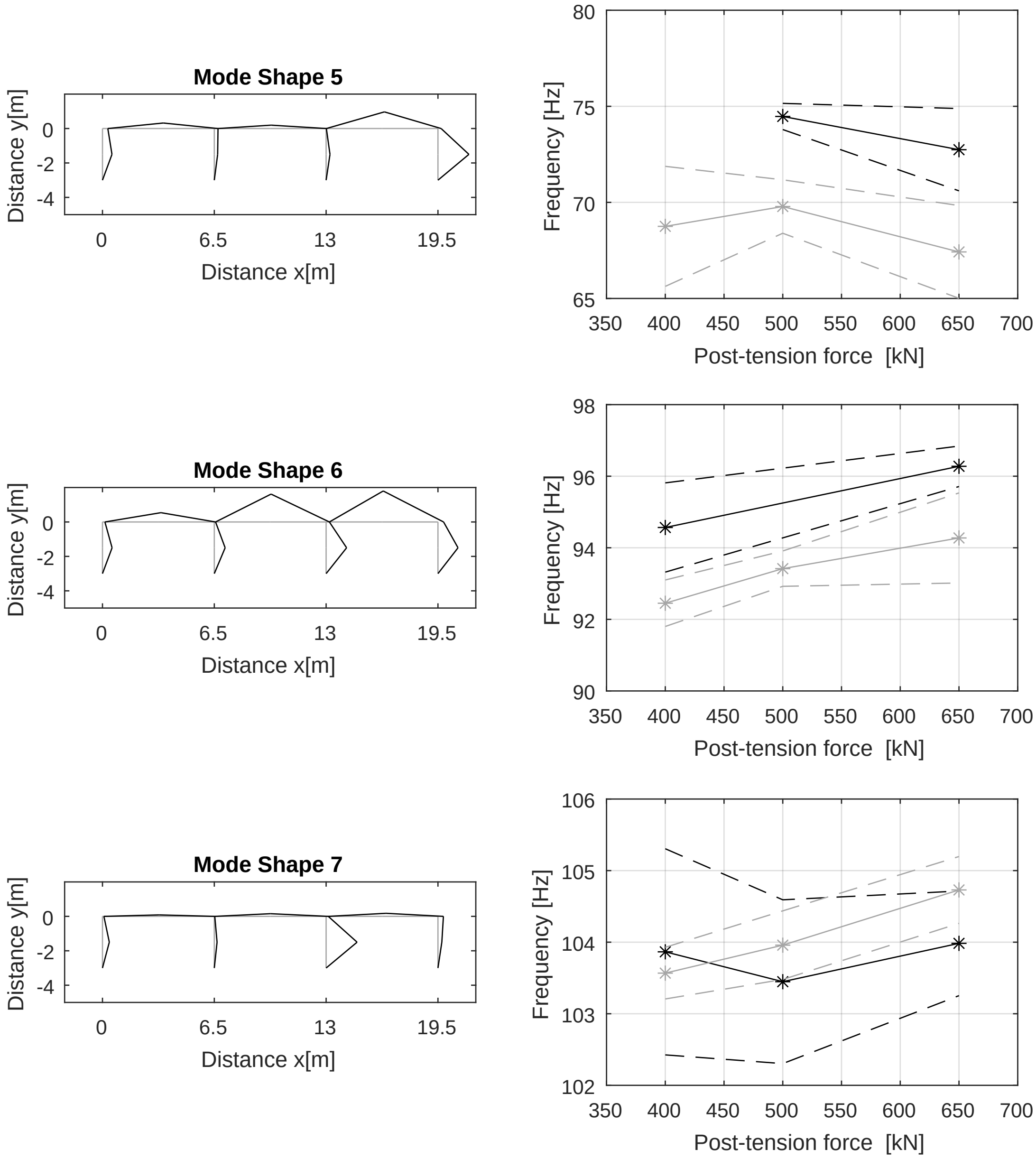


Fig. 6.7: Comparison of the main frequencies 5-7 from the 6 systems (acceleration sensors) (black: semi-rigid bottom connection, grey: pinned bottom connection; continuous line: mean-values, dashed lines: $\pm 2 \cdot \sigma$ confidence bound)

6.2.5 Comparison to a simplified analytical model

A simplified analytical model is proposed. The frame is approximated as a 1 degree of freedom (DOF) system. The mass of the 1-DOF system corresponds to the mass of the three beams and half the mass of the four columns (ca. 2300 kg). The stiffness of the columns is approximated according to Chopra [43], for three different assumptions: first, assuming that the beam is rigid, second that the beam has no stiffness and third with a realistic stiffness ratio between the beam and column stiffness (neglecting shear deformations). All three assumptions neglect the effect of the post-tensioned joint. Table 6.1 presents the obtained results for the fundamental frequency, for a fixed bottom column connection and a pinned bottom column connection. The frequency values range between 8.46Hz and 23.9Hz.

Tab. 6.1: Analytical model - results for different beam stiffness's

Model Id	Bottom connection	Beam stiffness (EI_b)	f_1 [Hz]
1	fixed	0	16.9
2	fixed	∞	23.9
3	fixed	intermediate	22.0
4	pinned	0	8.46
5	pinned	∞	12.0
6	pinned	intermediate	11.0

From a comparison with the test data, it can be noted that the designated "rigid" bottom column connection is not a 100% rigid connection, since the fundamental frequency should be doubled due to the change from pinned to fixed support (according to the analytical model), whereas in the tests the measured increase is only roughly 1 Hz. For the pinned bottom connection the frequency should realistically lie somewhere between the model assuming no stiffness of the beams and the intermediate stiffness ratio between columns and beams, since the post-tensioned joint is not a perfectly rigid joint. The test data lies however, closer to the "no stiffness" assumption. It has to be noted that the 1-DOF model is an extremely simplified model and is purely presented here to verify the order of magnitude of the test data. For subsequent investigations, a numerical model of the structure is developed. This is, however, beyond the scope of this research report and will be presented in related publications.

6.3 Comparison: pushover tests and dynamic tests

The period of the structure can be estimated from the pushover-curves according to [44] for a system with one degree of freedom:

$$T = 2 \cdot \pi \sqrt{\frac{u \cdot W}{F \cdot g}} \tag{6.3}$$

The eigenfrequency is then:

$$f = \frac{1}{T} \tag{6.4}$$

The weight of the superstructure of the frame is approximately 2'300 kg. The obtained values for the eigenfrequencies are summarised in Table 6.2 and compared to the eigenfrequencies obtained from the dynamic tests for a pinned bottom connection. The values were estimated for the pushover-curves at a force F of 150 kN for the second loading cycle.

Tab. 6.2: Estimated eigenfrequencies from impact hammer tests and pushover tests

Tendon force	Eigenfrequency [Hz]	
	Dynamic (mean-values)	Pushover
high (600 – 650kN)	8.54	8.2
intermediate (500kN)	8.58	7.8
low (400kN)	8.58	7.3
fixed column base (500kN)	9.6	8.8

The values estimated from the pushover-curves are smaller than the ones from the dynamic modal vibration tests, especially for the low and intermediate tendon forces. The values from the pushover-curves match the softening behaviour as the tendon force decreases, i.e., the eigenfrequencies get smaller with smaller tendon forces and vice versa. During the dynamic tests, the excitation level is very low, as is the displacement of the test specimen. Therefore, the difference in stiffness between the specimens with the different post-tensioning forces is not measurable.

Chapter 7

Summary

7.1 Pushover tests

The pushover tests on a 2D post-tensioned timber frame demonstrated that the behaviour of the beam-column connections of the outer columns differs from the behaviour of the connections of the inner ones. The tests additionally exhibited a favourable self-centring behaviour of the post-tensioned timber system. Moreover, the tests showed that the lateral stiffness of the frame depends on the tendon force; the higher the tendon force the higher the lateral stiffness and vice versa.

During the pushover tests, an unintended failure occurred in a poorly fabricated finger joint. The system could be loaded again after the failure occurred to an even higher load level, but with an altered lateral stiffness. The tests results were compared with the results obtained from an analytical model, which was already introduced by the authors [25] based on the connection tests for a single column-beam joint tested in vertical loading. The model is able to reproduce the test results for the inner and outer connections equally well and can thereby be validated additionally for horizontal load cases.

7.2 Dynamic tests

The 2D post-tensioned timber frame was subjected to a modal vibration testing campaign (prior to the pushover tests). From this experimental campaign, the main modal characteristics, such as eigenfrequencies, damping ratios and mode shapes of the structure could be determined. Furthermore, the influence of the bottom column support on the dynamic behaviour could be analysed and a significant effect was noticed. The analysis of the influence of the tendon force level on the dynamic behaviour revealed that there is no significant influence of the post-tension load for forces ranging from 400 to 650 kN. The eigenfrequencies determined from the static pushover tests are in good agreement with the fundamental eigenfrequencies determined from the dynamic tests.

Appendix A

Drawings

A.1 Specimen and test setup

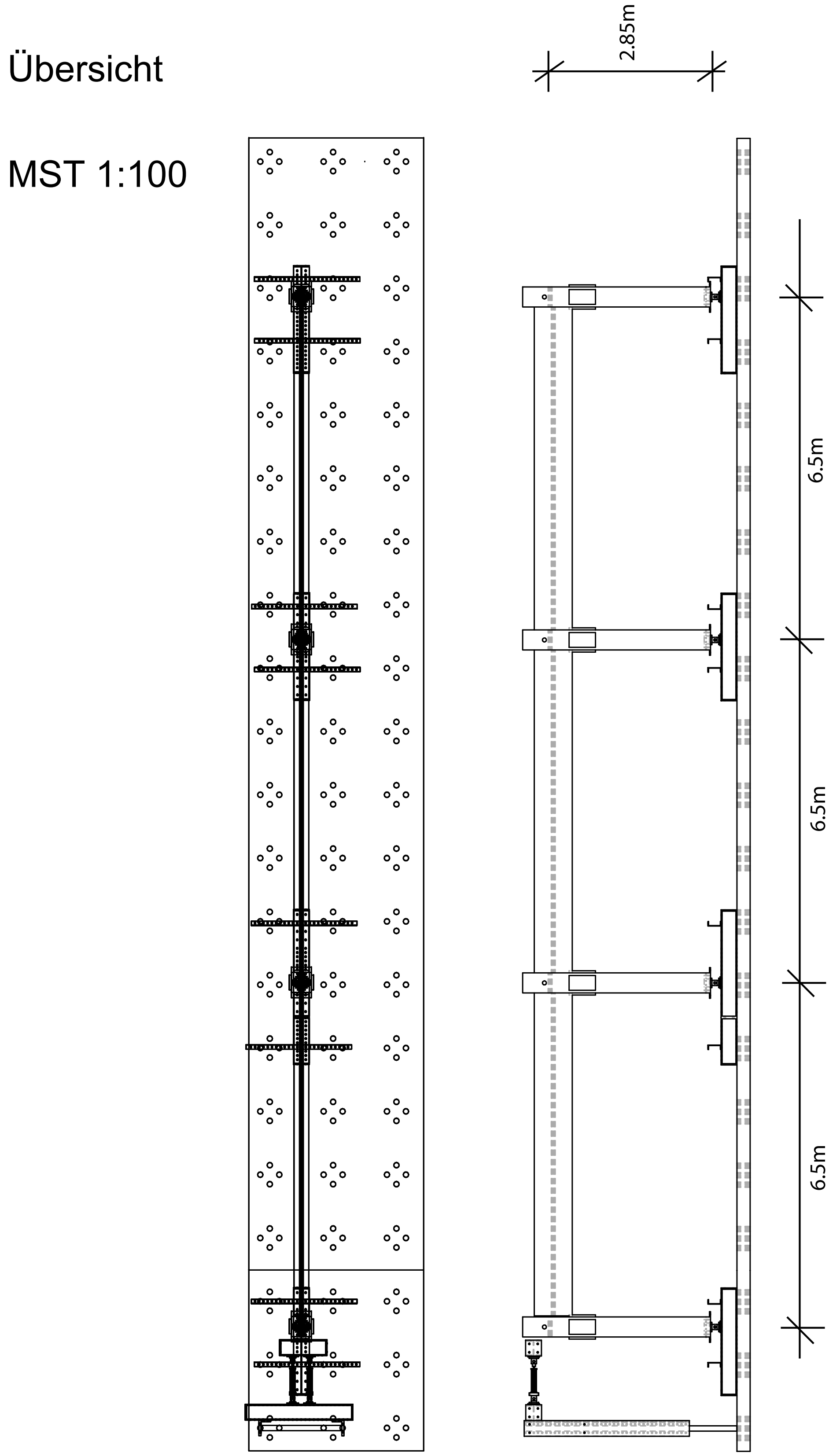


Fig. A.1: Technical drawing of the test setup

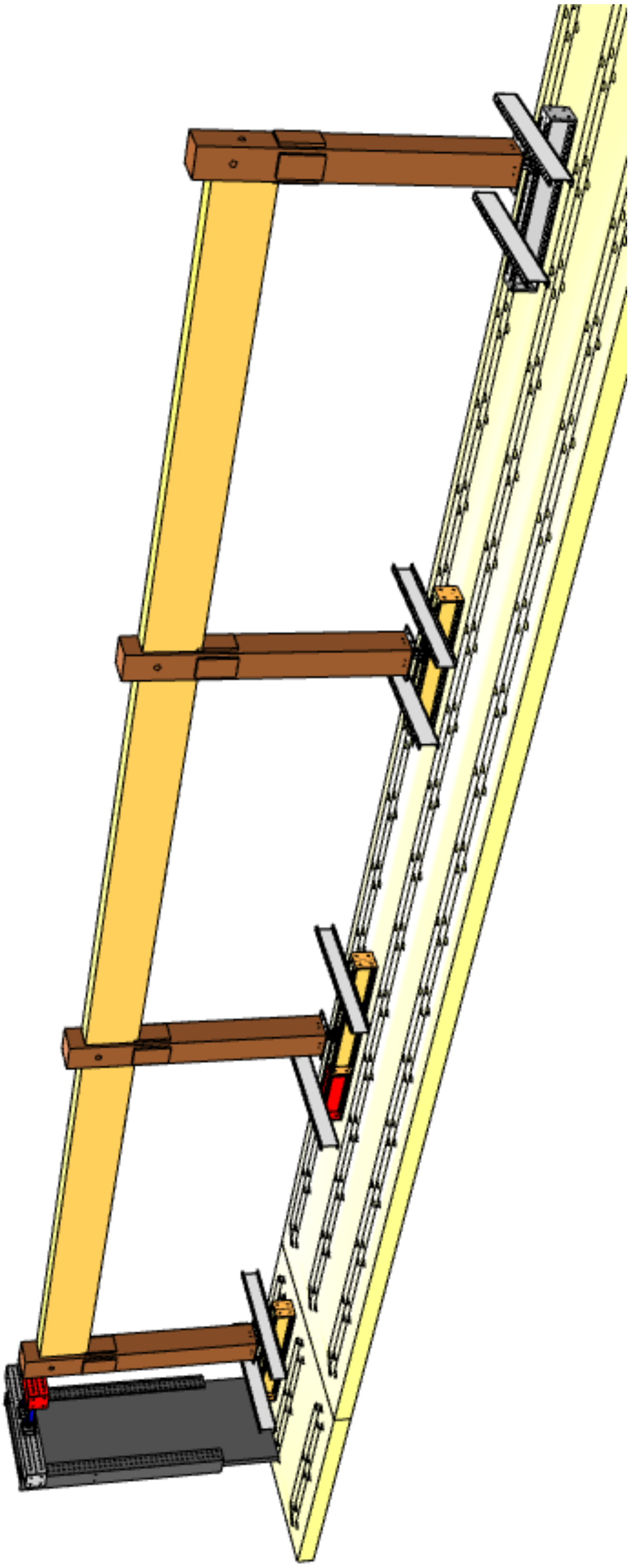


Fig. A.2: 3D visualization of the test setup

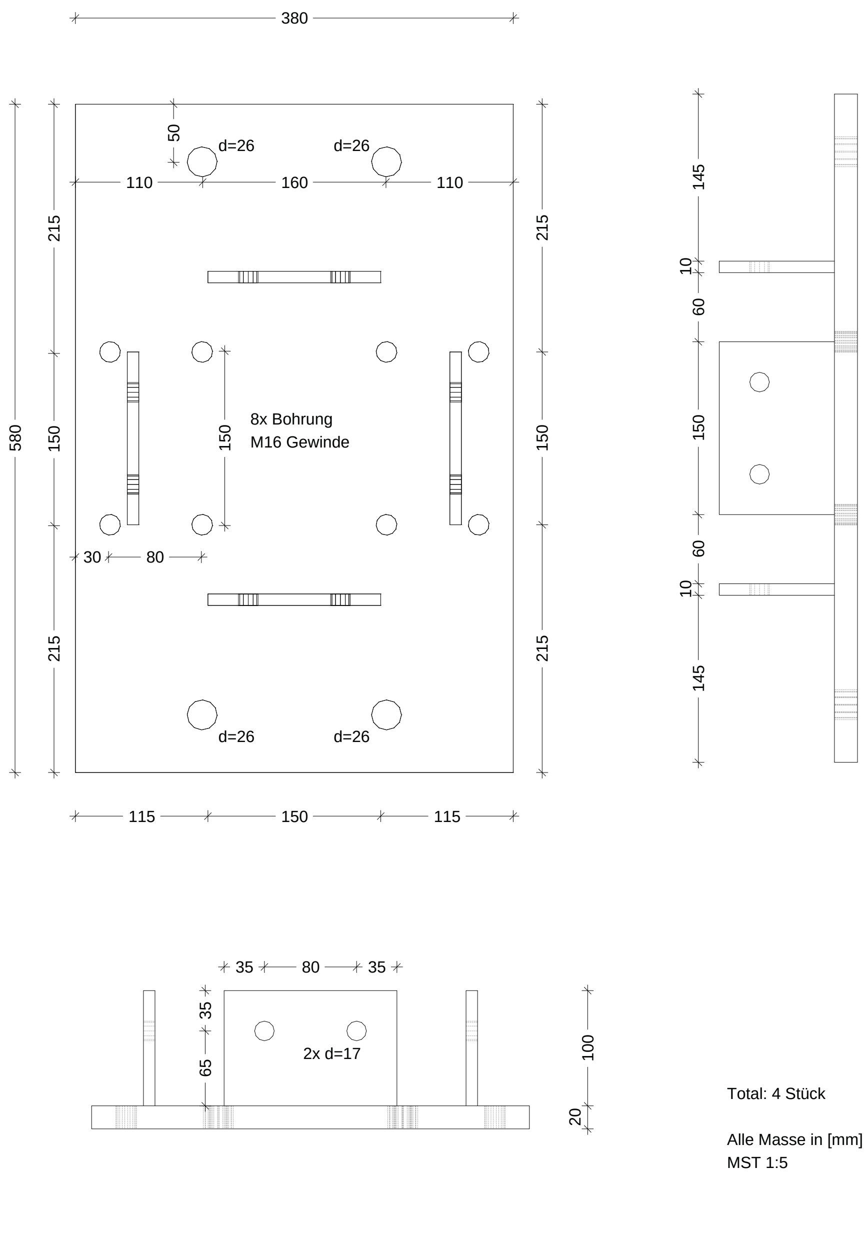


Fig. A.3: Column base plate

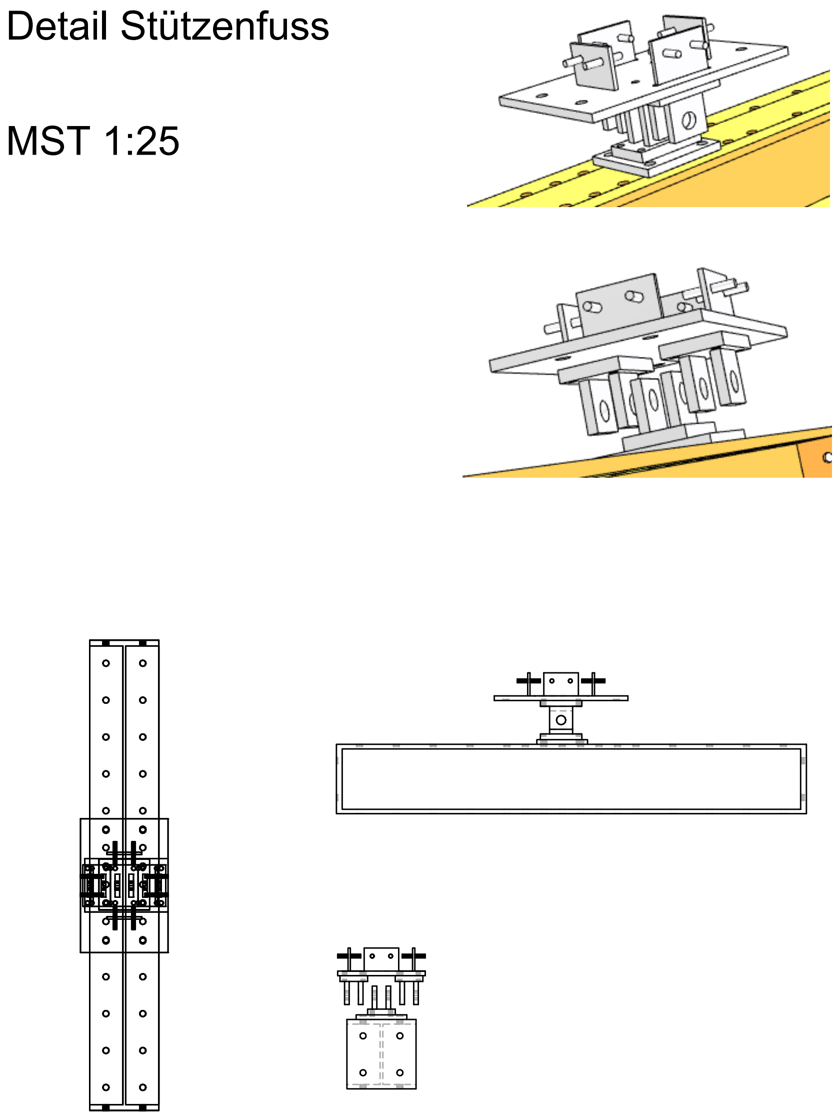


Fig. A.4: Column base connection

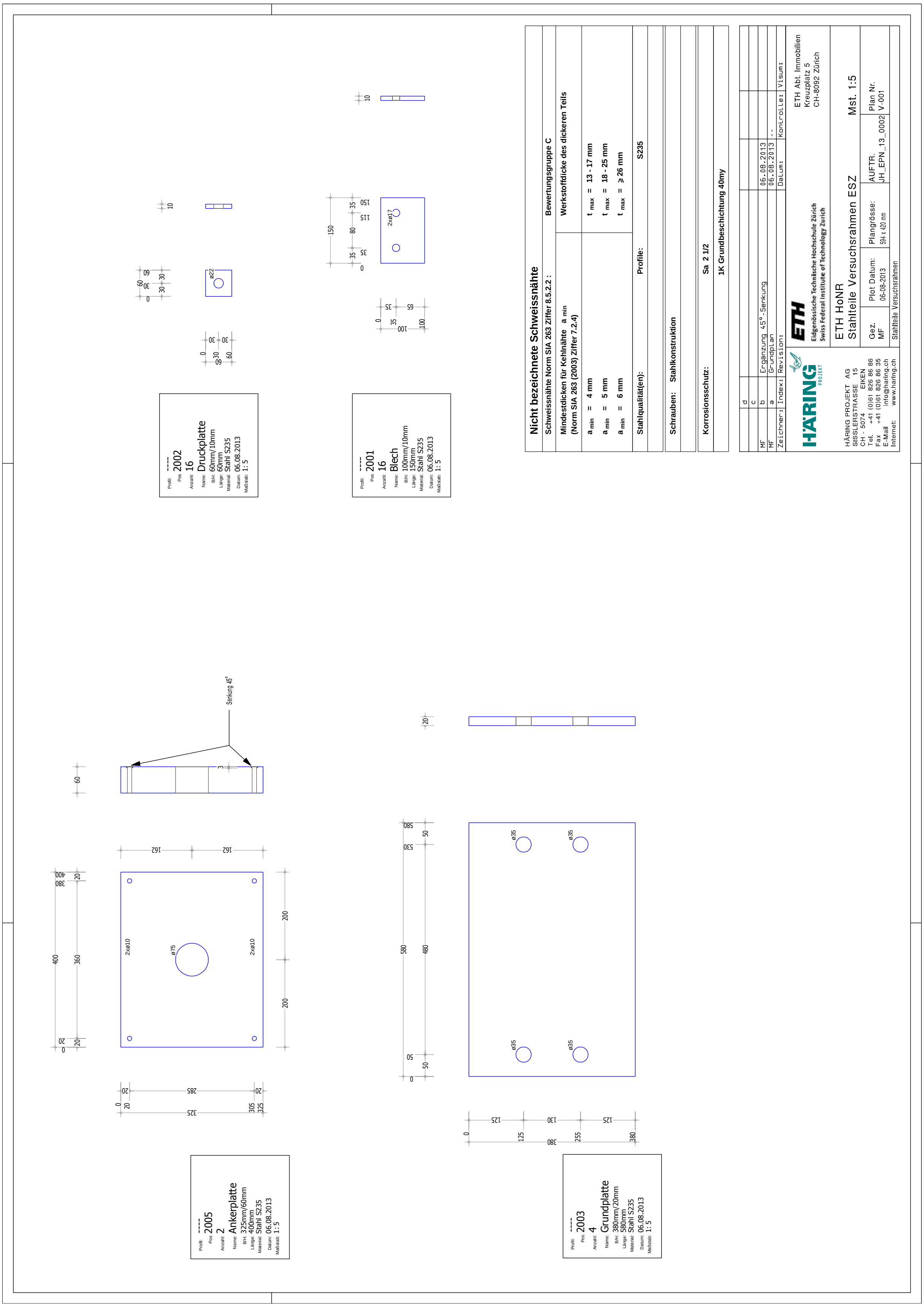


Fig. A.5: Tendon anchorage plate and column base plate

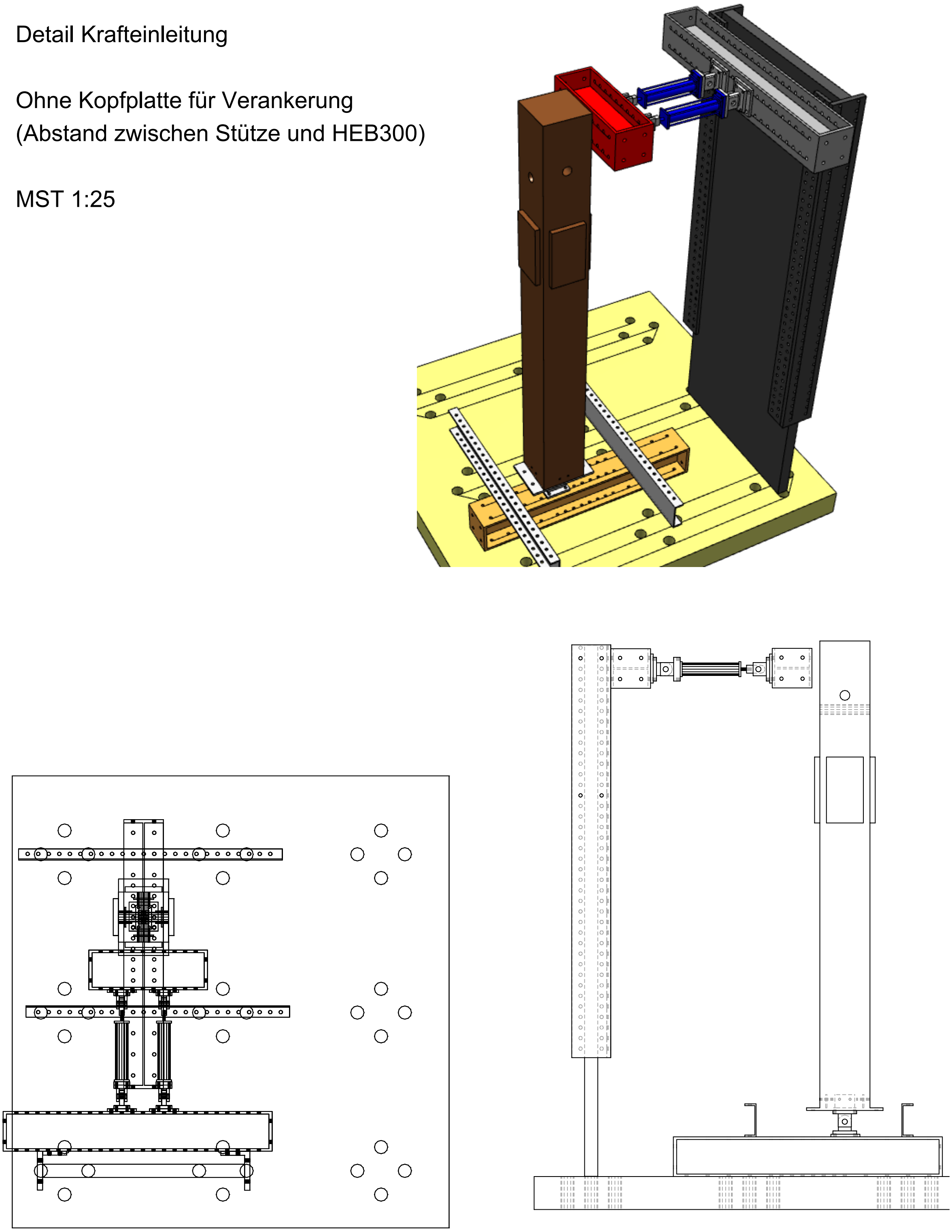


Fig. A.6: Visualization and drawing of the load application construction

Appendix B

Test protocols

B.1 Pushover Test 1

Tab. B.1: Protocol pushover test 1 (26.03.2014)

Time	Event
08:50	Applying tendon force of 530 kN
09:04	Starting load cycles: Applying lateral force, gap opening was observed at 165 kN
09:25	End of test

B.2 Pushover Test 2

Tab. B.2: Protocol pushover test 2 (26.03.2014)

Time	Event
11:07	Applying tendon force of 550 kN
11:15	Starting load cycles: Applying lateral force
11:30	End of test

B.3 Pushover Test 3

Tab. B.3: Protocol pushover test 3 (26.03.2014)

Time	Event
13:40	Applying tendon force of 625 kN
13:45	First load cycle: Applying lateral force up to 180 kN
13:47	Second load cycle: Applying lateral force up to 190 kN
13:50	End of test

B.4 Pushover Test 4

Tab. B.4: Protocol pushover test 4 (26.03.2014)

Time	Event
13:56	Applying tendon force of 680 kN
14:00	First load cycle: Applying lateral force up to 100 kN
14:09	Second load cycle: Applying lateral force up to 110 kN
14:11	End of test

B.5 Pushover Test 5

Tab. B.5: Protocol pushover test 5 (27.03.2014)

Time	Event
11:52	Applying tendon force of 530 kN
12:00	First load cycle: Applying lateral force up to 100 kN
12:04	Second load cycle: Applying lateral force up to 150 kN
12:07	Third load cycle
12:10	Fourth load cycle: Applying lateral force up to 225 kN
12:12	End of test

B.6 Pushover Test 6

Tab. B.6: Protocol pushover test 6 (27.03.2014)

Time	Event
15:34	Applying tendon force of 535 kN
15:42	First load cycle: Applying lateral force up to 100 kN
15:44	Second load cycle: Applying lateral force up to 150 kN
15:48	Third load cycle: Applying later force up to 200 kN
15:52	End of test

B.7 Pushover Test 7

Tab. B.7: Protocol pushover test 7 (27.03.2014)

Time	Event
16:15	Applying tendon force of 530 kN
16:21	First load cycle: Applying lateral force up to 100 kN
16:27	Second load cycle: Applying lateral force up to 150 kN
16:30	Third load cycle: Applying later force up to 190 kN
16:35	End of test

B.8 Pushover Test 8

Tab. B.8: Protocol pushover test 8 (31.03.2014)

Time	Event
10:52	Applying tendon force of 570 kN
10:59	First load cycle: Applying lateral force up to 100 kN
11:02	Second load cycle: Applying lateral force up to 150 kN
11:05	Third load cycle: Applying later force up to 175 kN
11:12	End of test

B.9 Pushover Test 9

Tab. B.9: Protocol pushover test 9 (31.03.2014)

Time	Event
11:18	Applying tendon force of 620 kN
11:24	First load cycle: Applying lateral force up to 100 kN
11:29	Second load cycle: Applying lateral force up to 150 kN
11:32	Third load cycle: Applying later force up to 175 kN
11:37	End of test

B.10 Pushover Test 10

Tab. B.10: Protocol pushover test 10 (31.03.2014)

Time	Event
11:37	Applying tendon force of 680 kN
11:42	First load cycle: Applying lateral force up to 100 kN
11:47	Second load cycle: Applying lateral force up to 150 kN
11:49	Third load cycle: Applying later force up to 175 kN
11:55	End of test

B.11 Pushover Test 11

Tab. B.11: Protocol pushover test 11 (31.03.2014)

Time	Event
14:08	Applying tendon force of 420 kN
14:13	First load cycle: Applying lateral force up to 100 kN
14:16	Second load cycle: Applying lateral force up to 150 kN
14:19	Third load cycle: Applying later force up to 200 kN
14:23	End of test

B.12 Pushover Test 12

Tab. B.12: Protocol pushover test 12 (31.03.2014)

Time	Event
14:24	Applying tendon force of 325 kN
14:26	First load cycle: Applying lateral force up to 100 kN
14:30	Second load cycle: Applying lateral force up to 150 kN
14:35	Third load cycle: Applying later force up to 200 kN
14:40	End of test

B.13 Pushover Test 13

Tab. B.13: Protocol pushover test 13 (31.03.2014)

Time	Event
14:56	Applying tendon force of 230 kN
14:57	First load cycle: Applying lateral force up to 100 kN
14:59	Second load cycle: Applying lateral force up to 165 kN
15:05	End of test

B.14 Pushover Test 14

Tab. B.14: Protocol pushover test 14 (31.03.2014)

Time	Event
15:56	Applying tendon force of 225 kN
15:57	First load cycle: Applying lateral force up to 100 kN
15:59	Second load cycle: Applying lateral force up to 170 kN
16:05	End of test

B.15 Pushover Test 15

Tab. B.15: Protocol pushover test 15 (31.03.2014)

Time	Event
16:06	Applying tendon force of 430 kN
16:08	First load cycle: Applying lateral force up to 100 kN
16:10	Second load cycle: Applying lateral force up to 150 kN
16:17	Third load cycle: Applying later force up to 200 kN
16:23	End of test

B.16 Pushover Test 16

Tab. B.16: Protocol pushover test 16 (31.03.2014)

Time	Event
16:23	Applying tendon force of 330 kN
16:24	First load cycle: Applying lateral force up to 100 kN
16:28	Second load cycle: Applying lateral force up to 150 kN
16:32	Third load cycle: Applying later force up to 225 kN
16:36	End of test

B.17 Pushover Test 17

Tab. B.17: Protocol pushover test 17

Time	Event
09:02	Applying tendon force of 525 kN
09:05	Applying dead load of 10 kN (beam 2, beam 1 and then beam 3)
09:20	First load cycle: Applying lateral force up to 50 kN
09:22	Second load cycle: Applying lateral force up to 100 kN
09:24	Third load cycle: Applying later force up to 125 kN
09:30	Removing dead load of 10 kN (beam 3, beam 2 and then beam 1)
09:35	End of test

B.18 Pushover Test 18

Tab. B.18: Protocol pushover test 18

Time	Event
10:09	Applying tendon force of 610 kN
10:11	Applying dead load of 10 kN (beam 2, beam 1 and then beam 3)
10:15	First load cycle: Applying lateral force up to 50 kN
10:17	Second load cycle: Applying lateral force up to 100 kN
10:20	Third load cycle: Applying later force up to 125 kN
10:23	Fourth load cycle: Applying later force up to 150 kN
10:25	Removing dead load of 10 kN (beam 3, beam 2 and then beam 1)
10:27	End of test

B.19 Pushover Test 19

Tab. B.19: Protocol pushover test 19

Time	Event
10:30	Applying tendon force of 680 kN
10:32	Applying dead load of 10 kN (beam 2, beam 1 and then beam 3)
10:36	First load cycle: Applying lateral force up to 50 kN
10:38	Second load cycle: Applying lateral force up to 100 kN
10:40	Third load cycle: Applying later force up to 125 kN
10:43	Removing dead load of 10 kN (beam 3, beam 2 and then beam 1)
10:45	End of test

B.20 Pushover Test 20

Tab. B.20: Protocol pushover test 20

Time	Event
11:13	Applying tendon force of 710 kN
11:15	Applying dead load of 10 kN (beam 2, beam 1 and then beam 3)
11:18	First load cycle: Applying lateral force up to 50 kN
11:19	Second load cycle: Applying lateral force up to 100 kN
11:21	Third load cycle: Applying later force up to 125 kN
11:25	Removing dead load of 10 kN (beam 3, beam 2 and then beam 1)
11:27	End of test

B.21 Pushover Test 21

Tab. B.21: Protocol pushover test 21

Time	Event
11:30	Applying tendon force of 620 kN
11:31	Applying dead load of 10 kN (beam 2, beam 1 and then beam 3)
11:33	First load cycle: Applying lateral force up to 50 kN
11:35	Second load cycle: Applying lateral force up to 100 kN
11:37	Third load cycle: Applying later force up to 150 kN
11:40	Removing dead load of 10 kN (beam 3, beam 2 and then beam 1)
11:45	End of test

B.22 Pushover Test 22

Tab. B.22: Protocol pushover test 22

Time	Event
11:47	Applying tendon force of 530 kN
11:49	Applying dead load of 10 kN (beam 2, beam 1 and then beam 3)
11:52	First load cycle: Applying lateral force up to 50 kN
11:53	Second load cycle: Applying lateral force up to 100 kN
11:54	Third load cycle: Applying later force up to 125 kN
11:55	Removing dead load of 10 kN (beam 3, beam 2 and then beam 1)
12:00	End of test

B.23 Pushover Test 23

Tab. B.23: Protocol pushover test 23

Time	Event
16:06	Applying tendon force of 525 kN
16:13	First load cycle: Applying lateral force up to 250 kN
16:21	Second load cycle: Applying lateral force up to 250 kN
16:30	End of test

B.24 Pushover Test 24

Tab. B.24: Protocol pushover test 24

Time	Event
16:40	Applying tendon force of 420 kN
16:41	First load cycle: Applying lateral force
16:46	End of test

B.25 Pushover Test 25

Tab. B.25: Protocol pushover test 25

Time	Event
16:50	Applying tendon force of 320 kN
16:51	First load cycle: Applying lateral force up to 230 kN
17:30	End of test

B.26 Pushover Test 26

Tab. B.26: Protocol pushover test 26

Time	Event
15:17	Applying tendon force of 420 kN
15:23	Start load cycles
15:35	End of test

B.27 Pushover Test 27

Tab. B.27: Protocol pushover test 27

Time	Event
15:37	Applying tendon force of 325 kN
15:38	Start load cycles
	DAQ crashed

B.28 Pushover Test 28

Tab. B.28: Protocol pushover test 28

Time	Event
16:16	Applying tendon force of 265 kN
16:22	Start load cycles
16:35	End of test

B.29 Pushover Test 29

Tab. B.29: Protocol pushover test 29

Time	Event
17:21	Applying tendon force of 220 kN
17:22	Start load cycles
17:27	End of test

B.30 Shaker tests

Tab. B.30: Shaker tests

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed	Shaker controls Acceleration [g]	Displacement [mm]	Frequency [Hz]	Sweep	Sweep rate [Hz/s]
1	P7	h	400	x		0.99→ 2.83→ 6.3	10.0→ 22→ 13.9	7.0→ 8.0→ 15.0	linear	0.2
2	P7	h	400	x		0.99→ 2.83→ 6.3	10.0→ 22→ 13.9	7.0→ 8.0→ 15.0	linear	0.1
3	P7	h	400		x	0.99→ 2.83→ 6.3	10.0→ 22→ 13.9	7.0→ 8.0→ 15.0	linear	0.1
4	P7	h	400		x	0.99→ 2.83→ 6.3	10.0→ 22→ 13.9	7.0→ 8.0→ 15.0	linear	0.1
5	P7	v	400		x	2.01→ 6.3	10.0→ 0.64	10.0→ 70.0	linear	1.0
6	P7	v	400		x	6.3 → 6.3	5.01→ 0.87	25.0→ 60.0	linear	0.5
7	P7	v	400	x		6.3 → 6.3	5.01→ 0.87	25.0→ 60.0	linear	0.5
8	P7	v	400	x		5.8 → 5.8	4.6 → 0.29	25.0→ 100.0	linear	0.5
9	P7	v	500	x		5.8 → 5.8	4.6 → 0.24	25.0→ 110.0	linear	0.5
10	P7	v	500	x		5.8 → 5.8	4.6→ 0.24	25.0→ 110.0	linear	0.5
11	P7	v	500		x	5.8 → 5.8	4.6 → 0.24	25.0→ 110.0	linear	0.5
12	P7	v	500		x	5.8 → 5.8	4.6 → 0.24	25.0→ 110.0	linear	0.5
13	P7	h	500		x	0.99→ 2.83→ 5.8	10.0→ 22→ 12.81	7.0→ 8.0→ 15.0	linear	0.1
14	P7	h	500		x	0.99→ 2.83→ 5.8	10.0→ 22→ 12.81	7.0→ 8.0→ 15.0	linear	0.1
15	P7	h	500	x		0.99→ 2.83→ 5.8	10.0→ 22→ 12.81	7.0→ 8.0→ 15.0	linear	0.1
16	P7	h	500	x		0.99→ 2.83→ 5.8	10.0→ 22→ 12.81	7.0→ 8.0→ 15.0	linear	0.1
17	P7	h	650	x		0.99→ 2.83→ 5.8	10.0→ 22→ 12.81	7.0→ 8.0→ 15.0	linear	0.1
18	P7	h	650	x		0.99→ 2.83→ 5.8	10.0→ 22→ 20.01	7.0→ 8.0→ 12.0	linear	0.1
19	P7	h	650		x	0.99→ 2.83→ 5.8	10.0→ 22→ 20.01	7.0→ 8.0→ 12.0	linear	0.1
20	P7	h	650		x	0.99→ 2.83→ 5.8	10.0→ 22→ 20.01	7.0→ 8.0→ 12.0	linear	0.1
21	P7	v	650		x	5.8 → 5.8	4.61→ 0.24	25.0→ 110.0	linear	0.5
22	P7	v	650		x	5.8 → 5.8	4.61→ 0.24	25.0→ 110.0	linear	0.5
23	P7	v	650	x		5.8 → 5.8	4.61→ 0.24	25.0→ 110.0	linear	0.5

Tab. B.30: Shaker tests

Test	Position	Orientation	P_0	Columns		Shaker controls				
No.		vert/hor	[kN]	pinned	fixed	Acceleration [g]	Displacement [mm]	Frequency [Hz]	Sweep	Sweep rate [Hz/s]
24	P7	v	650	x		5.8 → 5.8	4.61→ 0.24	25.0→ 110.0	linear	0.5
25	P3	h	650	x		0.99→ 2.83→ 5.8	10.0→ 22→ 20.01	7.0→ 8.0→ 12.0	linear	0.2
26	P3	h	650	x		0.99→ 2.83→ 5.8	10.0→ 22→ 20.01	7.0→ 8.0→ 12.0	linear	0.1
27	P3	v	650	x		5.8 → 5.8	4.61→ 0.24	25.0→ 110.0	linear	1.0
28	P3	v	650	x		5.8 → 5.8	4.61→ 0.24	25.0→ 110.0	linear	0.5
29	P3	v	650		x	5.8 → 5.8	4.61→ 0.24	25.0→ 110.0	linear	0.5
30	P3	v	650		x	5.8 → 5.8	4.61→ 0.24	25.0→ 110.0	linear	0.5
31	P3	h	650		x	1.29→ 3.59→ 5.8	10.0→22.0→17.05	8.0→ 9.0→ 13.0	linear	0.1
32	P3	h	650		x	1.29→ 3.59→ 5.8	10.0→22.0→17.05	8.0→ 9.0→ 13.0	linear	0.1
33	P3	h	500		x	1.29→ 3.59→ 5.8	10.0→22.0→17.05	8.0→ 9.0→ 13.0	linear	0.1
34	P3	h	500		x	1.29→ 3.59→ 5.8	10.0→22.0→17.05	8.0→ 9.0→ 13.0	linear	0.1
35	P3	v	500		x	5.8 → 5.8	4.61→ 0.24	25.0→ 110.0	linear	0.5
36	P3	v	500		x	5.8 → 5.8	4.61→ 0.24	25.0→ 110.0	linear	0.5
37	P3	v	500	x		5.8 → 5.8	4.61→ 0.24	25.0→ 110.0	linear	0.5
38	P3	v	500	x		5.8 → 5.8	4.61→ 0.24	25.0→ 110.0	linear	0.5
39	P3	h	500	x		0.99→ 2.83→ 5.8	10.0→ 22→ 20.01	7.0→ 8.0→ 12.0	linear	0.1
40	P3	h	500	x		0.99→ 2.83→ 5.8	10.0→ 22→ 20.01	7.0→ 8.0→ 12.0	linear	0.1
41	P3	h	400	x		0.99→ 2.83→ 5.8	10.0→ 22→ 20.01	7.0→ 8.0→ 12.0	linear	0.1
42	P3	h	400	x		0.99→ 2.83→ 5.8	10.0→ 22→ 20.01	7.0→ 8.0→ 12.0	linear	0.1
43	P3	v	400	x		5.8 → 5.8	4.61→ 0.24	25.0→ 110.0	linear	0.5
44	P3	v	400	x		5.8 → 5.8	4.61→ 0.24	25.0→ 110.0	linear	0.5
45	P3	v	400		x	5.8 → 5.8	4.61→ 0.24	25.0→ 110.0	linear	0.5
46	P3	v	400		x	5.8 → 5.8	4.61→ 0.24	25.0→ 110.0	linear	0.5

Tab. B.30: Shaker tests

Test No.	Position	Orientation vert/hor	P_0 [kN]	Columns pinned	Columns fixed	Shaker controls: Acceleration [g]	Shaker controls: Displacement [mm]	Shaker controls: Frequency [Hz]	Shaker controls: Sweep	Shaker controls: Sweep rate [Hz/s]
47	P3	h	400		x	0.99→ 2.84→ 5.8	10.0→22.0→17.05	7.0→ 8.0→ 13.0	linear	0.1
48	P3	h	400		x	0.99→ 2.84→ 5.8	10.0→22.0→17.05	7.0→ 8.0→ 13.0	linear	0.1

Tab. B.31: Shaker Tests with QDeadalus measurements

Test	Position	Orientation	P_0	Columns		Shaker controls				
No.		vert/hor	[kN]	pinned	fixed	Acceleration [g]	Displacement [mm]	Frequency [Hz]	Sweep	Sweep rate [Hz/s]
4	P7	h	280		x	1.11 → 5.36	22.0→ 22.0	5.0→ 11.0	linear	0.1
5	P7	h	280		x	3.20 → 3.99	22.0→ 22.0	8.5→ 9.5	linear	0.02
6	P7	h	210		x	1.11 → 4.43	22.0→ 22.0	5.0→ 10.0	linear	0.1
7	P7	h	210		x	3.20 → 3.99	22.0→ 22.0	8.5→ 9.5	linear	0.1
8	P7	v	255		x	6.0 → 6.0	13.3→ 1.86	15.0→40.0	linear	0.1
9	P7	h	300	x		1.11 → 5.36	22.0→ 22.0	5.0→ 11.0	linear	0.2
10	P7	h	300	x		2.17 → 4.43	22.0→ 22.0	7.0→ 10.0	linear	0.05
11	P7	h	400	x		0.99 → 2.49→ 4.43	10.0→22.0→22.0	7.0→ 7.5→ 10.0	linear	0.05
12	P7	h	400	x		0.99 → 2.49→ 4.43	10.0→22.0→22.0	7.0→ 7.5→ 10.0	linear	0.05
13	P7	h	500	x		0.99 → 2.49→ 4.43	10.0→22.0→22.0	7.0→ 7.5→ 10.0	linear	0.05
14	P7	h	500	x		0.99 → 2.49→ 4.43	10.0→22.0→22.0	7.0→ 7.5→ 10.0	linear	0.05
15	P7	h	600	x		0.99 → 2.49→ 4.43	10.0→22.0→22.0	7.0→ 7.5→ 10.0	linear	0.05
16	P7	h	600	x		0.99 → 2.49→ 4.43	10.0→22.0→22.0	7.0→ 7.5→ 10.0	linear	0.05
17	P7	h	600	x		0.99 → 2.49→ 4.43	10.0→22.0→22.0	7.0→ 7.5→ 10.0	linear	0.05

Nomenclature

Abbreviations

CMIF	Complex mode indication function
COV	Coefficient of variation
CSI	Combined deterministic-stochastic subspace model
DAQ	Data acquisition unit
DC	Direct Current (Zero frequency)
DOF	Degree of freedom
FBG	Fibre bragg grating sensor
FRF	Frequency response function
LVDT	Linear Variable Differential Transformer (displacement measurement)
MAC	Modal assurance criterion
$\text{MAC}_{\text{quality}}$	Quality indicator for the mode shape (mean-value of the off-diagonal elements in the MAC-matrix)
MPC	Modal phase collinearity
MPD	Mean phase deviation
nonpar	Nonparametric model
pLSCF	Poly-reference least squares complex frequency domain model
RMFD	Right matrix fraction description
SSI	Stochastic subspace model
SSIcov	Covariance-driven stochastic subspace identification method
SV_1	1st singular value

Upper-case roman letters

A_c	Area of the column

A_p	Cross section area tendon
D	Diagonal distance - shear panel
D'	Diagonal distance - shear panel (deformed)
E_0	Modulus of elasticity parallel to the grain
E_{90}	Modulus of elasticity perpendicular to the grain
E_c	Young's modulus of the column
E_p	Modulus of elasticity of the tendon
F	Horizontal force
F_{max}	Maximum horizontal force
G	Shear modulus
G_c	Shear modulus of the column
I_c	Moment of Inertia of the column
$K_{hor,max}$	Maximal stiffness of a post-tensioned timber frame under horizontal load
K_{hor}	Measured horizontal stiffness
K_i	Stiffness of inner column connection
K_o	Stiffness of outer column connection
K_{tot}	Total stiffness of all connections in a frame
L_p	Length of the tendon
N	Number of data points
$N_{samples}$	Number of samples
N_s	Number of strands
P_0	Initial tendon force
P_{max}	Applicable design load for the tendon
R	Resulting force
T	Period
W	Weight, reactive weight

Lower-case roman letters

$\tilde{d}$	Cut-off distance for hierarchical clustering
d	Distance between modes
f	Frequency

f_{Nyq}	Nyquist frequency ($f_{\mathrm{s}}/2$)
$f_{c,0,k}$	Compressive strength parallel to the grain
$f_{c,90,k}$	Compressive strength perpendicular to the grain
$f_{p,k}$	Tensile strength of the tendon
f_s	Sampling frequency
g	Acceleration due to gravity
h_c	Column height
u	Horizontal displacement of the frame

Upper-case greek letters

σ	Standard deviation
σ_0	Initial compressive stress

Lower-case greek letters

γ	Shear angle
ϕ	Mode shape vector
ρ_k	Characteristic density at 12% moisture content
ρ_{mean}	Mean density at 12% moisture content
ρ_{meas}	Measured density
θ	Rotation due to moment
$\theta_{col,el}$	Elastic rotation of the column
θ_{GA}	Rotation due to shear deformation
θ_{tot}	Total rotation in the beam-column interface
ξ	Damping ratio

References

[1] Priestley, M.N. “Overview of PRESSS research program”. *PCI Journal* 36 (1991), pp. 50–57.

[2] Priestley, M.N. “The PRESSS Program-Current Status and Proposed Plans for Phase III”. *PCI Journal* 41 (1996), pp. 22–40.

[3] Pampanin, S., Priestley, M.N., and Sritharan, S. “Analytical modelling of the seismic behaviour of precast concrete frames designed with ductile connections”. *Journal of Earthquake Engineering* 5 (2001), pp. 329–367.

[4] Palermo, A., Pampanin, S., and Calvi, G.M. “The use of controlled rocking in the seismic design of bridges”. *Proceedings of the 8th World Conference on Timber Engineering WCTE, Lahti, Finland.* 2004.

[5] Palermo, A., Pampanin, S., and Buchanan, A. “Experimental investigations on LVL seismic resistant wall and frame subassemblies”. *Proceedings of the 1st First European Conference on Earthquake Engineering and Seismology, Geneva, Switzerland.* 2006.

[6] Palermo, A., Pampanin, S., Fragiacomo, M., Buchanan, A., and Deam, B. “Innovative seismic solutions for multi-storey LVL timber buildings”. *Proceedings of the 9th World Conference on Timber Engineering WCTE, Portland, OR, USA*. 2006.

[7] Buchanan, A., Deam, B., Fragiacomo, M., Pampanin, S., and Palermo, A. “Multi-storey prestressed timber buildings in New Zealand”. *Structural Engineering International* 18.2 (2008), pp. 166–173.

[8] Iqbal, A., Pampanin, S., and Buchanan, A. “Seismic Performance of Prestressed Timber Beam-Column Sub-Assemblies”. *Proceedings of the New Zealand Society for Eearthquake Engineering Conference, Wellington, New Zealand.* 2010.

[9] Newcombe, M., Pampanin, S., and Buchanan, A. “Global response of a two storey Pres-Lam timber building”. *Proceedings of the New Zealand Society for Eearthquake Engineering Conference, Wellington, New Zealand.* 2010.

[10] Beerschoten, W. van, Palermo, A., Carradine, D., Sarti, F., and Buchanan, A. "Experimental Investigation on the Stiffness of Beam-Column Connections in Post-Tensioned Timber Frames". *Proceedings of the Structural Engineering World Conference, Como, Italy.* 2011.

[11] Smith, T., Pampanin, S., Carradine, D., Buchanan, A., Ponzo, F., Cesare, A., and Nigro, D. "Experimental investigations into post-tensioned timber frames with advanced damping systems". *Proceedings of Il XIV Convegno di Ingegneria Sismica, Associazione Nazionale di Ingegneria Sismica, Bari, Italy.* 2011.

[12] Pampanin, S., Palermo, A., Buchanan, A., Fragiacomo, M., and Deam, B. "Code provisions for seismic design of multi-storey post-tensioned timber buildings". *Proceedings of the CIB W18 Workshop on Timber Structures, Florence, Italy.* 2006.

[13] Newcombe, M., Pampanin, S., Buchanan, A., and Palermo, A. *Seismic design of multi-storey post-tensioned timber buildings.* Master Thesis, University of Pavia, Italy. 2008.

[14] Newcombe, M.P. *Multistorey Timber Buildings Seismic Design Guide.* Department of Civil and Natural Resources Engineering, University of Canterbury, NZ, 2010.

[15] Newcombe, M., Cusiel, M., Pampanin, S., Palermo, A., and Buchanan, A. "Simplified Design of Post-Tensioned Timber Frames". *Proceedings of theCIB W18 Workshop on Timber Structures, Nelson, New Zealand.* 2010.

[16] Beerschoten, W. van, Palermo, A., Carradine, D., and Buchanan, A. "Failure Criteria for Post-tensioned Timber Beams". *Conference note presented at the CIB W18 Workshop on Timber Structures, Vaxjo, Sweden.* 2012.

[17] Buchanan, A., Palermo, A., Carradine, D., and Pampanin, S. "Post-tensioned timber frame buildings". *Structural Engineer* 89.17 (2011), pp. 24–30.

[18] Wanninger, F. and Frangi, A. "Post-tensioned timber connections, experimental analysis of the long term behaviour". *Proceedings of the 13th World Conference on Timber Engineering WCTE, Quebec City, Canada.* 2014.

[19] Wanninger, F. and Frangi, A. *Investigation of a post-tensioned timber connection - test report.* Tech. rep. 355. Institute of Structural Engineering - Timber Structures, 2014.

[20] European Committee for Standardization (CEN). "EN 338 - Structural Timber - Strength classes; German version". *DIN Deutsches Institut für Normung e. V., Berlin, Germany* (2009).

[21] Swiss Standards Association. "SIA 265 - Timber Structures". *Swiss Society of Engineers and Architects, Zurich, Switzerland* (2012).

[22] Stahlton AG. *Vorspanntechnik [Post-tensioning technolgy]*. In German. 2012.

[23] Wanninger, F., Frangi, A., and Steiger, R. "Bearing stiffness in wood-to-wood compression joints". *Engineering Structures* 101 (2015), pp. 631–640.

[24] Leyder, C., Wanninger, F., Frangi, A., and Chatzi, E. "Dynamic response of an innovative hybrid structure in hardwood". *Proceedings of the Institution of Civil Engineers-Construction Materials* 168.3 (2015), pp. 132–143.

[25] Wanninger, F. and Frangi, A. "Experimental and analytical analysis of a post-tensioned timber connection under gravity loads". *Engineering Structures* 70 (2014), pp. 117–129.

[26] Guillaume, S., Clerc, J., Leyder, C., Ray, J., and Kistler, M. "Contribution of the Image-Assisted Theodolite System QDaedalus to Geodetic Static and Dynamic Deformation Monitoring". *3rd Joint International Symposium on Deformation Monitoring (JISDM), Vienna, Austria*. 2016.

[27] Charalampous, E., Psimoulis, P., Guillaume, S., Spiridonakos, M., Klis, R., Bürki, B., Rothacher, M., Chatzi, E., Luchsinger, R., and Feltrin, G. "Measuring sub-mm structural displacements using QDaedalus: a digital clip-on measuring system developed for total stations". *Applied Geomatics* 7.2 (2015), pp. 91–101.

[28] Wanninger, F. and Frangi, A. "Experimental and analytical analysis of a post-tensioned timber connection under gravity loads". *Engineering Structures* 70 (2014), pp. 117–129.

[29] Reynders, E., Schevenels, M., and De Roeck, G. *MACEC 3.3 - A matlab toolbox for experimental and operational modal analysis*. KU Leuven, Faculty of Engineering, Department of civil engineering, Structural mechanics section. 2014.

[30] Reynders, E., Houbrechts, J., and De Roeck, G. "Fully automated (operational) modal analysis". *Mechanical Systems and Signal Processing* 29 (2012), pp. 228–250.

[31] Reynders, E. "System identification methods for (operational) modal analysis: review and comparison". *Archives of Computational Methods in Engineering* 19.1 (2012), pp. 51–124.

[32] Pappa, R.S., Elliott, K.B., and Schenk, A. *A consistent-mode indicator for the eigensystem realization algorithm*. National Aeronautics and Space Administration, Langley Research Center, 1992.

[33] Allemang, R.J. and Brown, D.L. "A correlation coefficient for modal vector analysis". *Proceedings of the 1st international modal analysis conference*. Vol. 1. SEM, Orlando, 1982, pp. 110–116.

[34] Reynders, E., Pintelon, R., and De Roeck, G. "Uncertainty bounds on modal parameters obtained from stochastic subspace identification". *Mechanical Systems and Signal Processing* 22.4 (2008), pp. 948–969.

[35] Döhler, M. and Mevel, L. "Efficient multi-order uncertainty computation for stochastic subspace identification". *Mechanical Systems and Signal Processing* 38.2 (2013), pp. 346–366.

[36] Reynders, E., Maes, K., Lombaert, G., and De Roeck, G. "Uncertainty quantification in operational modal analysis with stochastic subspace identification: Validation and applications". *Mechanical Systems and Signal Processing* 66 (2016), pp. 13–30.

[37] Efron, B. "Bootstrap methods: another look at the jackknife". *The annals of Statistics* (1979), pp. 1–26.

[38] Cauberghe, B. "Applied frequency-domain system identification in the field of experimental and operational modal analysis". *Praca doktorska, VUB, Brussel* (2004).

[39] Wanninger, F. "Post-tensioned timber frame structures". PhD thesis. ETH Zurich, 2015.

[40] Jeary, A. "Damping in structures". *Journal of Wind Engineering and Industrial Aerodynamics* 72 (1997), pp. 345–355.

[41] Li, Q., Yang, K., Wong, C., and Jeary, A. "The effect of amplitude-dependent damping on wind-induced vibrations of a super tall building". *Journal of Wind Engineering and Industrial Aerodynamics* 91.9 (2003), pp. 1175–1198.

[42] Rainieri, C., Fabbrocino, G., and Cosenza, E. "Some remarks on experimental estimation of damping for seismic design of civil constructions". *Shock and Vibration* 17.4, 5 (2010), pp. 383–395.

[43] Chopra, A.K. *Dynamics of structures: theory and applications to earthquake engineering.* Pearson Prentice-Hall, 2007.

[44] Chopra, A.K. and Goel, R.K. "A modal pushover analysis procedure for estimating seismic demands for buildings". *Earthquake Engineering & Structural Dynamics* 31 (2002), pp. 561–582.