Isolation System for Biosense institute Building

Expert report

Content

1. Introduction

1.1. Scope

This report describes the design of the seismic and noise isolation system of the Biosense institute Building. The design is done by non-linear time history analysis based on compatible accelerograms.

1.2. Design targets

The design targets of the seismic and noise isolation system are:

- 95 % quantile value of base shear force < 276 kN (276 kN is the maximum earthquake load computed for the structure without base isolation).
- 95 % quantile value of total lateral displacement of base isolator ≤ ±150 mm (horizontal free distance between target structure and surrounding structure = 150 mm).
- Displacement capacity of seismic isolation system must include a reliability factor > 2 compared to the 95 % quantile value of the displacement of seismic isolator expected for the Design Seismic Situation.
- No pounding of target structure on surrounding structure.
- The re-centring error must be less than 20 % relative to the displacement capacity of the isolation system for the Design Seismic Situation.
- 95 % quantile value of Peak Floor Acceleration (PFA) < 0,2 g.
- 95 % quantile value of inter-storey drift < 0,5 %.
- Attenuation of structure born noise at disturbing frequencies > 17 Hz.

1.3. Mandatory design approach

The following methods for the design of the seismic and noise isolation system are mandatory:

- Nonlinear time history analysis of the target structure with seismic and noise isolation system must be performed.
- The design must be based on at least 20 accelerograms being compatible with the site-specific elastic response spectrum of the Design Seismic Situation (Design Earthquake).
- The target structure can be modelled linear as it will remain in the elastic region due to the presence of the seismic isolation system.
- The main nonlinearities of the seismic and noise isolation systems must be taken into consideration in the modelling.
- The results (state variables of interest, see 1.4) of the computations must be assessed by the 95 % quantile value to account for the probabilistic nature of the compatible accelerograms.

1.4. State variables of interest

The 95 % quantile values of the following state variables must be computed:

- base shear,
- horizontal force of isolation system,
- horizontal displacement of isolation system,
- PFAs of all storeys,
- inter-storey drifts of all storeys, and
- re-centring error.

2. Data

2.1. Structural data

The data of the target structure needed for nonlinear time history analysis is given in Table 1, Table 2 Table 3 and Table 4. These data are based on the following assumptions:

- The masses of the fundament plate (fp: above isolator) and of all stories are based on 100 % dead load, 100 % equipment load and 50 % live load.
- The vertical load on 1 isolator is based on the assumption of 4 isolators.
- The eigenfrequency of the first horizontal bending mode is valid for the fixed-base condition.
- The modal damping ratios of all modes are in agreement with EC8 Standard.

Table 1. Masses of fundament plate (fp) and storeys on all isolators based on 100 % dead load plus 100 % equipment load plus 50 % live load.

m_{fp} (t)	m_1 (t)	m_2 (t)	m_3 (t)	m_4 (t)
175,92	159,18	159,79	168,19	84,73

Table 2. Vertical seismic loads on all isolators and on 1 isolator based on 100 % dead load plus 100 % equipment load plus 50 % live load.

N_S on all isolators	N_S on one isolator (assuming 4 isolators)
7,3335 MN	1,8334 MN

Table 3. Vertical coordinates of all levels.

Fundament plate	Mass 1	Mass 2	Mass 3	Mass 4
0,95 m	4,80 m	8,55 m	12,80 m	16,70 m

Table 4. Eigenfrequencies of first horizontal bending modes in both main directions for fixed-base condition and modal damping ratio for all considered modes.

f_1 (x-direction)	f_1 (y-direction)	ζ
2,262 Hz	2,390 Hz	5 %

2.2. Elastic response spectrum

The seismic input is defined by the site-specific horizontal elastic response spectrum for the Design Seismic Situation (Design Earthquake, DE, Figure 1):

- a_{gR} = 0,10 g
- importance factor γ = 1,20
- $a_g = a_{gR} \times \gamma$ = 1,20 g
- spectrum type 2, soil class B: S=1,35, T_B=0,05 s, T_C=0,25 s, T_D=1,20 s, η=1 (5 % damping) (according to EC8)

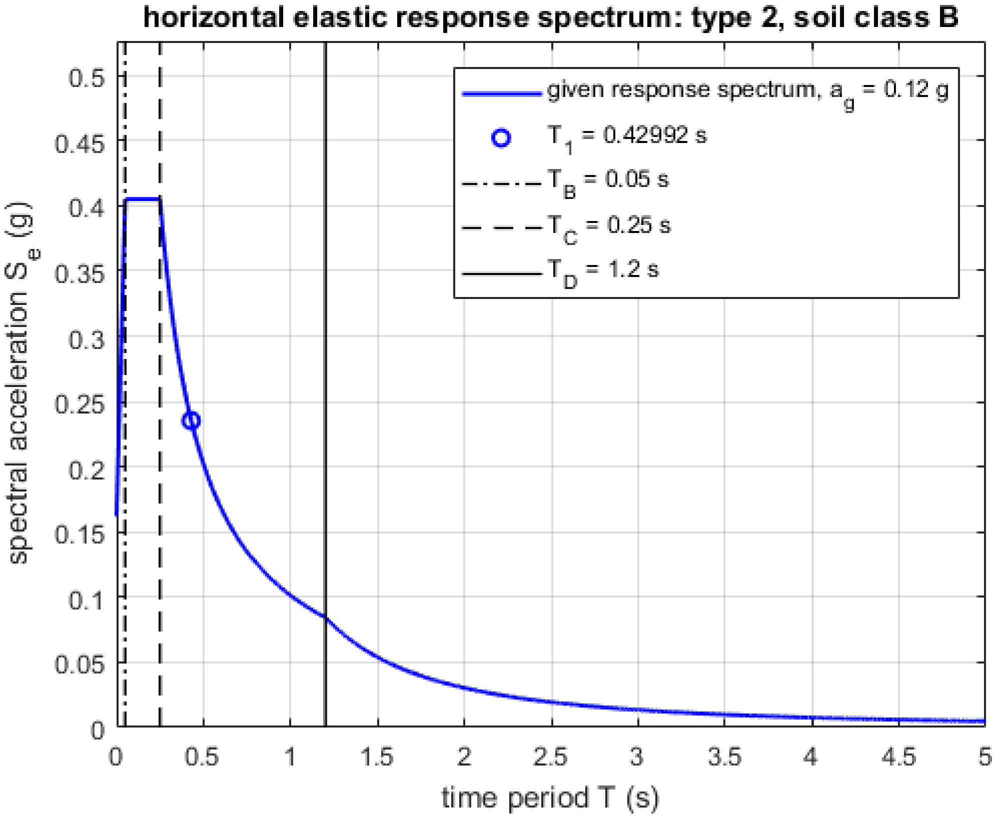


Figure 1. Elastic response spectrum for Design Seismic Situation.

2.3. Structure born noise

The intensity and frequency content (PSD: Power Spectral Density Estimate) of the structure born noise resulting from the environment (surrounding structure) are unknown at this stage of the project.

3. Design approach

The design approach is as follows:

1. **Compatible accelerograms** are computed that are compatible with the given response spectrum.
2. The compatible accelerograms are multiplied by **1,3 to obtain the resultant** of the two orthogonal components.
3. **Non-linear time history analyses** of the target structure (linear 5 degree-of-freedom system) with base isolator (linear restoring stiffness force, non-linear damping force) and hydraulic dampers (non-linear constitutive damping law) are performed for all compatible accelerograms; all computations are done for **nominal, lower and upper bound values** of the seismic isolation system.
4. The **peak values of the state variables of interest** are determined **for all computations**.
5. The **95 % quantile values of the peak values** of the state variables of interest are relevant for the design of the seismic isolation system.

4. Compatible accelerograms

Thirty (30) accelerograms being compatible with the given response spectrum are model-based computed (Figure 2). To double-check their compatibility the response spectra of all 30 accelerograms are computed and compared with the given response spectrum (Figure 3). All compatible accelerograms and according response spectra are given in the Appendix.

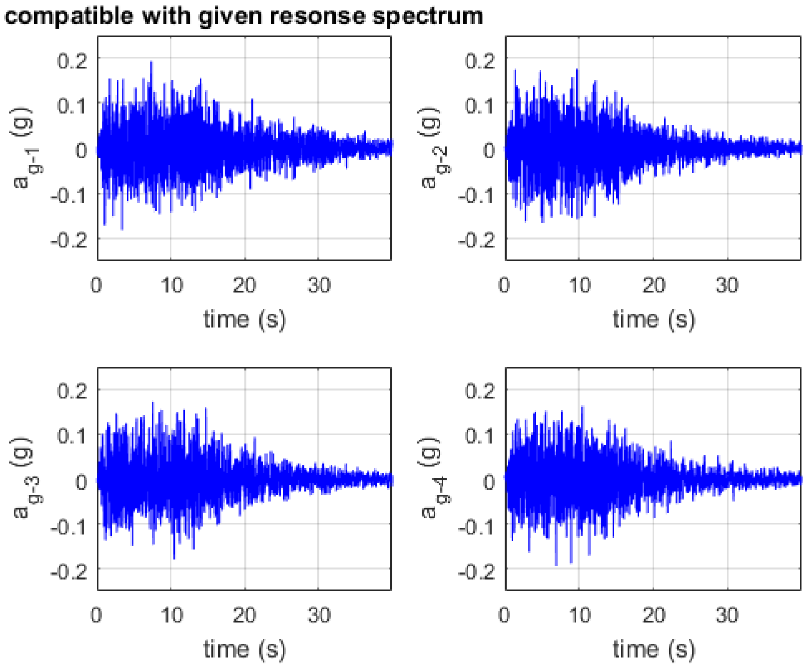


Figure 2. Accelerograms 1 to 4 compatible with given response spectrum.

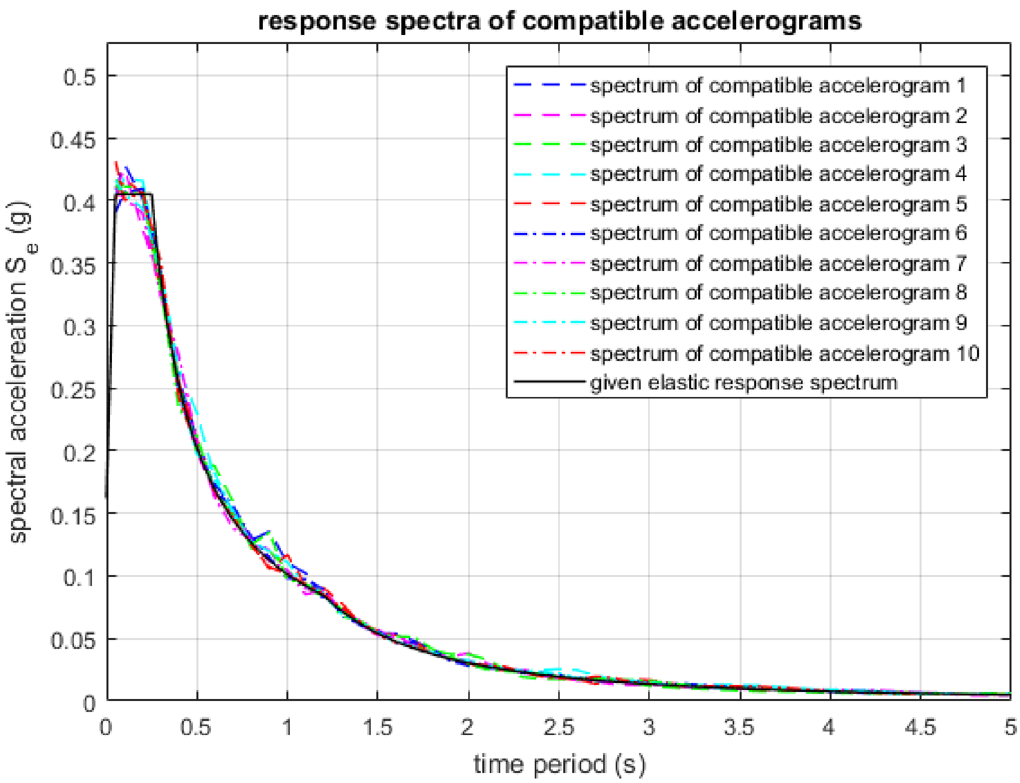


Figure 3. Spectra of accelerograms 1 to 10 being compatible with given response spectrum.

5. Design of seismic and noise isolation system

The design of the seismic and noise isolation system guarantees (Figure 4):

- Seismic protection of the target structure in horizontal direction by 4 curved surface sliders of type single to guarantee greatest rotational capability.
- Noise isolation of the target structure in all spatial directions by Elastomer-based pads between curved surface sliders and fundament plate of target structure.
- Hydraulic dampers located between surrounding structure and storey 3 to avoid pounding effects between the surrounding structure and the target structure; the constitutive law of the hydraulic dampers guarantees minimum coupling damping forces at ground shaking levels of 50 % and less of the Design Earthquake to guarantee best noise attenuation of the target structure at these very low ground shaking levels.

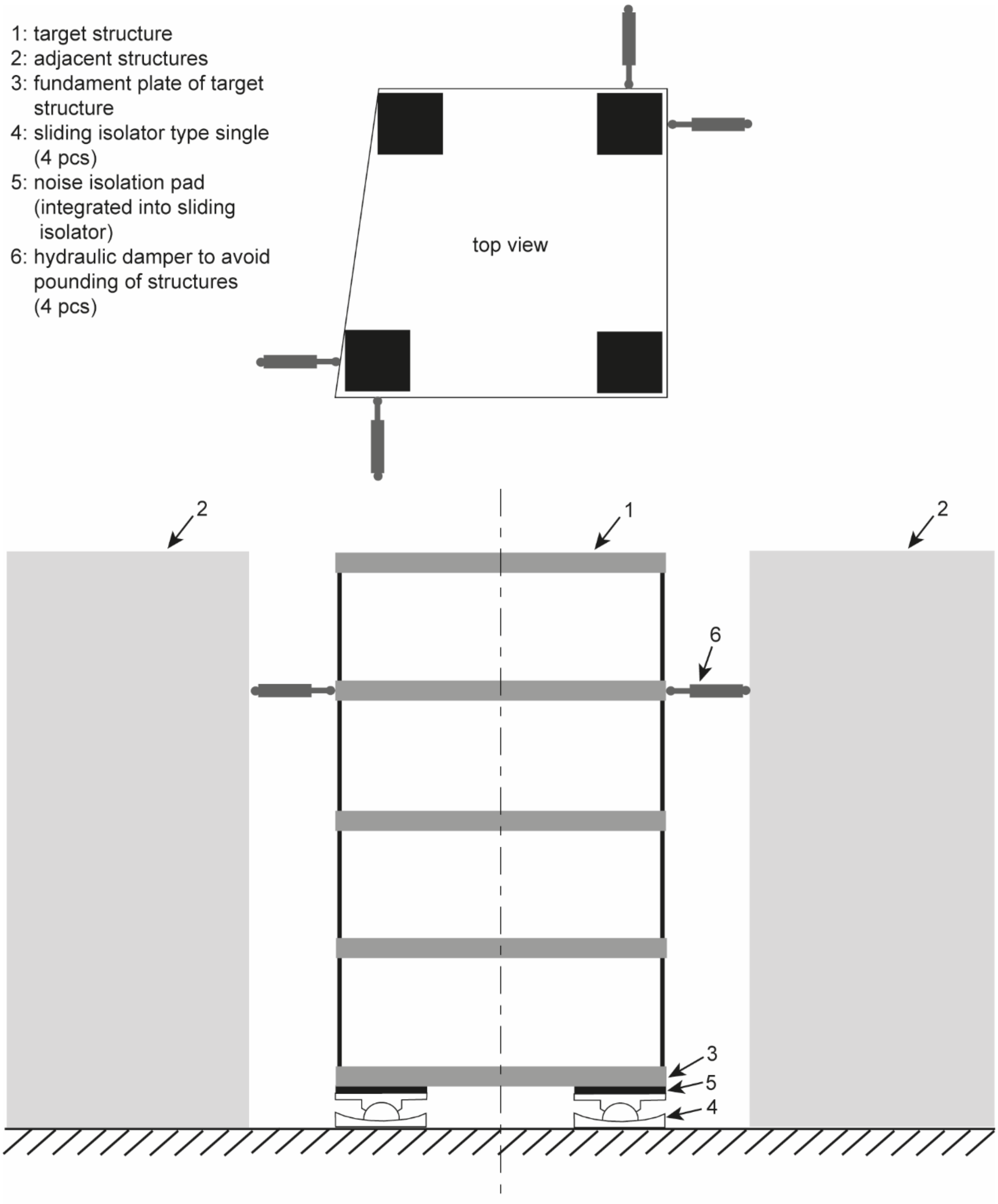


Figure 4. Layout of seismic and noise isolation system.

6. Non-linear time history analyses

6.1. Modelling

Structure:

- The structure is modelled as linear 5 degree-of-freedom system.
- The stiffness and damping elements of all stories are assumed to be equal. These parameters are tuned to generate the correct eigenfrequency of the first bending mode (average value of both orthogonal directions) and 5 % of critical damping (Figure 5, Figure 6).
- The fundament plate is assumed to be rigidly connected with the upper bearing plate of the base isolator.
- The base isolators are modelled by their linear coupling stiffness force and their non-linear damping force.
- The hydraulic dampers located between surrounding structure and target structure are modelled by their non-linear constitutive damping law.

6.2. Robust solver

The target structure with base isolators, hydraulic dampers and ground excitation by compatible accelerograms is computed in the time domain. The **non-linear and stiff differential equation system** is solved using the **robust solver *ode15s (stiff/NDF)*** with variable time step size, maximum time step size of 4e-4 s and relative error tolerance of 1e-3.

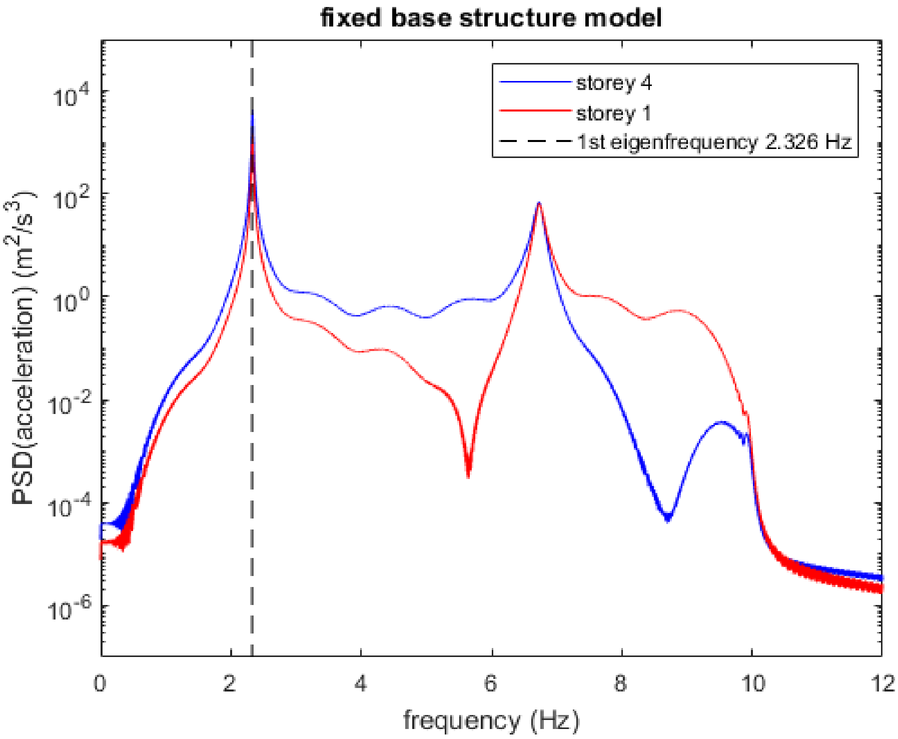


Figure 5. Stiffness validation of structural model to guarantee correct first eigenfrequency.

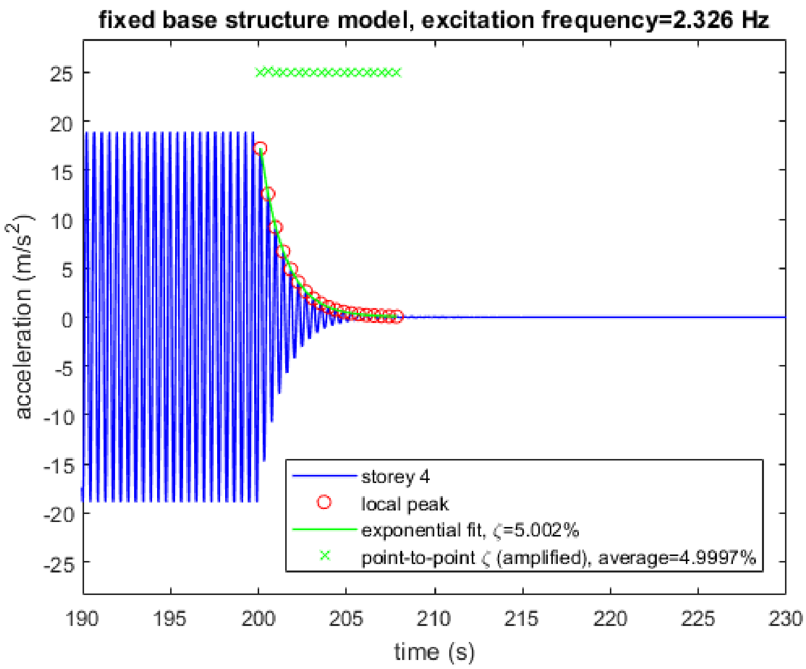


Figure 6. Damping validation of structural model to guarantee correct damping ratio.

6.3. Simulation examples

Main results of simulations based on the compatible accelerograms 1 and 14 are depicted in Figure 7 to Figure 14. These figures show how the simulations are performed and assessed by the according peak values for each simulation.

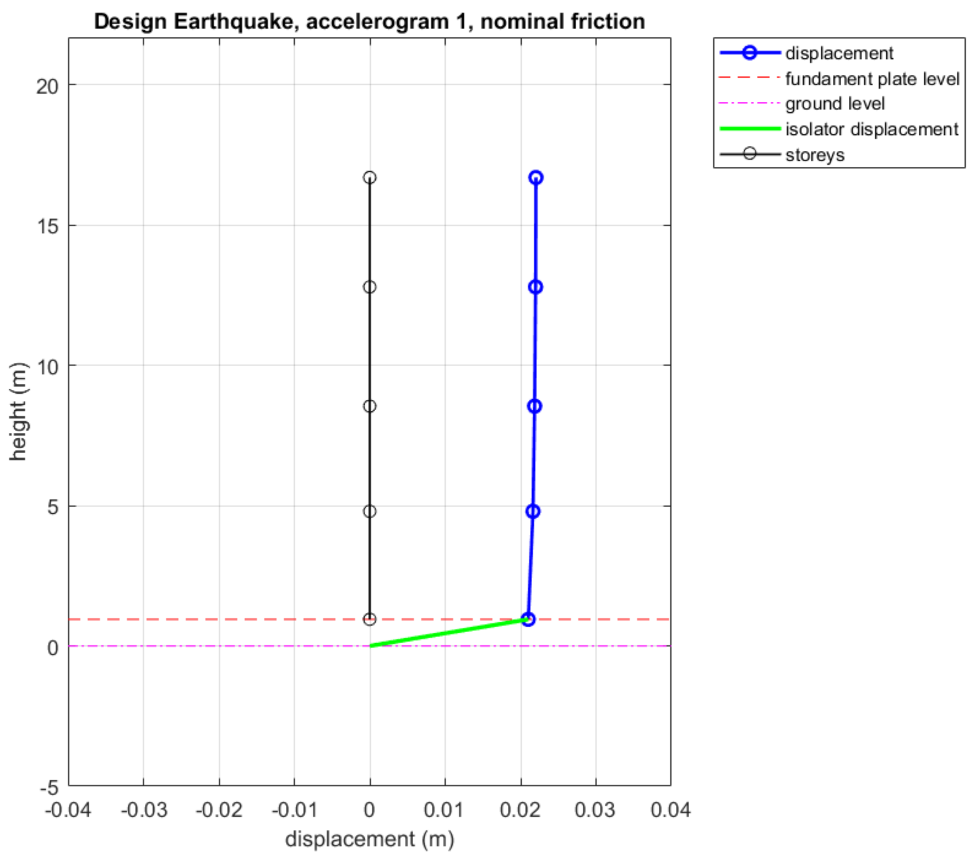


Figure 7. Structural displacements for compatible accelerogram 1 and nominal friction.

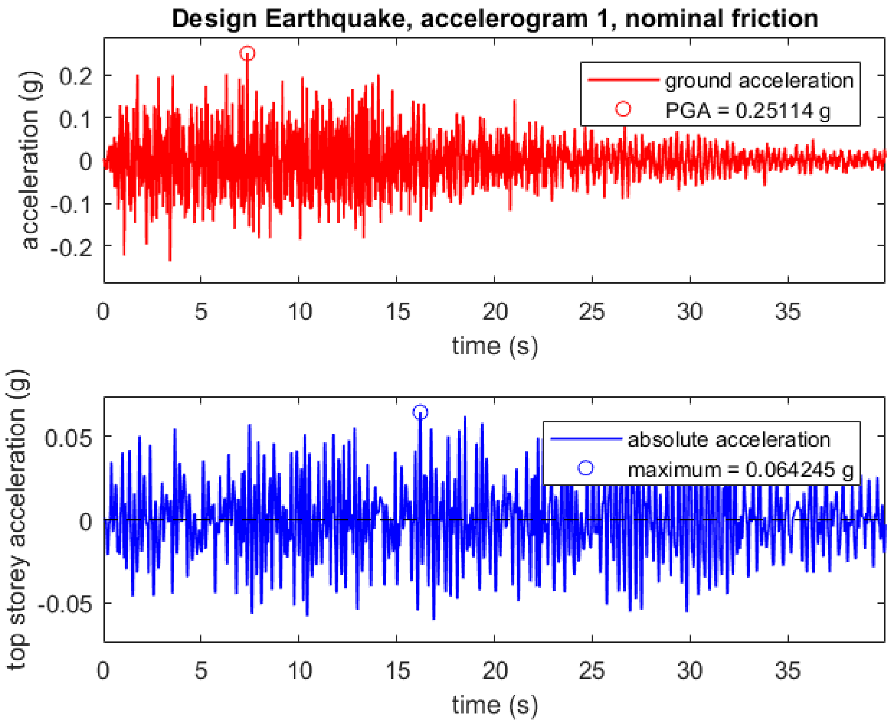


Figure 8. Compatible ground acceleration (above) and resulting absolute acceleration of top storey for compatible accelerogram 1 and nominal friction.

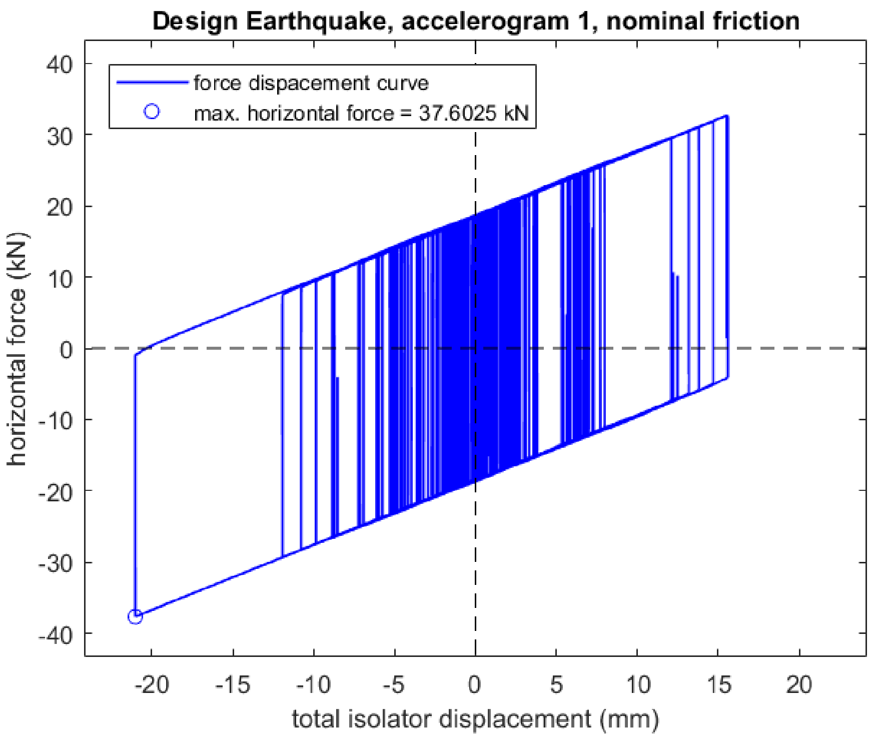


Figure 9. Longitudinal force versus longitudinal displacement of isolator for compatible accelerogram 1 and nominal friction.

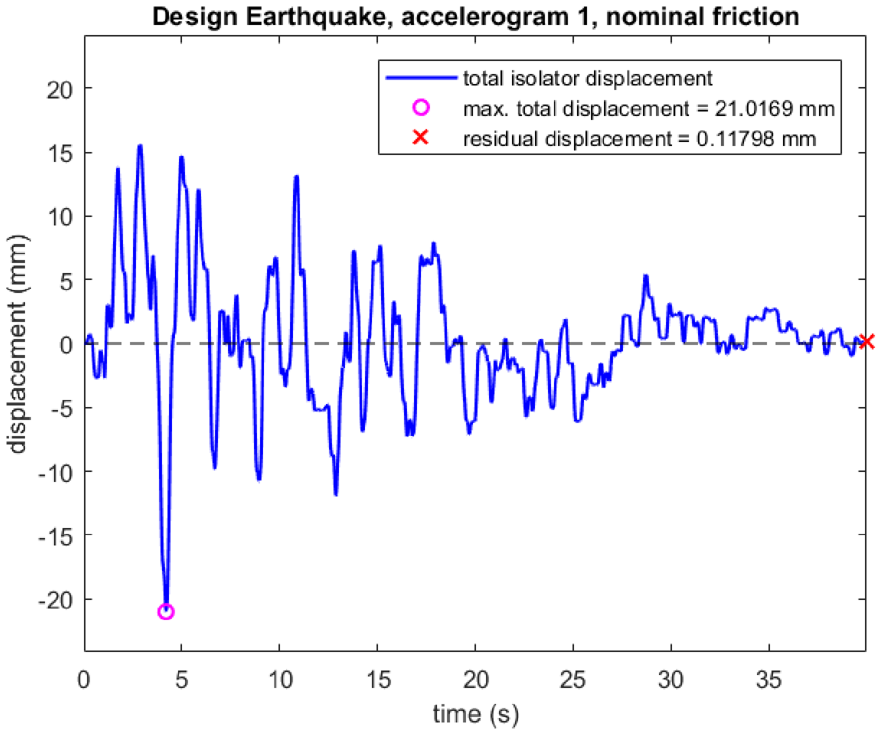


Figure 10. Isolator relative motion for compatible accelerogram 1 and nominal friction.

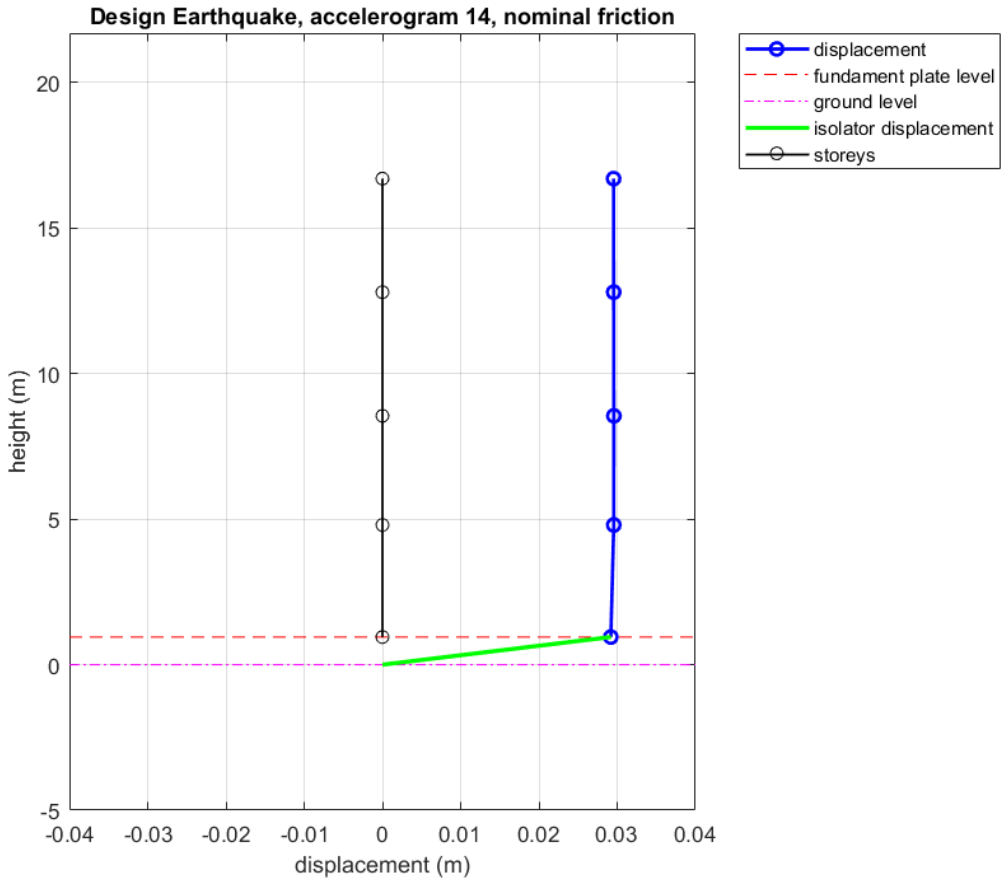


Figure 11. Structural displacements for compatible accelerogram 14 and nominal friction.

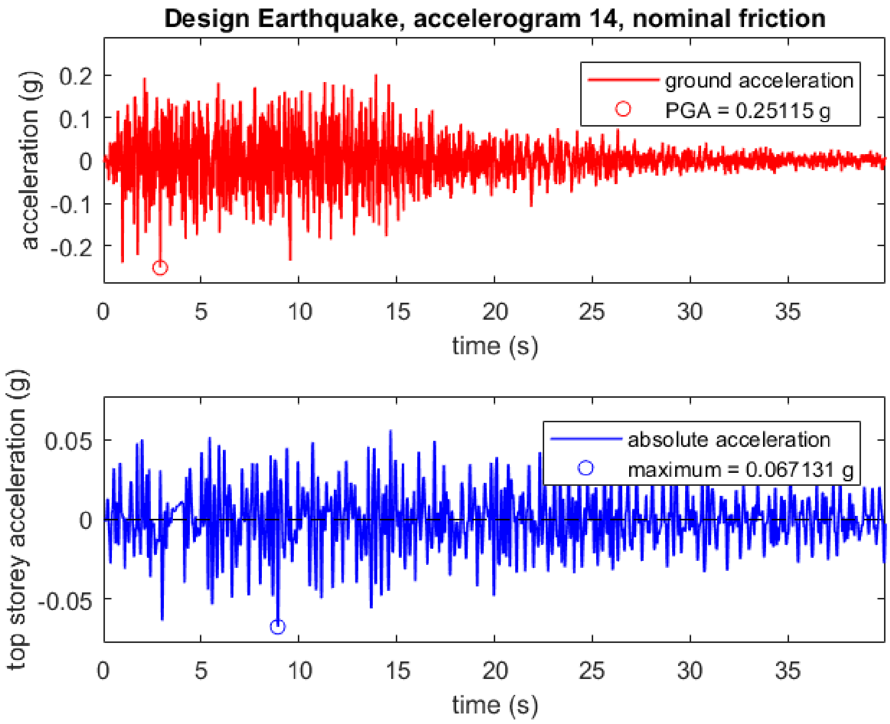


Figure 12. Compatible ground acceleration (above) and resulting absolute acceleration of top storey for compatible accelerogram 14 and nominal friction.

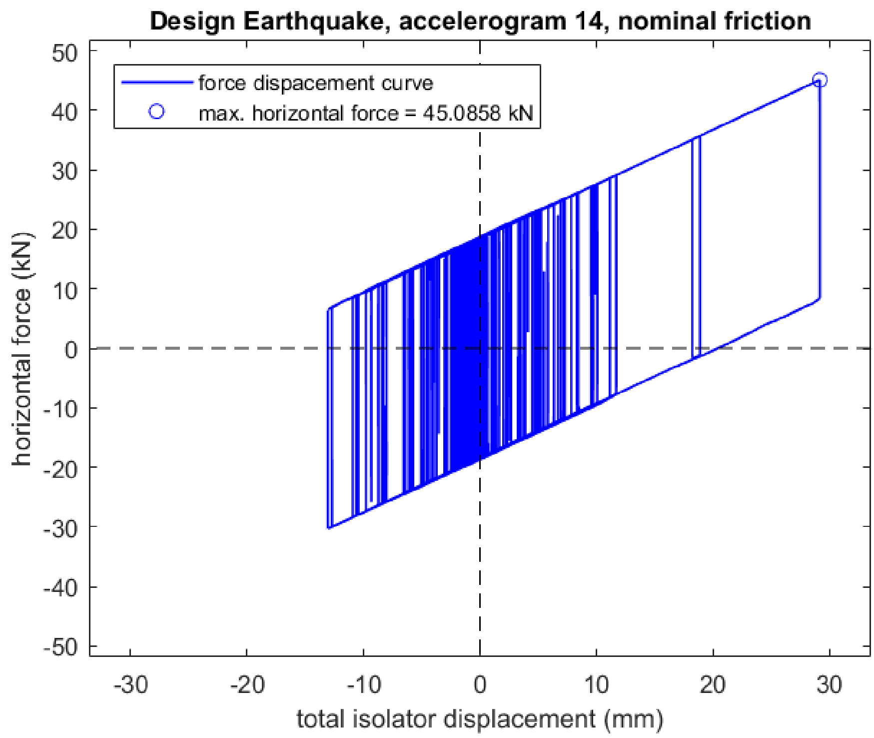


Figure 13. Longitudinal force versus longitudinal displacement of isolator for compatible accelerogram 14 and nominal friction.

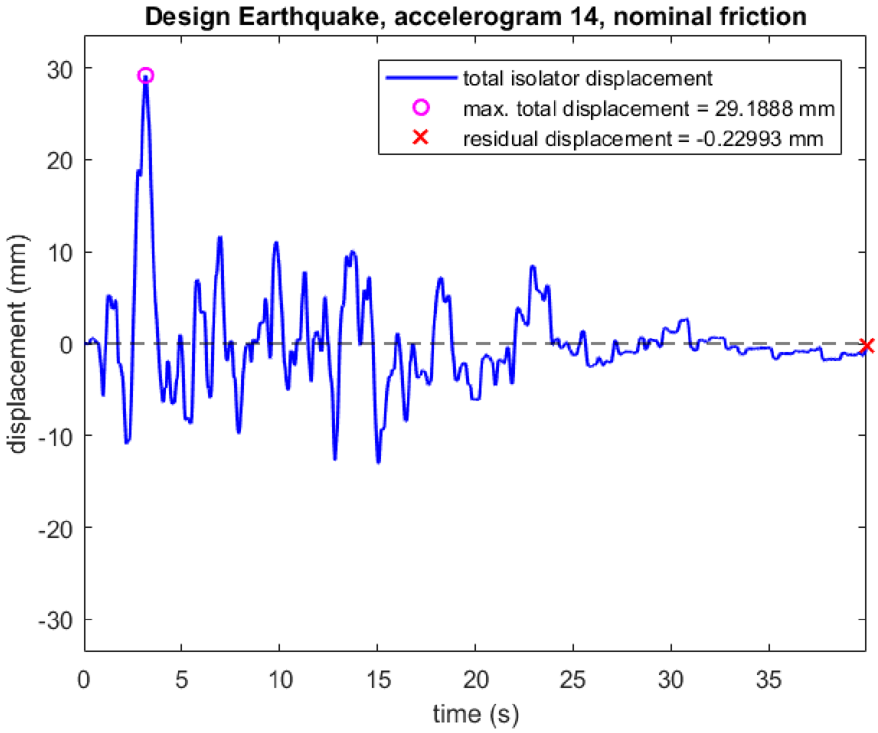


Figure 14. Isolator relative motion for compatible accelerogram 14 and nominal friction.

6.4. Hydraulic damper

The hydraulic dampers are designed to guarantee the produce behaviour:

- Minimum coupling damping force (linear constitutive damping law, low viscous coefficient) at ground shaking levels (Peak Ground Acceleration) of 50 % and less of the PGA of the compatible accelerograms to avoid coupling to the surrounding structure are low seismic excitation and thereby reduce the noise isolation performance of the target structure (Figure 15, Figure 16).
- Activation of the nonlinear constitutive damping (greater viscous coefficient, α<1) law at ground shaking levels of the compatible accelerograms (Figure 17, Figure 18).
- Further increasing nonlinear (greater viscous coefficient, α<1) damping forces (but limited by the according α-coefficient) are produced at ground shaking levels significantly above the PGA of the compatible accelerograms to avoid pounding even at unforeseen high ground shaking levels. In Figure 19 and Figure 20 the Design Seismic Situation is amplified by 2,5.

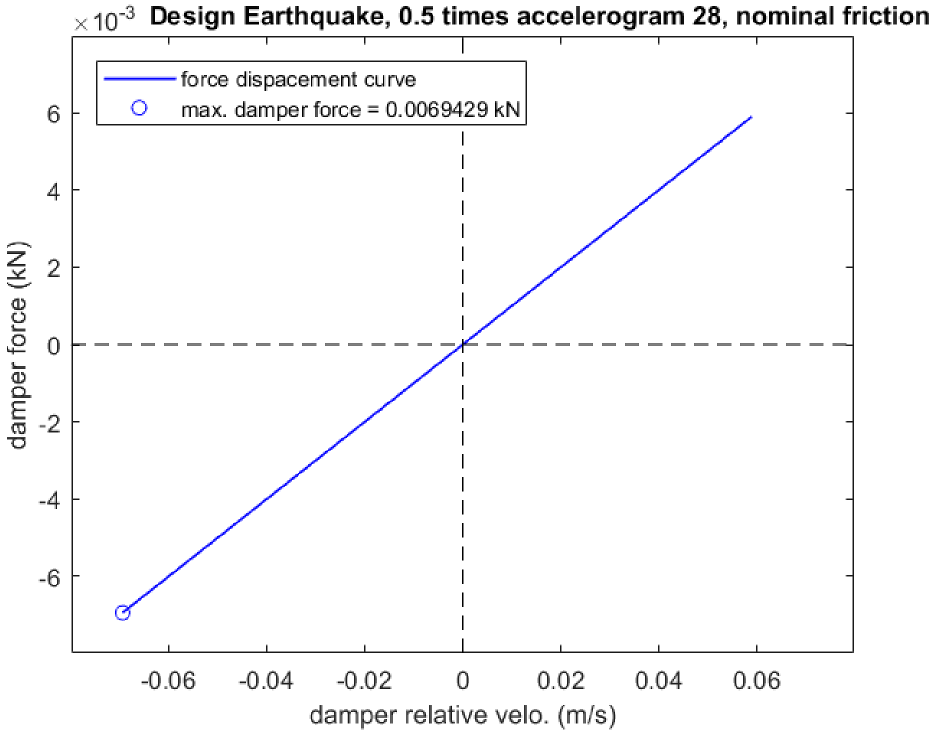


Figure 15. Force velocity curve of both hydraulic dampers in one main direction for 50 % of compatible accelerogram 28 and nominal friction of base isolator.

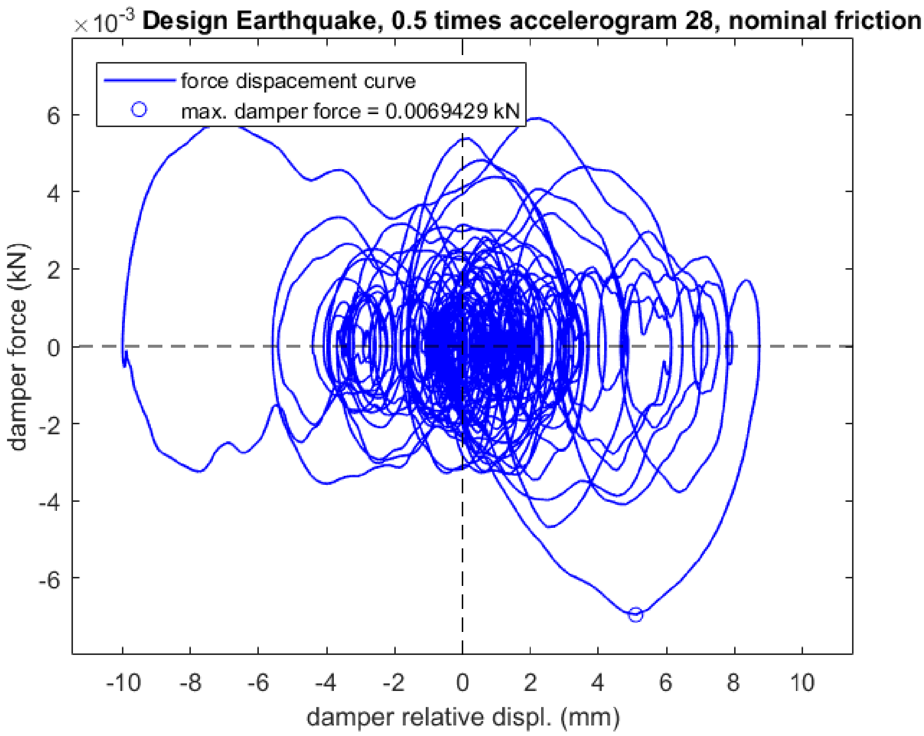


Figure 16. Force displacement curve of both hydraulic dampers in one main direction for 50 % of compatible accelerogram 28 and nominal friction of base isolator.

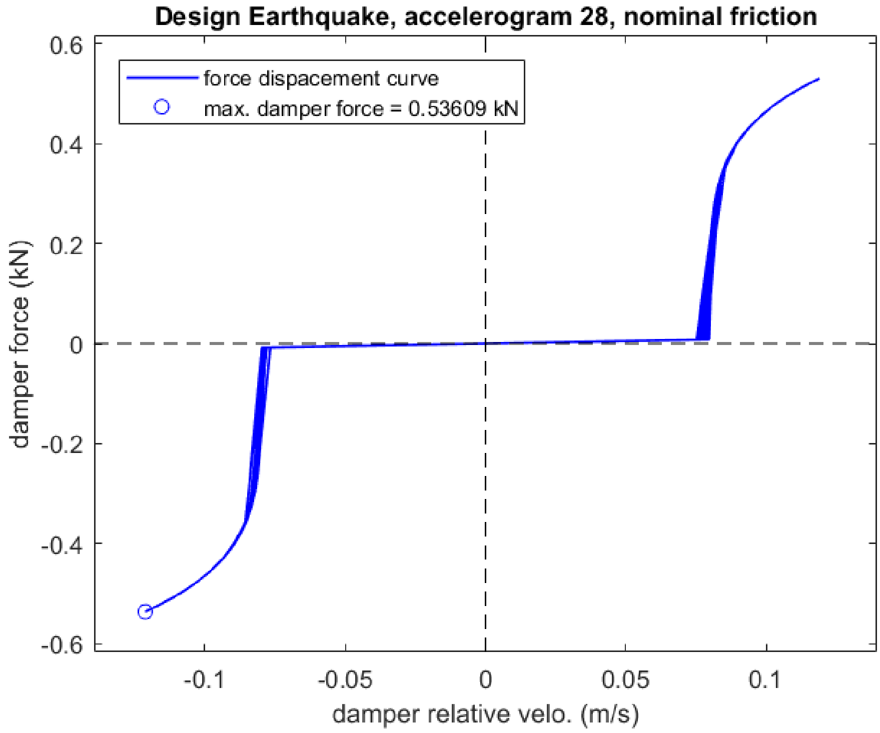


Figure 17. Force velocity curve of both hydraulic dampers in one main direction for 100 % of compatible accelerogram 28 and nominal friction of base isolator.

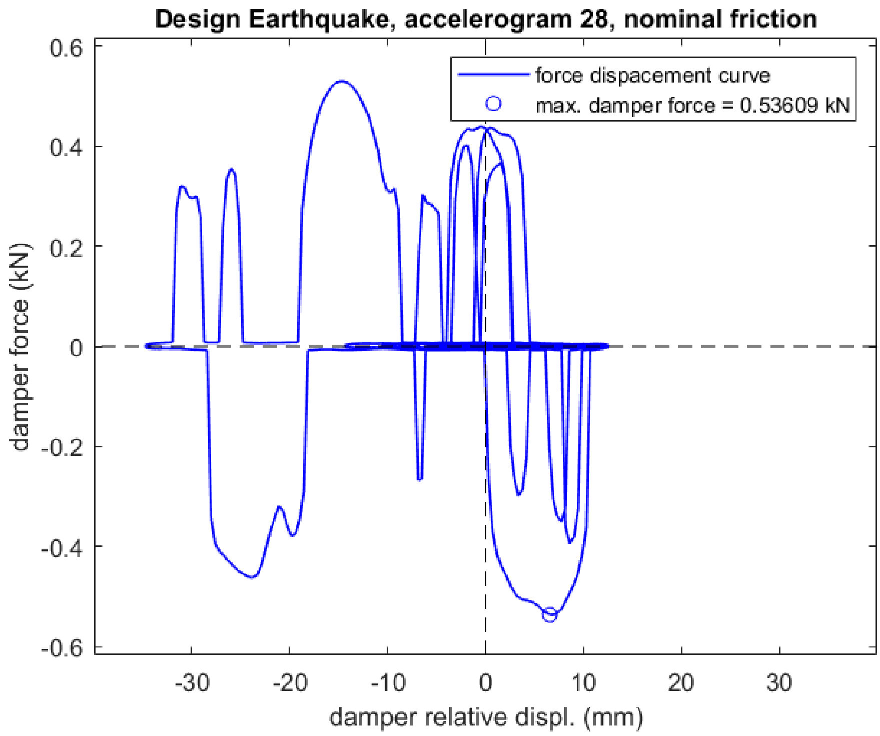


Figure 18. Force displacement curve of both hydraulic dampers in one main direction for 100 % of compatible accelerogram 28 and nominal friction of base isolator.

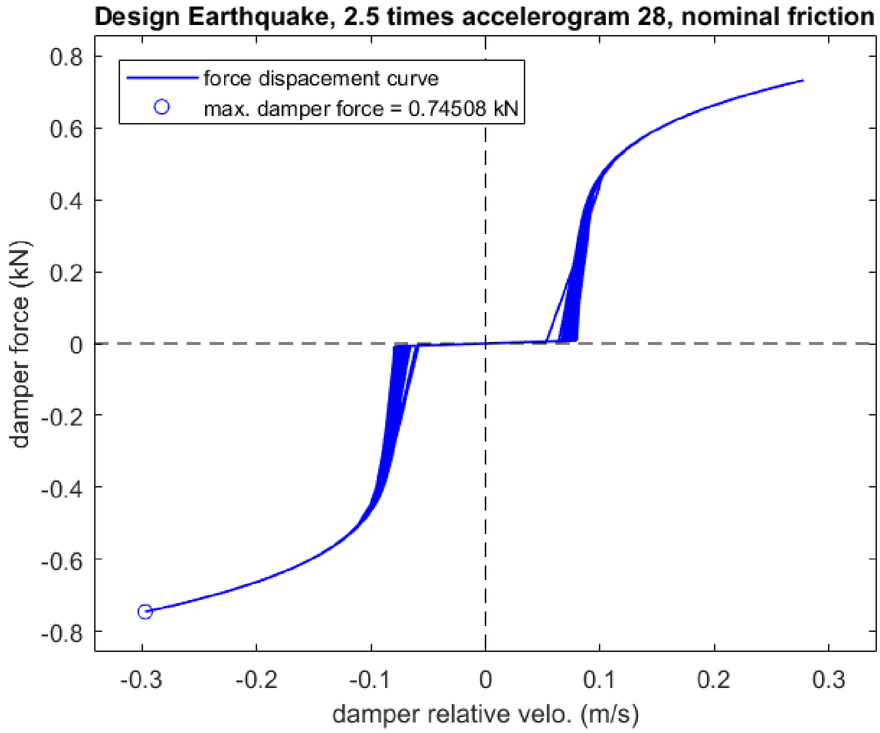


Figure 19. Force velocity curve of both hydraulic dampers in one main direction for 250 % of compatible accelerogram 28 and nominal friction of base isolator.

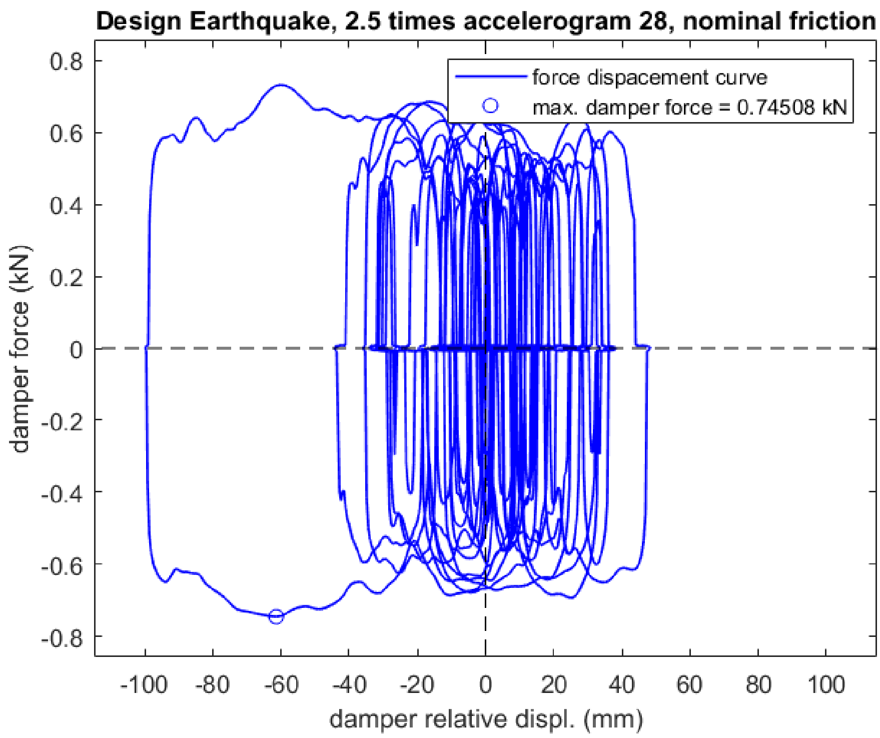


Figure 20. Force displacement curve of both hydraulic dampers in one main direction for 250 % of compatible accelerogram 28 and nominal friction of base isolator.

7. Noise isolation

The 3-dimensional noise isolation is produced by Elastomer-based pads between the seismic isolator and the fundament plate. The coupling of the target structure with the surrounding structure by the hydraulic dampers is minimized at low ground shaking levels (see 6.4) by the activated constitutive law of the hydraulic dampers at 50 % and less of the Design Seismic Situation.

At this stage of the project detailed requirements on the noise isolation system are lacking. Therefore, the Elastomer-based pads are designed for the commonly targeted **frequency where attenuation starts, i.e. at 17 Hz**. Hence Elastomer-based pads are designed to generate the natural frequency in vertical direction of the target structure of 10 Hz to 12 Hz (≈17/sqrt(2)).

8. Nominal, lower and upper bound isolator values

The isolation performance of the target structure with base isolator and viscous damper is computed for:

- **NOM (100 %)**: nominal friction of dynamic coefficient of friction of base isolator
- **LB (80 %)**: lower bound values of dynamic coefficient of friction of base isolator
- **UB (120 %)**: upper bound friction of dynamic coefficient of friction of base isolator

9. Results of seismic analyses

9.1. 95 % quantile values

The results of the seismic analyses are given in Table 5 and Table 6.

Table 5. Results from 30 compatible accelerograms, amplified by 1,3 (part 1).

State variables of interest	Assessment method	1,3 × compatible accelerograms		
		LB friction	NOM friction	UB friction
base shear of 1 isolator (%)	95 % quantile	2,2 %	2,4 %	2,6 %
	peak	2,6 %	2,7 %	2,7 %
	mean	1,9 %	2,1 %	2,2 %
horizontal force of 1 isolator (kN)	95 % quantile	41 kN	44 kN	47 kN
	peak	48 kN	49 kN	50 kN
	mean	36 kN	38 kN	40 kN
isolator horizontal displacement (mm)	95 % quantile	28 mm	28 mm	27 mm
	peak	36 mm	34 mm	31 mm
	mean	23 mm	21 mm	20 mm
PFA mass 4 (g)	95 % quantile	0,063 g	0,074 g	0,086 g
	peak	0,065 g	0,077 g	0,089 g
	mean	0,055 g	0,065 g	0,076 g
PFA mass 3 (g)	95 % quantile	0,050 g	0,059 g	0,068 g
	peak	0,051 g	0,061 g	0,072 g
	mean	0,044 g	0,052 g	0,060 g
PFA mass 2 (g)	95 % quantile	0,032 g	0,039 g	0,046 g
	peak	0,034 g	0,041 g	0,049 g
	mean	0,030 g	0,036 g	0,041 g
PFA mass 1 (g)	95 % quantile	0,038 g	0,044 g	0,051 g
	peak	0,041 g	0,045 g	0,052 g
	mean	0,034 g	0,041 g	0,047 g
PFA fundament plate (g)	95 % quantile	0,095 g	0,117 g	0,136 g
	peak	0,098 g	0,119 g	0,137 g
	mean	0,086 g	0,105 g	0,122 g

Table 6. Results from 30 compatible accelerograms, amplified by 1,3 (part 2).

State variables of interest	Assessment method	1,3 × compatible accelerograms		
		LB friction	NOM friction	UB friction
inter-storey drift between mass 4 and mass 3 (%)	95 % quantile	0,004 %	0,004 %	0,005 %
	peak	0,004 %	0,004 %	0,005 %
	mean	0,003 %	0,004 %	0,004 %
inter-storey drift between mass 3 and mass 2 (%)	95 % quantile	0,009 %	0,010 %	0,012 %
	peak	0,009 %	0,010 %	0,012 %
	mean	0,007 %	0,009 %	0,010 %
inter-storey drift between mass 2 and mass 1 (%)	95 % quantile	0,012 %	0,015 %	0,017 %
	peak	0,013 %	0,015 %	0,018 %
	mean	0,011 %	0,013 %	0,015 %
inter-storey drift between mass 1 and fundament plate (%)	95 % quantile	0,022 %	0,025 %	0,029 %
	peak	0,023 %	0,027 %	0,030 %
	mean	0,020 %	0,023 %	0,027 %
re-centring error (%)	95 % quantile	1,8 %	2,1 %	2,0 %
	peak	3,0 %	2,4 %	2,2 %
	mean	0,8 %	0,8 %	0,9 %

9.2. Displacement capacity

The expected horizontal displacement of the isolator at Design Seismic Situation is small, even the peak value (36 mm). The free space between the target structure and the surrounding structure is 150 mm.

It is suggested to design the base isolators and the hydraulic dampers for the displacement capacity of 150 mm to be on the very safe side:

- **base isolator displacement capacity: ±150 mm**
- **hydraulic damper stroke: 150 mm**

10. Design properties of seismic isolation system

10.1. Base isolator

The base isolator design properties are:

- 4 pieces
- Type Single
- Maximum rotation capability: according to EC8
- Seismic vertical load: 1,8334 MN (assuming 4 isolators)
- Isolation time period: 2,837 s
- Effective radius: 2 m
- Dynamic coefficient of friction: 1 % (±0,4 %)
- Displacement capacity: ±150 mm

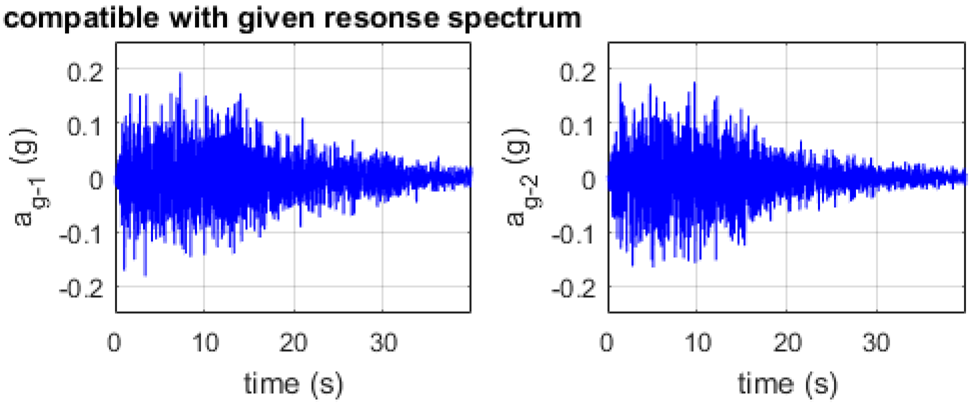
10.2. Hydraulic damper

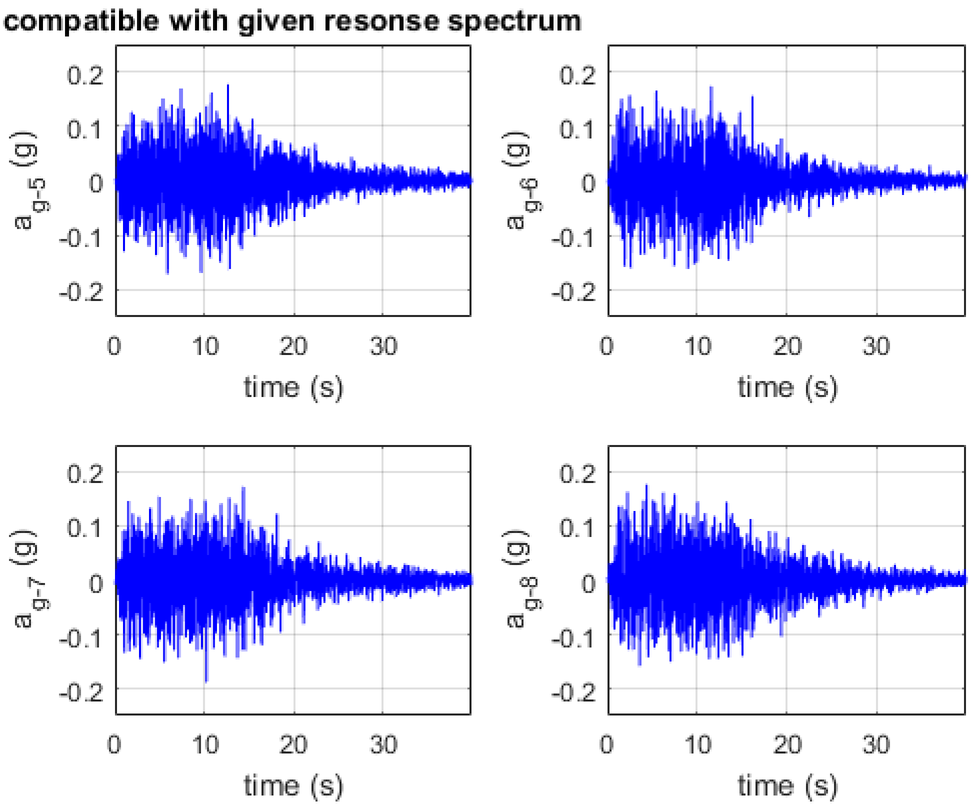
The hydraulic damper design properties are:

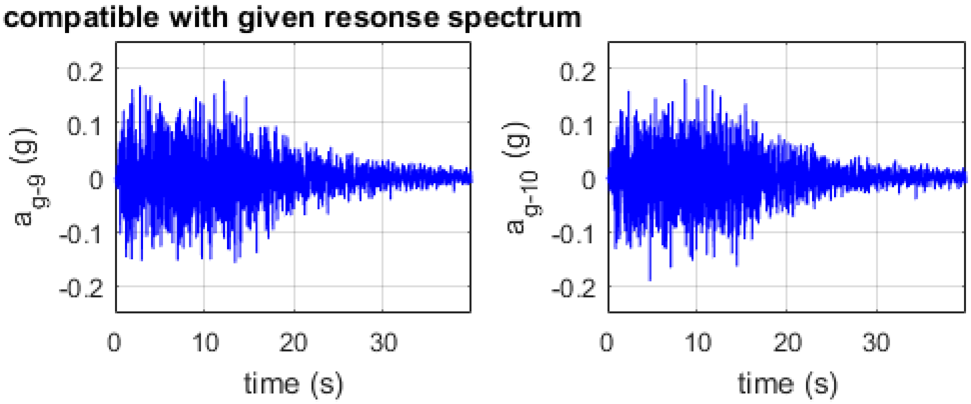
- 4 pieces
- Maximum force < 0,5 kN (for 1 hydraulic damper, at approx. 0,4 m/s)
- Maximum stroke: 150 mm
- Maximum rotation capability (spherical hinges): according to EC8
- Constitutive law at low damper relative velocities (≤0,08 m/s):
  - i) Velocity limit: 0,08 m/s
  - ii) Viscous coefficient: 100 Ns/m
  - iii) α-coefficient: 1
- Constitutive law at greater damper relative velocities (>0,08 m/s):
  - i) Viscous coefficient: 1000 Ns/m
  - ii) α-coefficient: 0,2

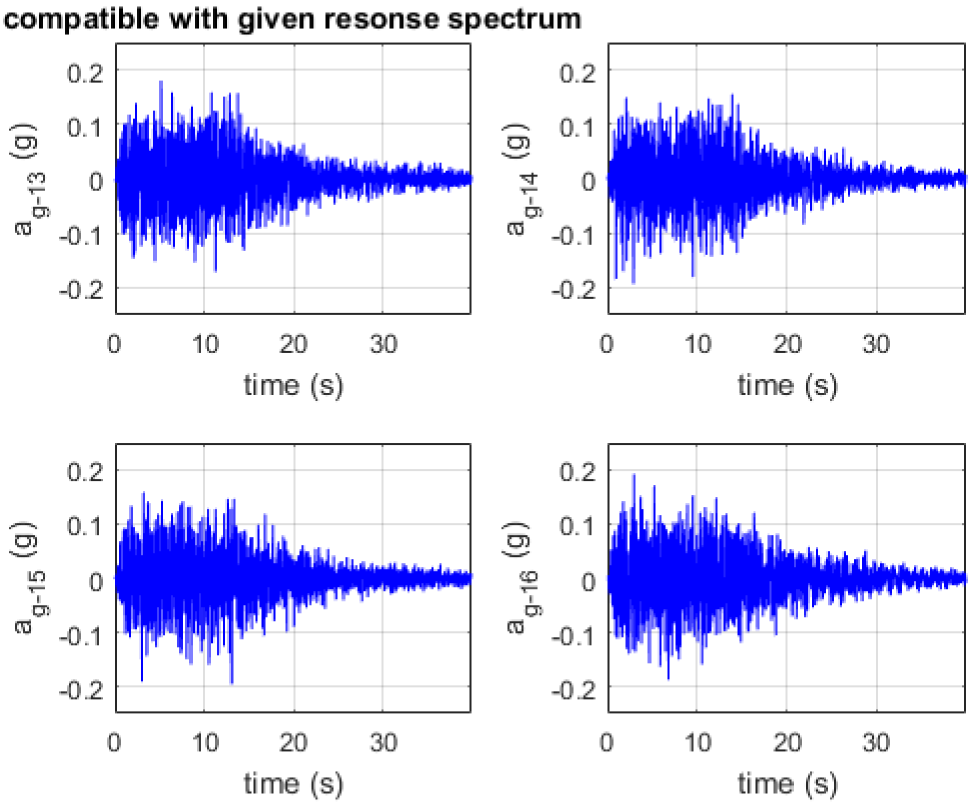
Appendix

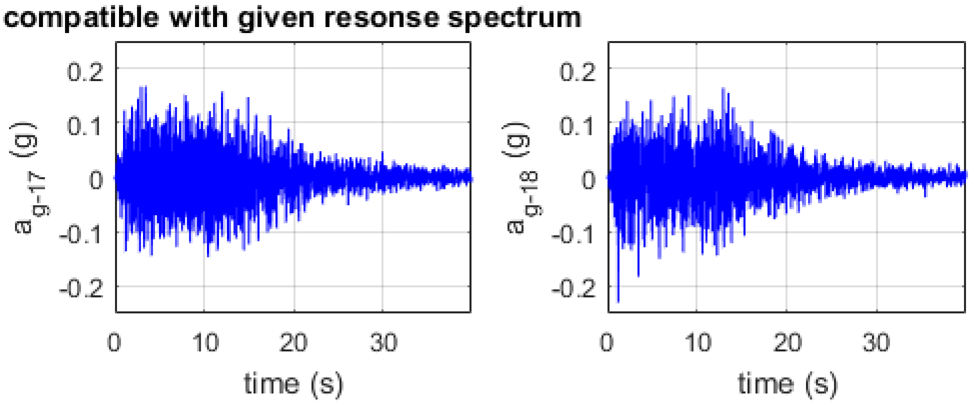
Accelerograms compatible with Design Seismic Situation

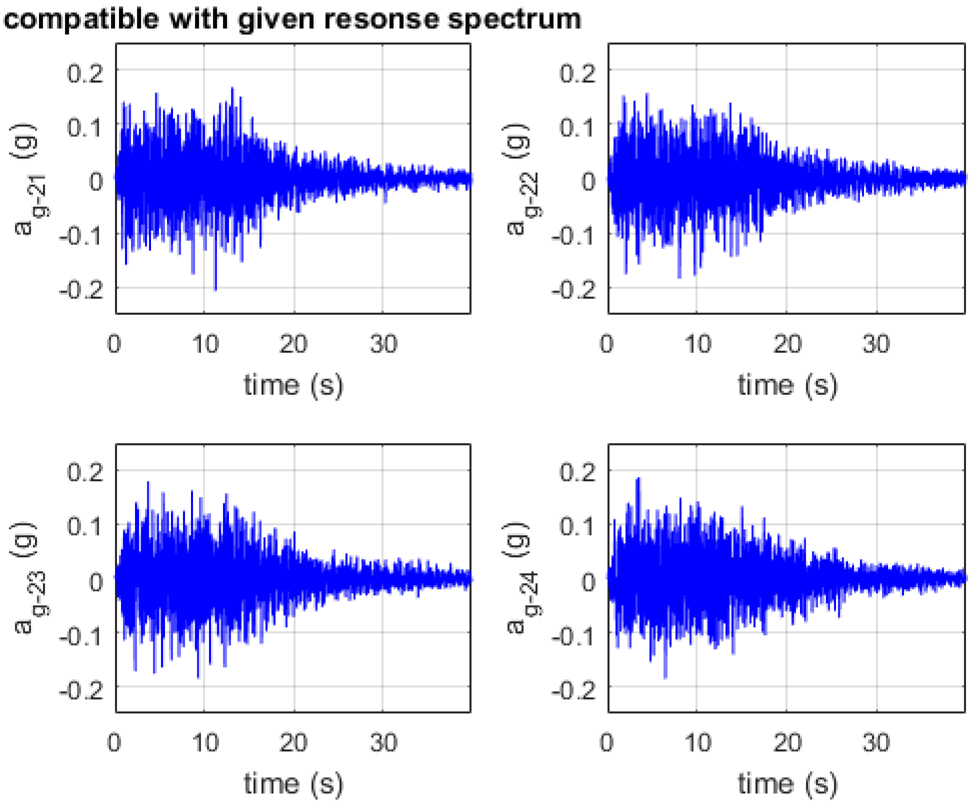


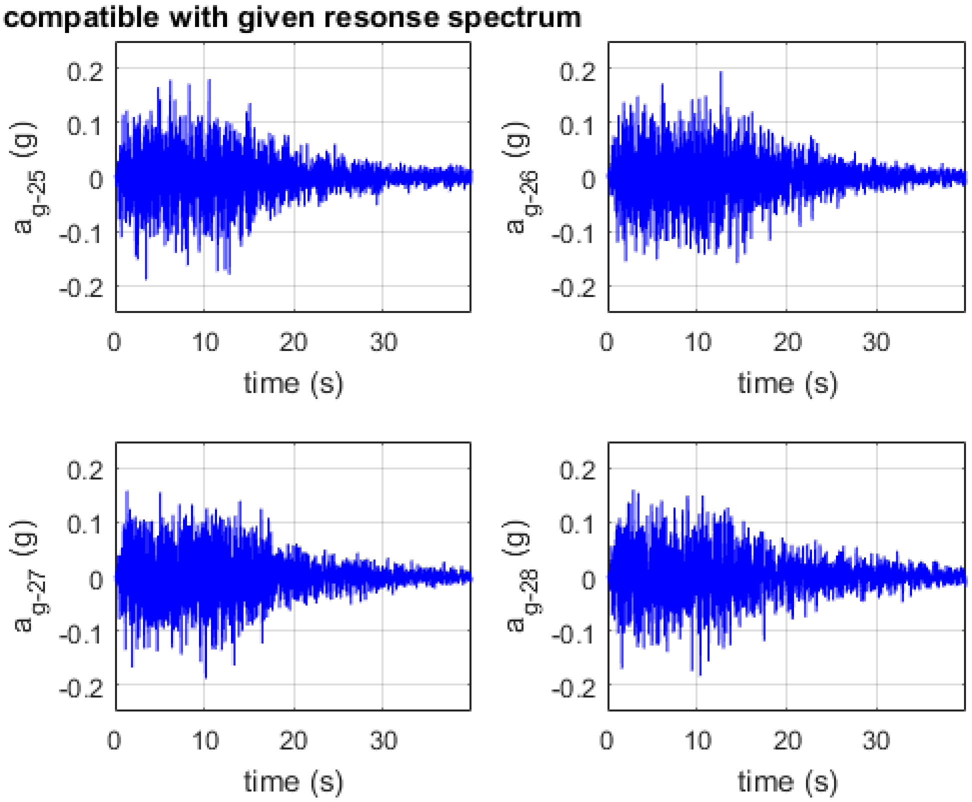


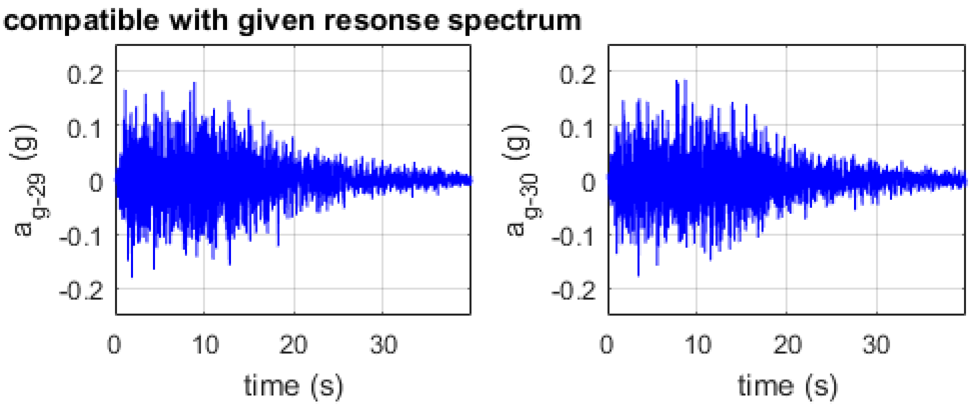

compatible with given resonse spectrum
a_{g-9} (g)
a_{g-10} (g)
a_{g-11} (g)
a_{g-12} (g)
0.2
0.1
0
-0.1
-0.2
0
10
20
30
time (s)


compatible with given resonse spectrum
a_{g-13} (g)
a_{g-14} (g)
a_{g-15} (g)
a_{g-16} (g)
0.2
0.1
0
-0.1
-0.2
0
10
20
30
time (s)

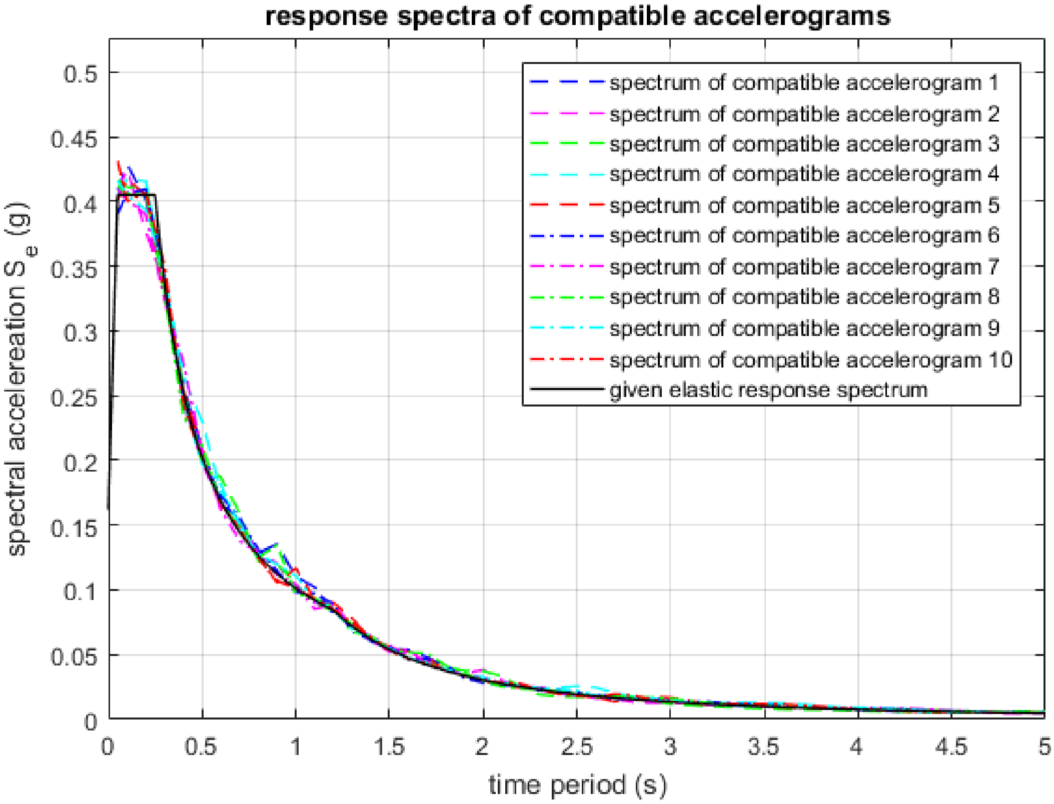

compatible with given resonse spectrum
a g-17 (g)
a g-18 (g)
a g-19 (g)
a g-20 (g)
time (s)

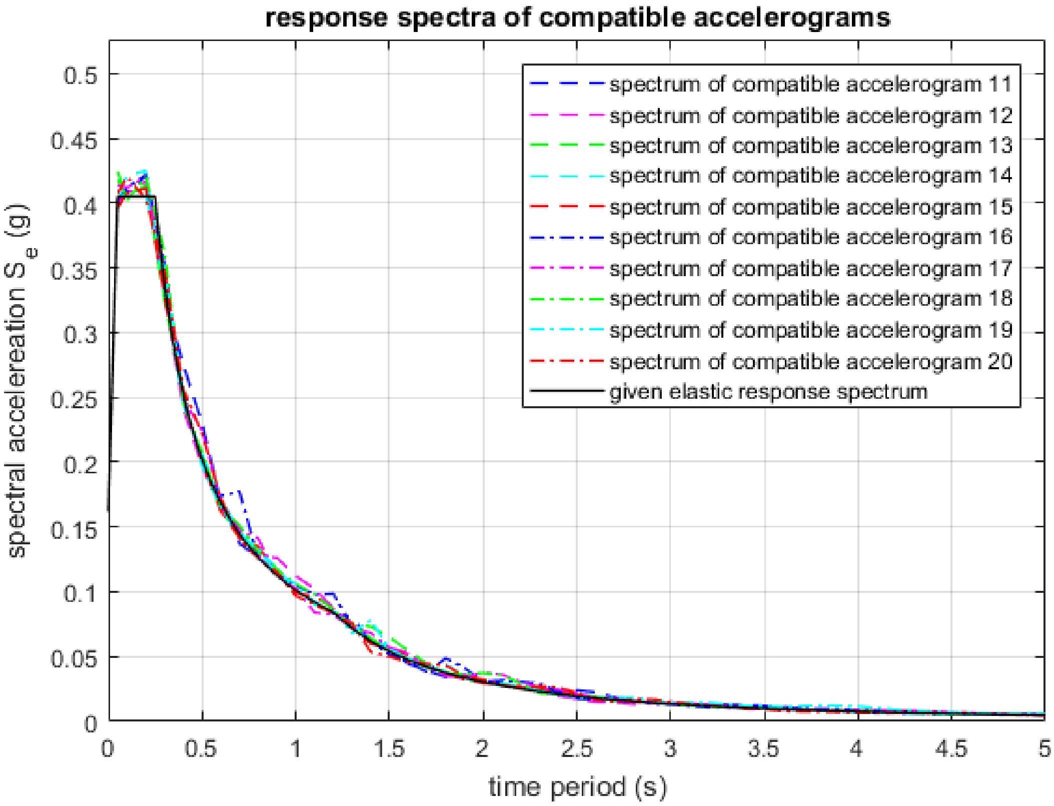

compatible with given resonse spectrum
a g-21 (g)
a g-22 (g)
a g-23 (g)
a g-24 (g)
time (s)

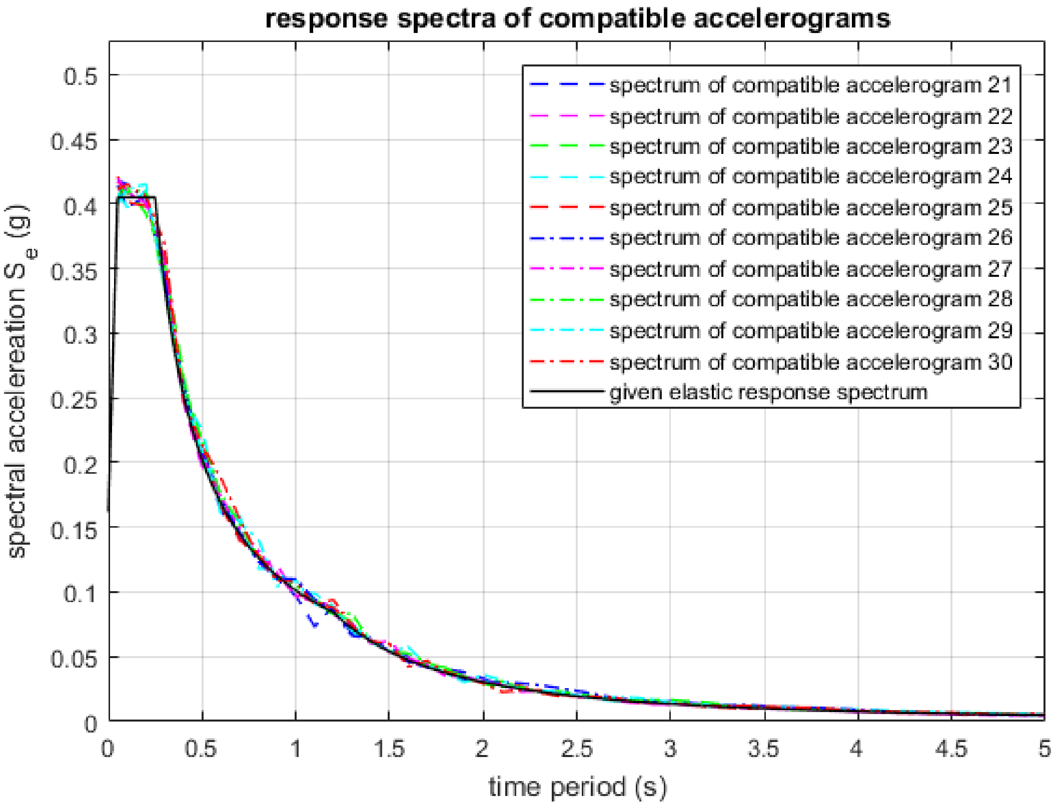

compatible with given resonse spectrum
a_{g-25} (g)
a_{g-26} (g)
a_{g-27} (g)
a_{g-28} (g)
0.2
0.1
0
-0.1
-0.2
0
10
20
30
time (s)


compatible with given resonse spectrum
a_{g-29} (g)
a_{g-30} (g)
0.2
0.1
0
-0.1
-0.2
0
10
20
30
time (s)

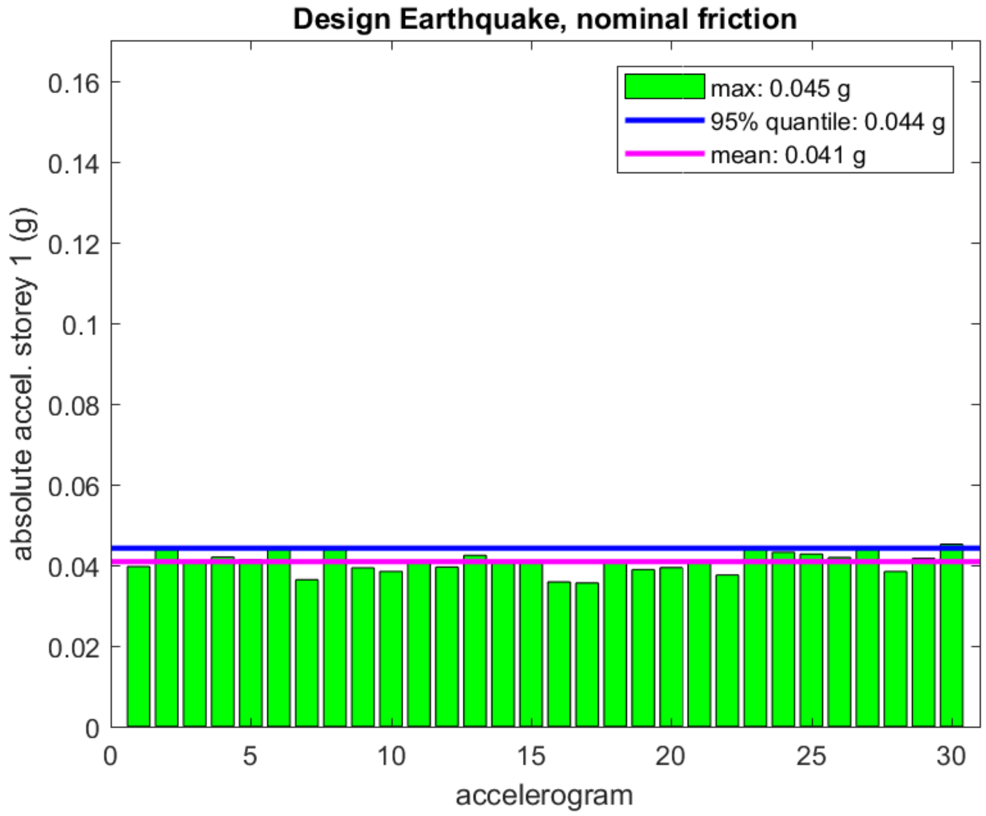
Response spectra of accelerograms compatible with Design Seismic Situation

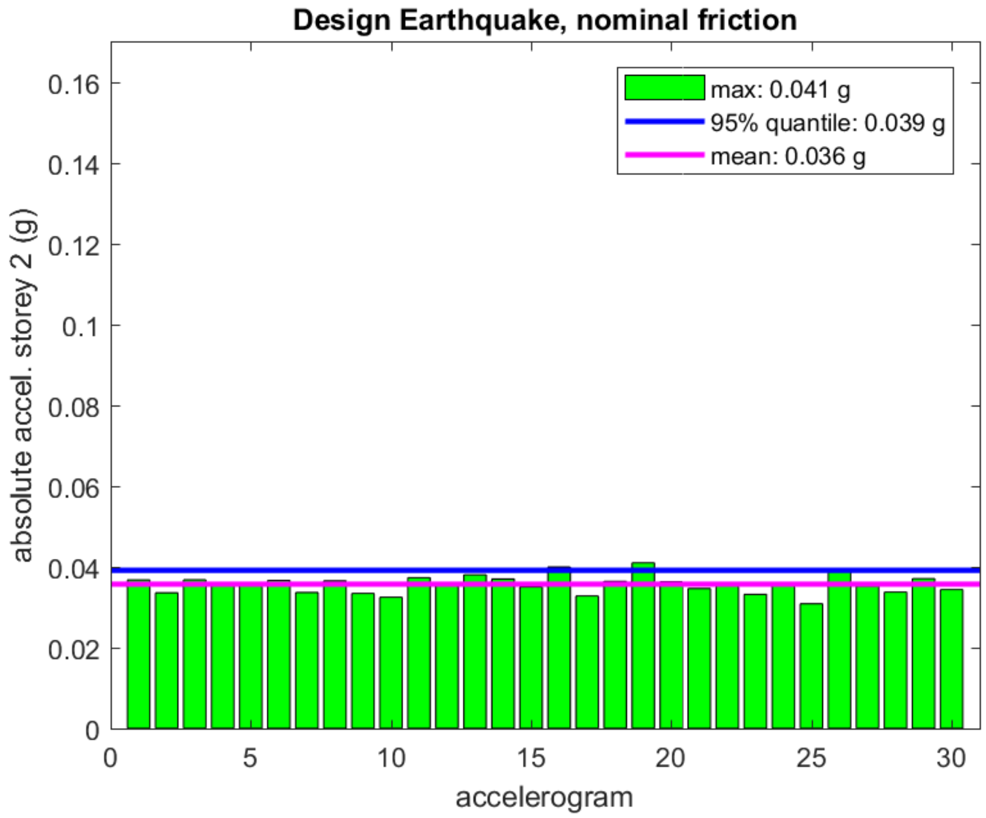


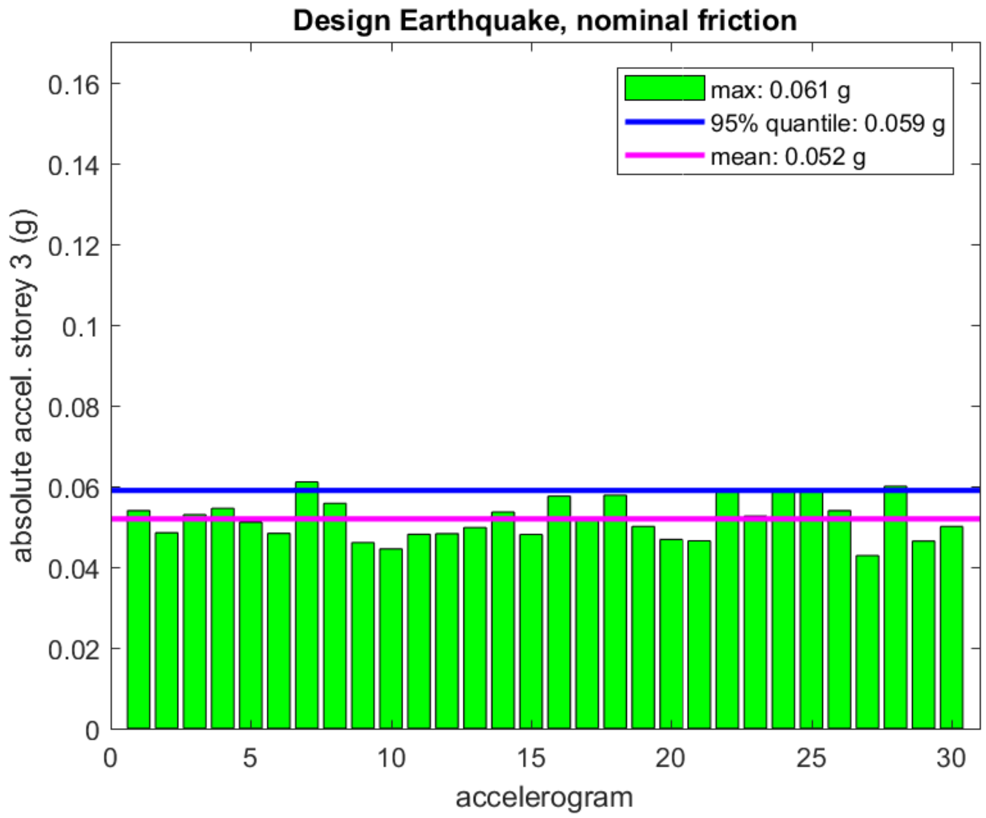



response spectra of compatible accelerograms
spectral accelereation S_e (g)
time period (s)
spectrum of compatible accelerogram 21
spectrum of compatible accelerogram 22
spectrum of compatible accelerogram 23
spectrum of compatible accelerogram 24
spectrum of compatible accelerogram 25
spectrum of compatible accelerogram 26
spectrum of compatible accelerogram 27
spectrum of compatible accelerogram 28
spectrum of compatible accelerogram 29
spectrum of compatible accelerogram 30
given elastic response spectrum
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

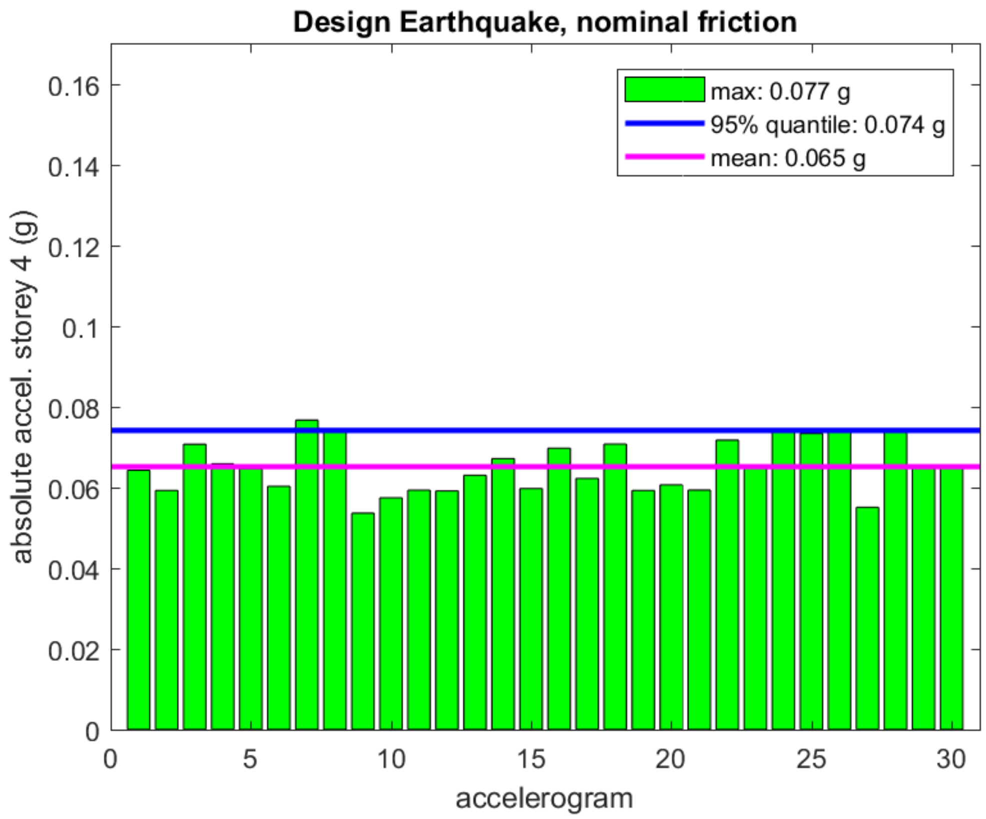
Results for Design Seismic Situation and nominal friction



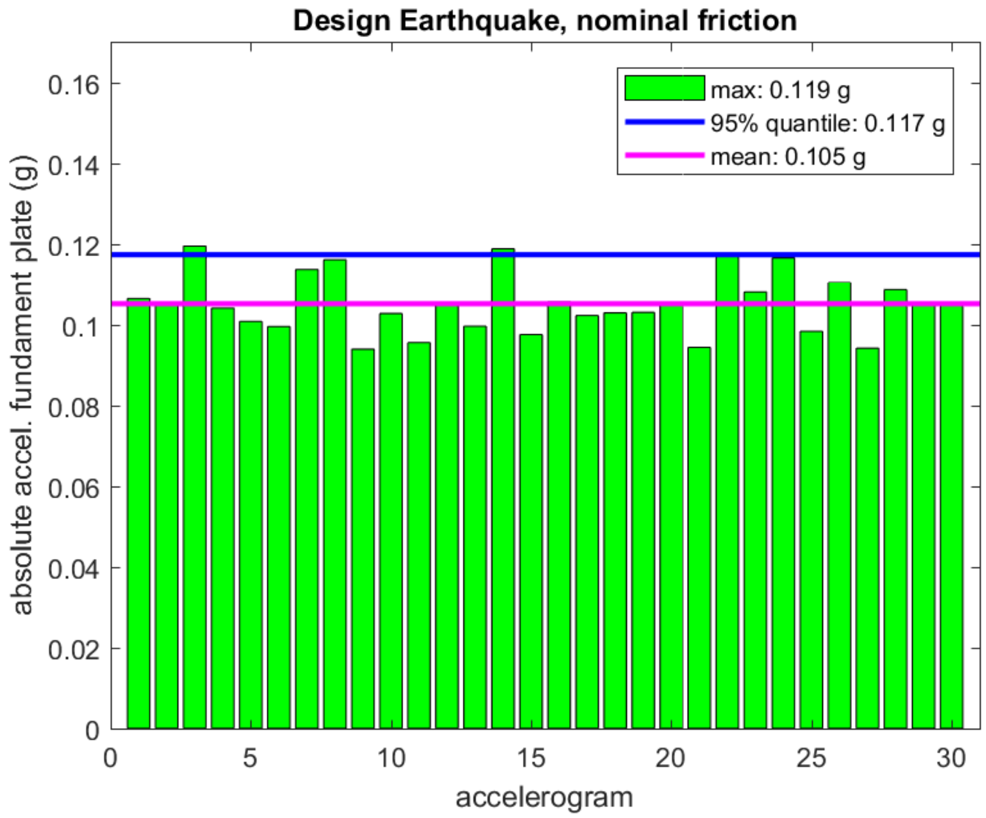


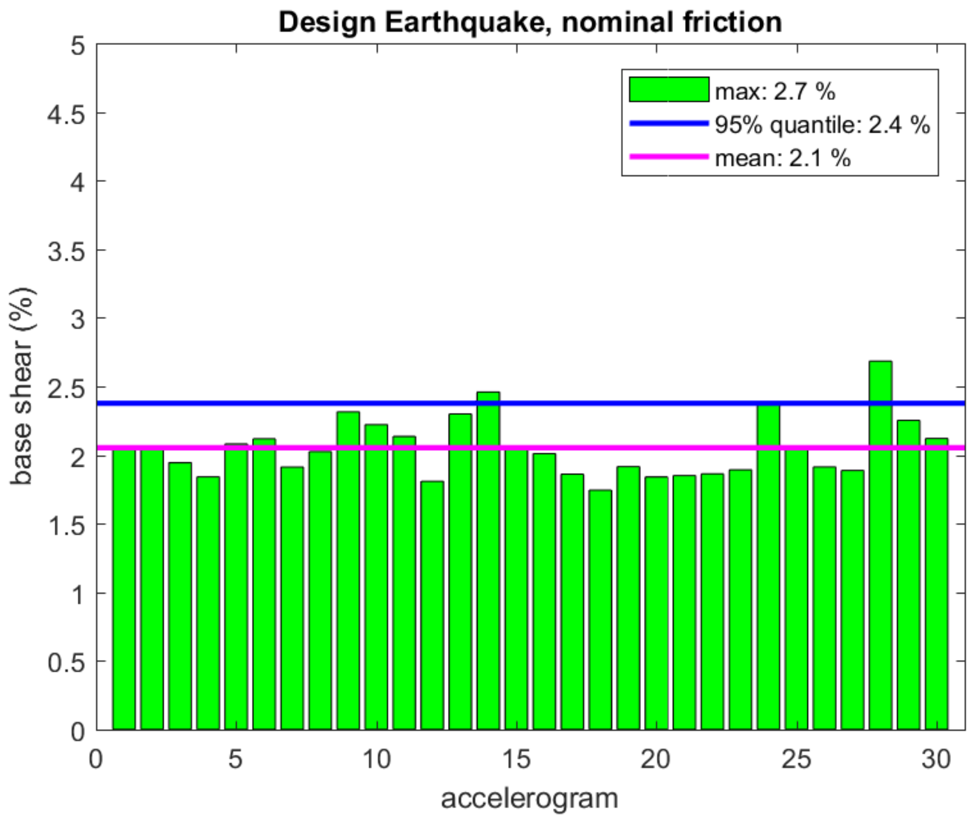


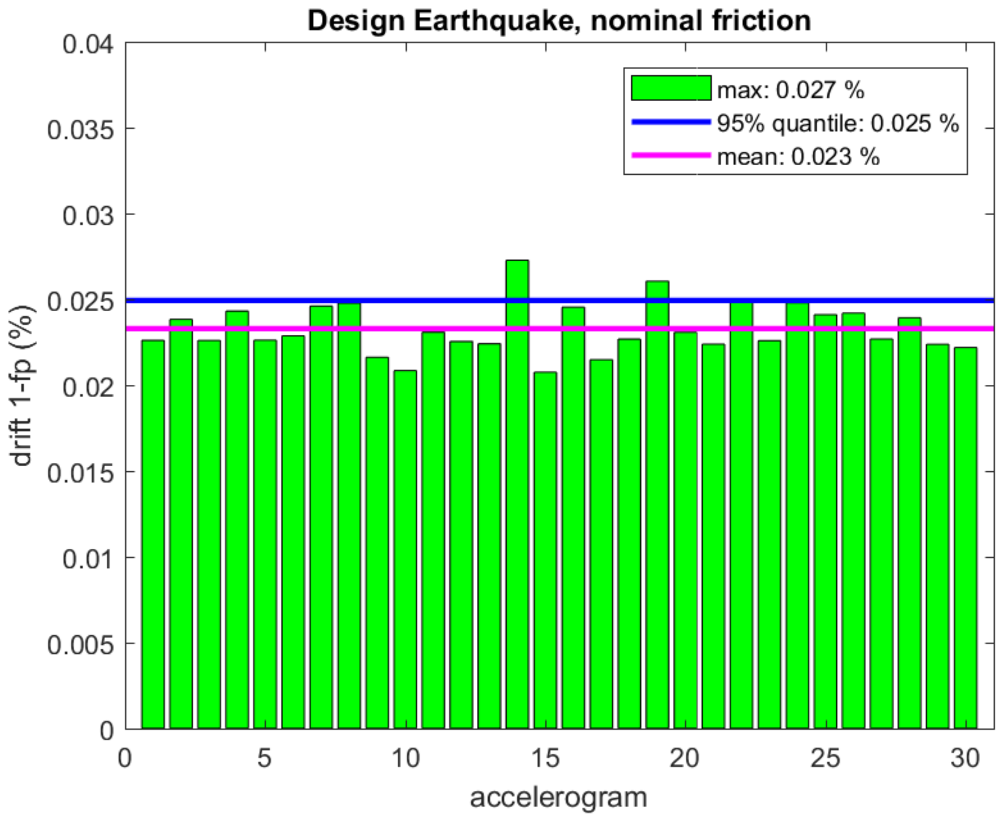
Design Earthquake, nominal friction
max: 0.061 g
95% quantile: 0.059 g
mean: 0.052 g
absolute accel. storey 3 (g)
accelerogram

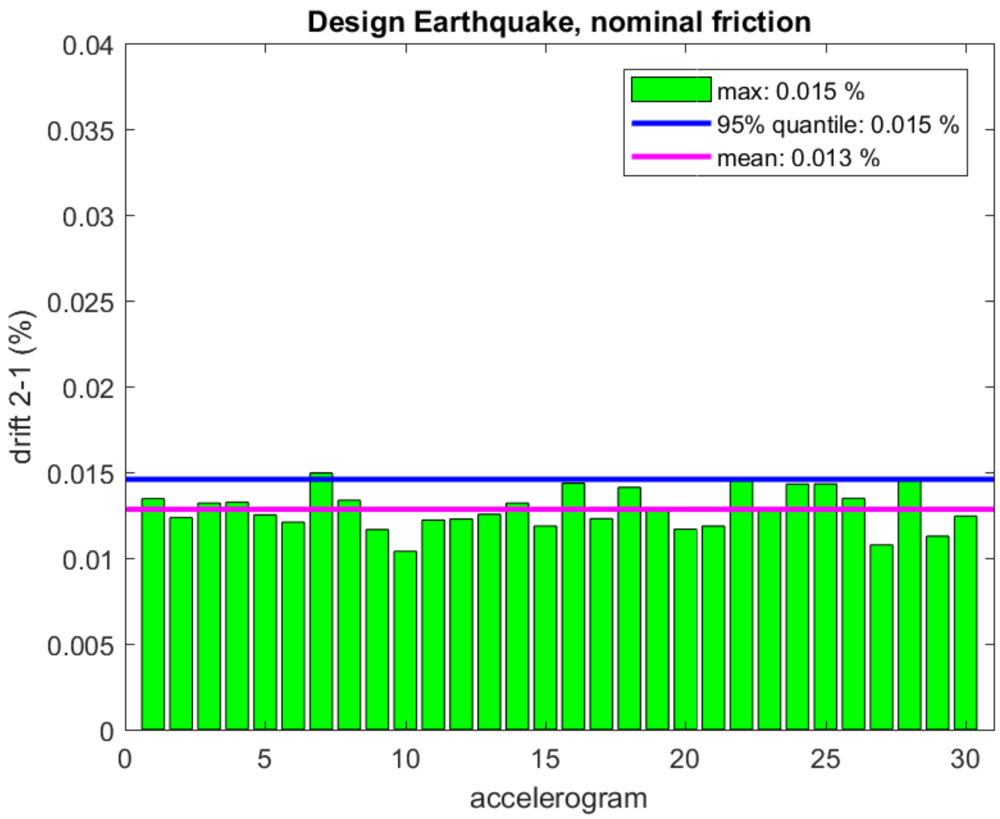


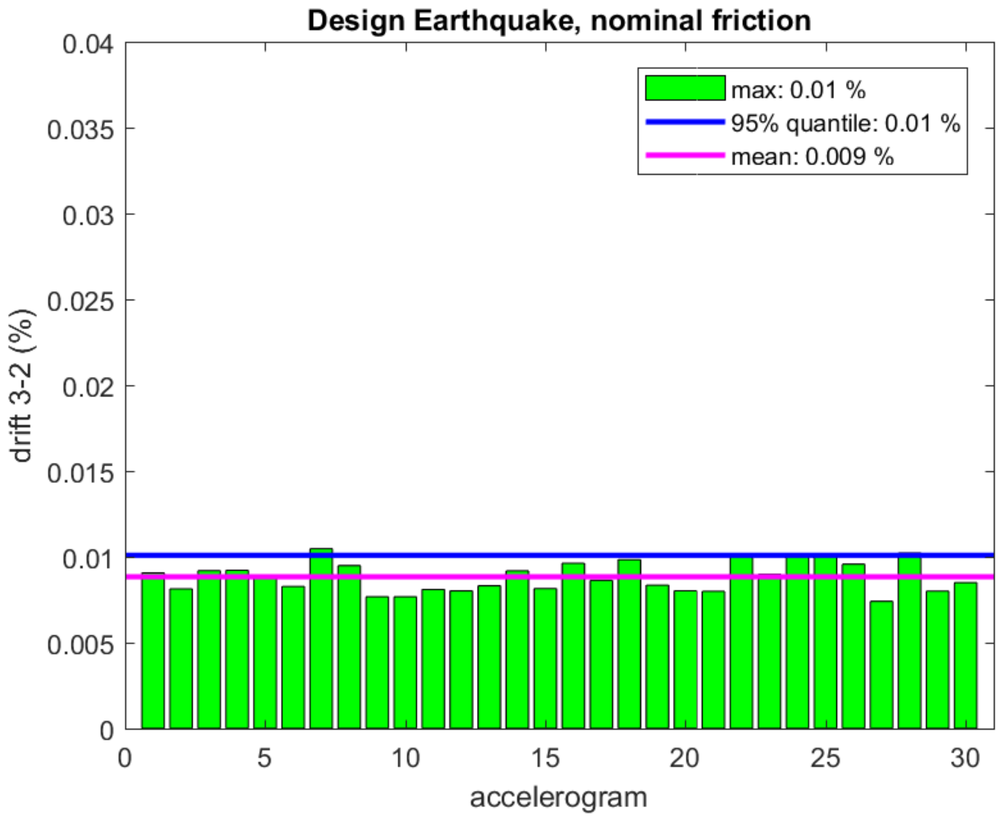
Design Earthquake, nominal friction
max: 0.077 g
95% quantile: 0.074 g
mean: 0.065 g
absolute accel. storey 4 (g)
accelerogram

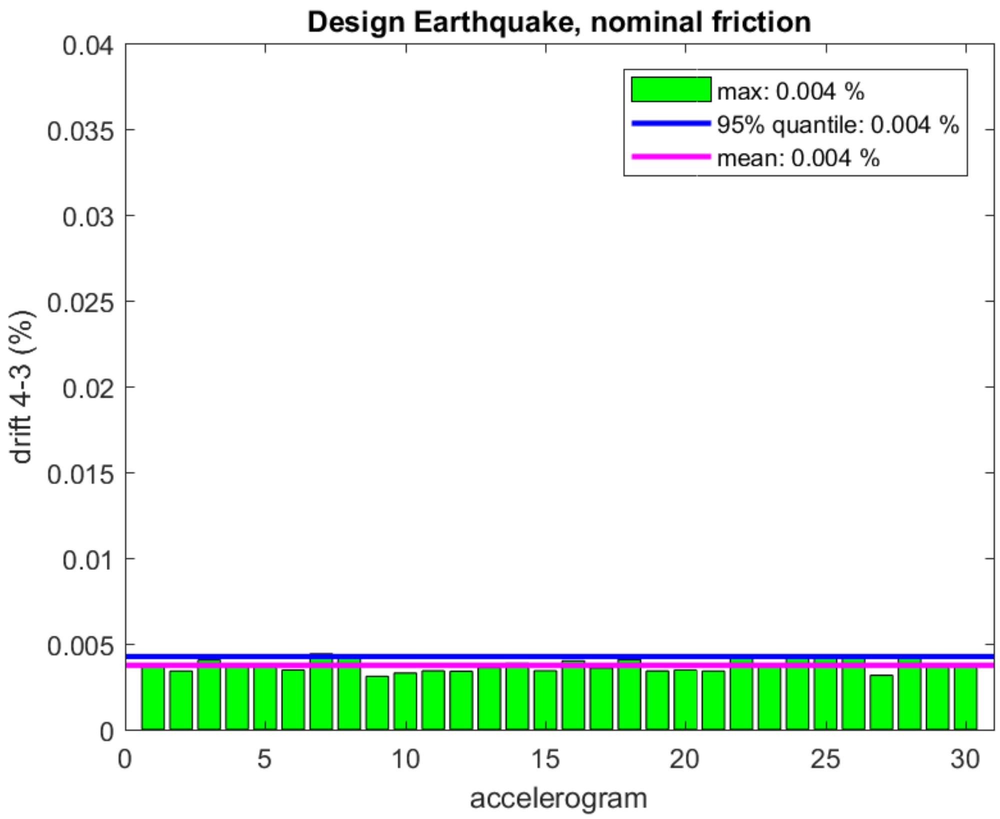

Design Earthquake, nominal friction
max: 0.119 g
95% quantile: 0.117 g
mean: 0.105 g
absolute accel. fundament plate (g)
accelerogram

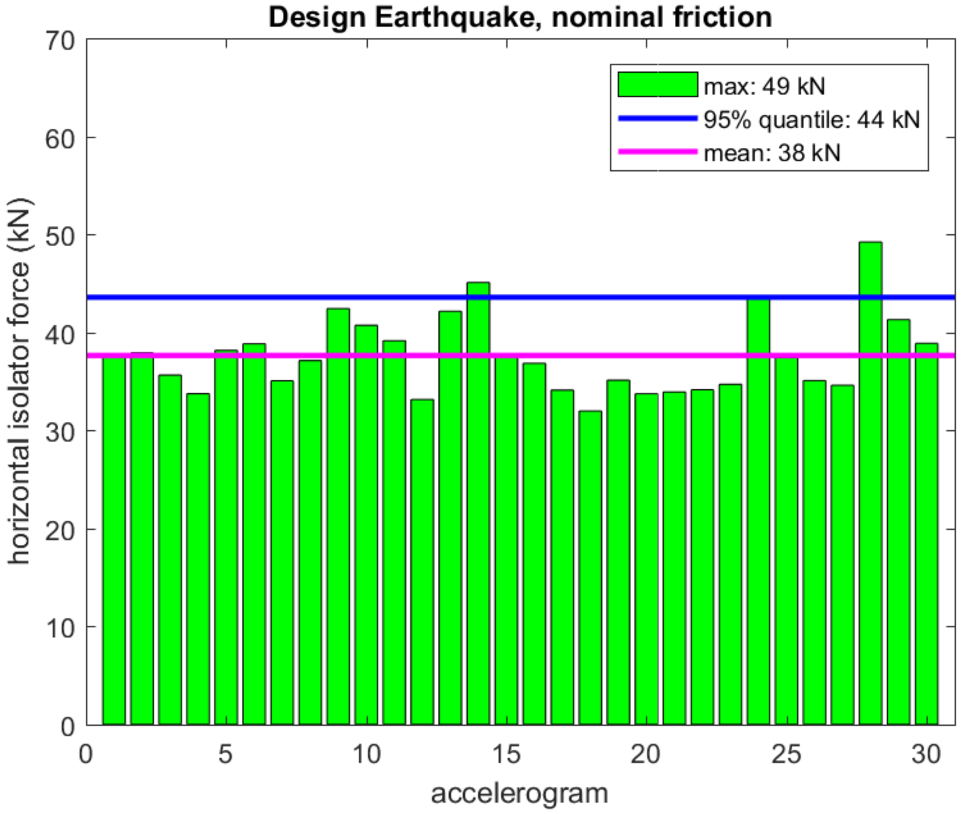

Design Earthquake, nominal friction
max: 2.7 %
95% quantile: 2.4 %
mean: 2.1 %
base shear (%)
accelerogram

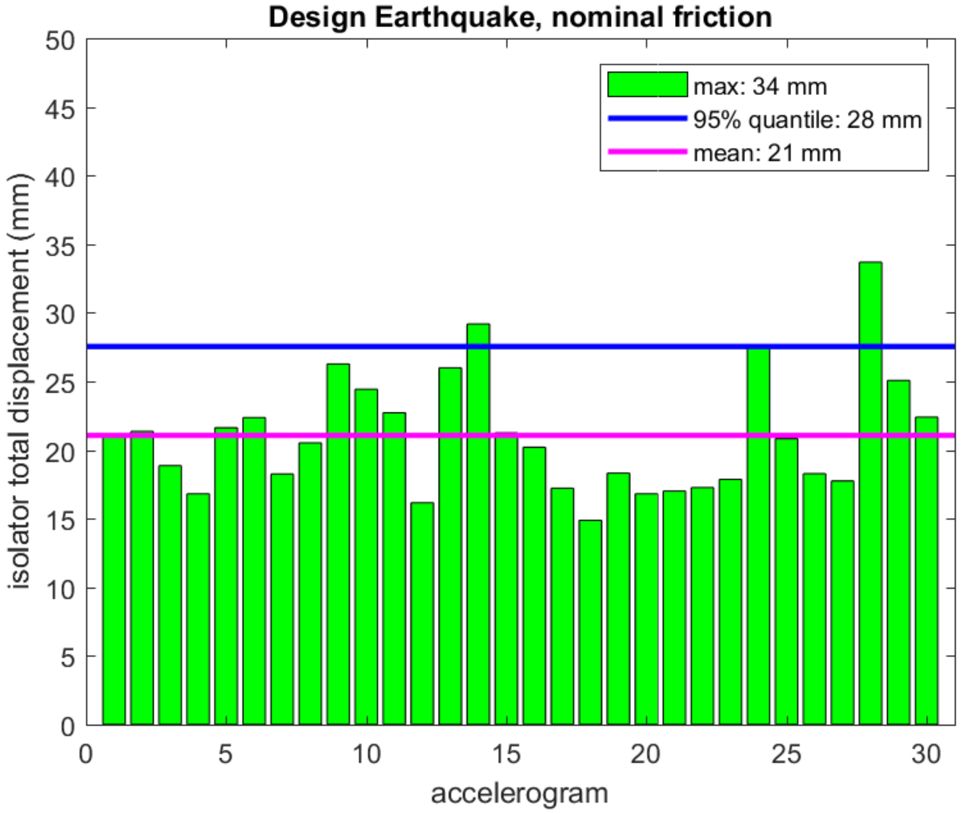

Design Earthquake, nominal friction
max: 0.027 %
95% quantile: 0.025 %
mean: 0.023 %
drift 1-fp (%)
accelerogram
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
5
10
15
20
25
30

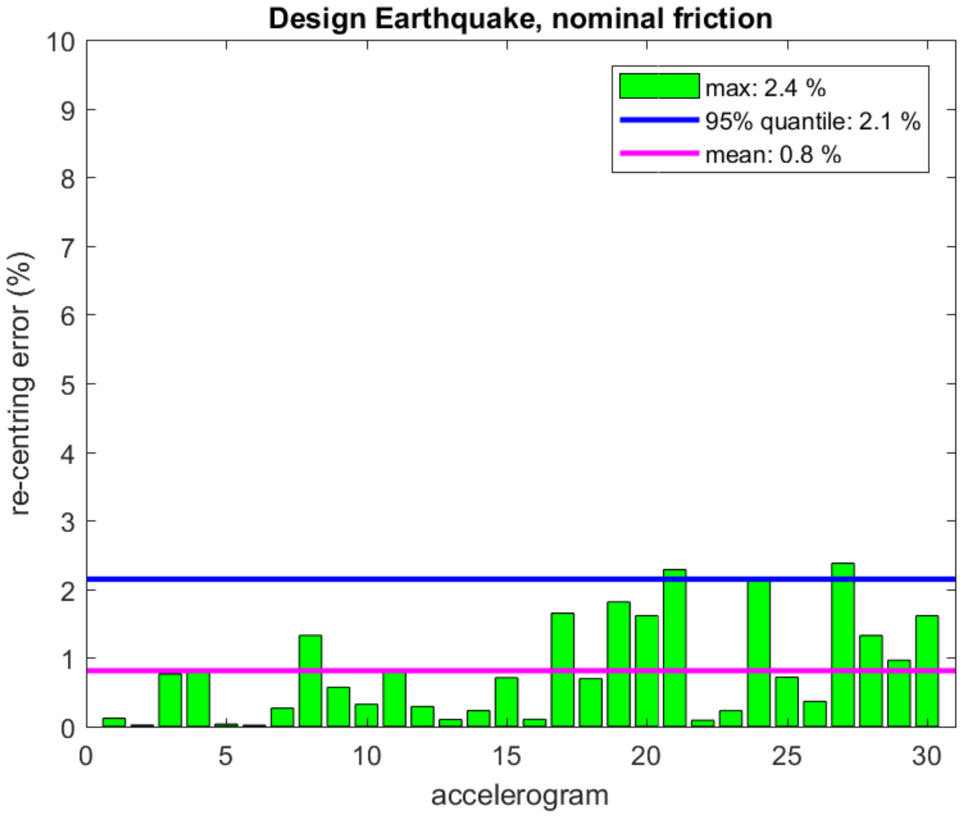

Design Earthquake, nominal friction
max: 0.015 %
95% quantile: 0.015 %
mean: 0.013 %
drift 2-1 (%)
accelerogram
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
5
10
15
20
25
30


Design Earthquake, nominal friction
max: 0.01 %
95% quantile: 0.01 %
mean: 0.009 %
drift 3-2 (%)
accelerogram


Design Earthquake, nominal friction
max: 0.004 %
95% quantile: 0.004 %
mean: 0.004 %
drift 4-3 (%)
accelerogram

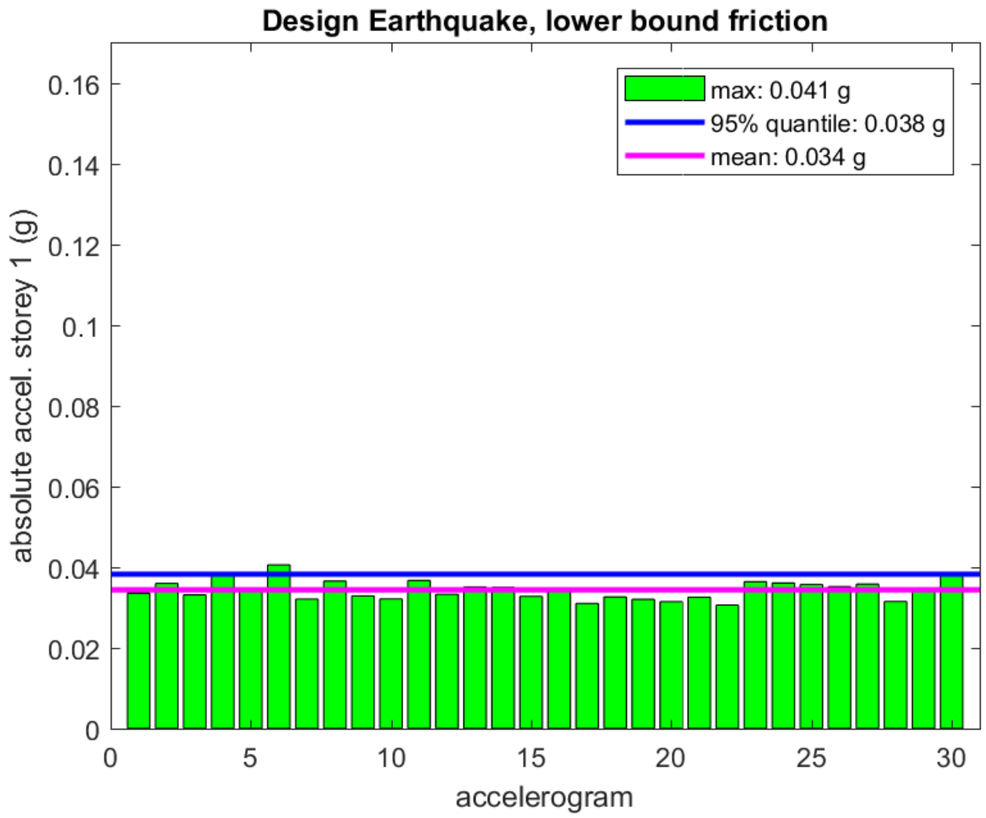

Design Earthquake, nominal friction
horizontal isolator force (kN)
accelerogram
max: 49 kN
95% quantile: 44 kN
mean: 38 kN
0
10
20
30
40
50
60
70
0
5
10
15
20
25
30

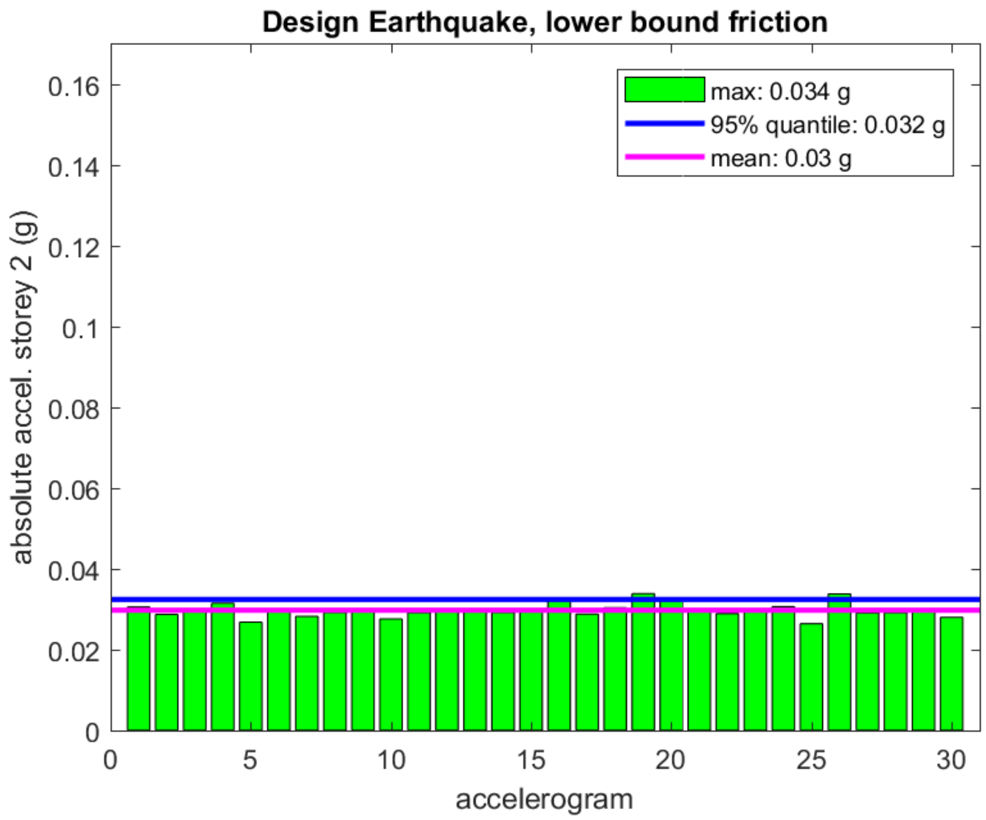

Design Earthquake, nominal friction
isolator total displacement (mm)
accelerogram
max: 34 mm
95% quantile: 28 mm
mean: 21 mm
0
5
10
15
20
25
30
35
40
45
50
0
5
10
15
20
25
30

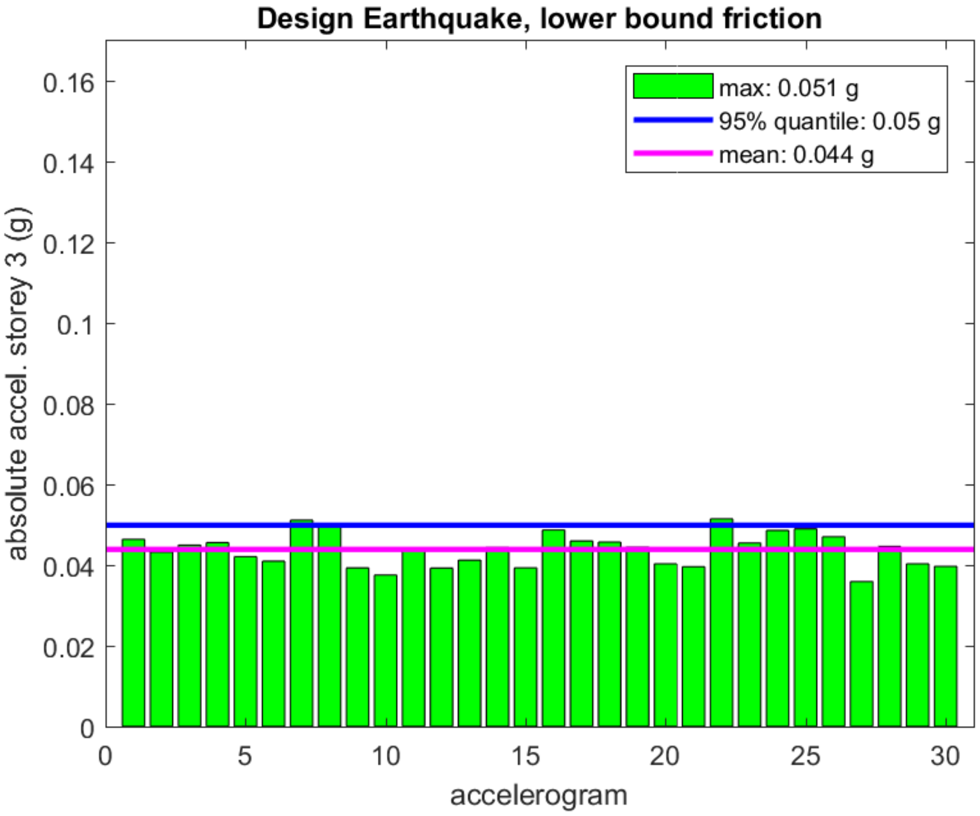


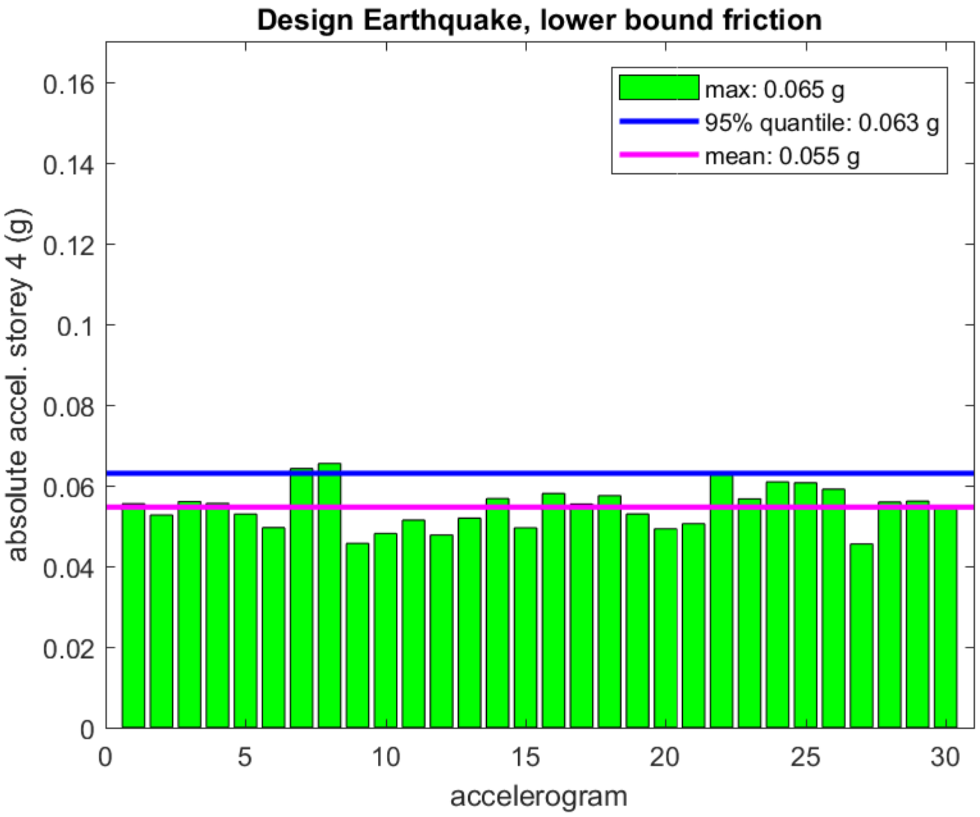
Design Earthquake, nominal friction
max: 2.4 %
95% quantile: 2.1 %
mean: 0.8 %
re-centring error (%)
accelerogram
0
1
2
3
4
5
6
7
8
9
10
0
5
10
15
20
25
30

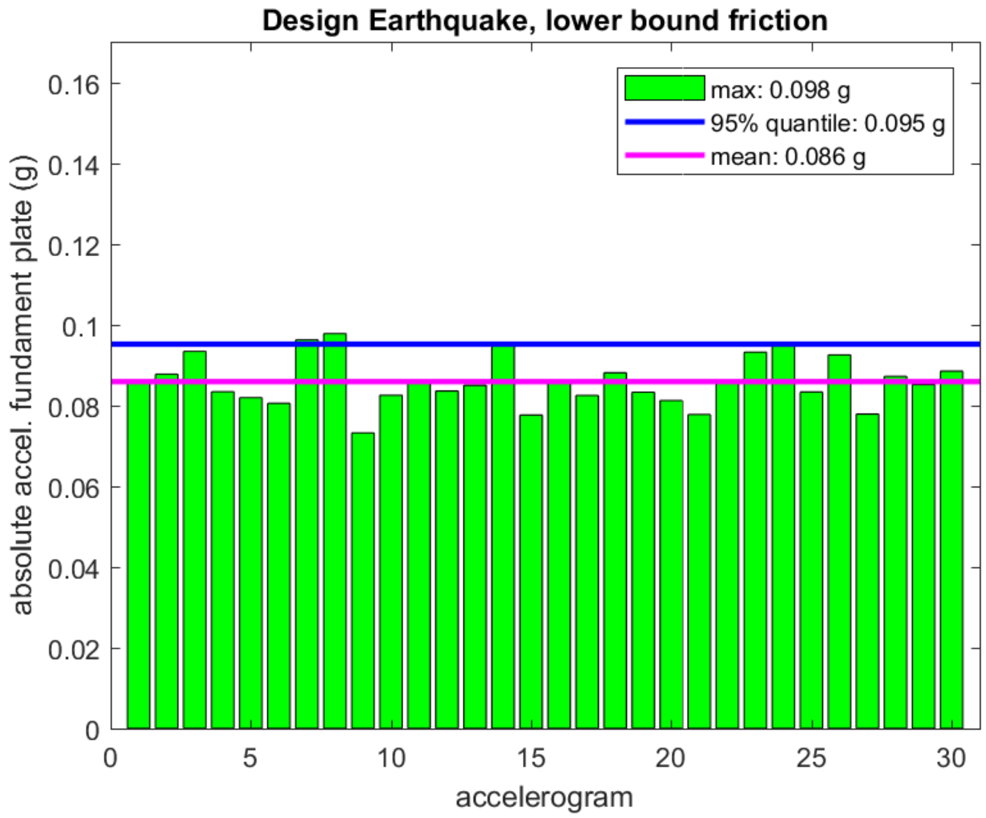
Results for Design Seismic Situation and lower bound friction

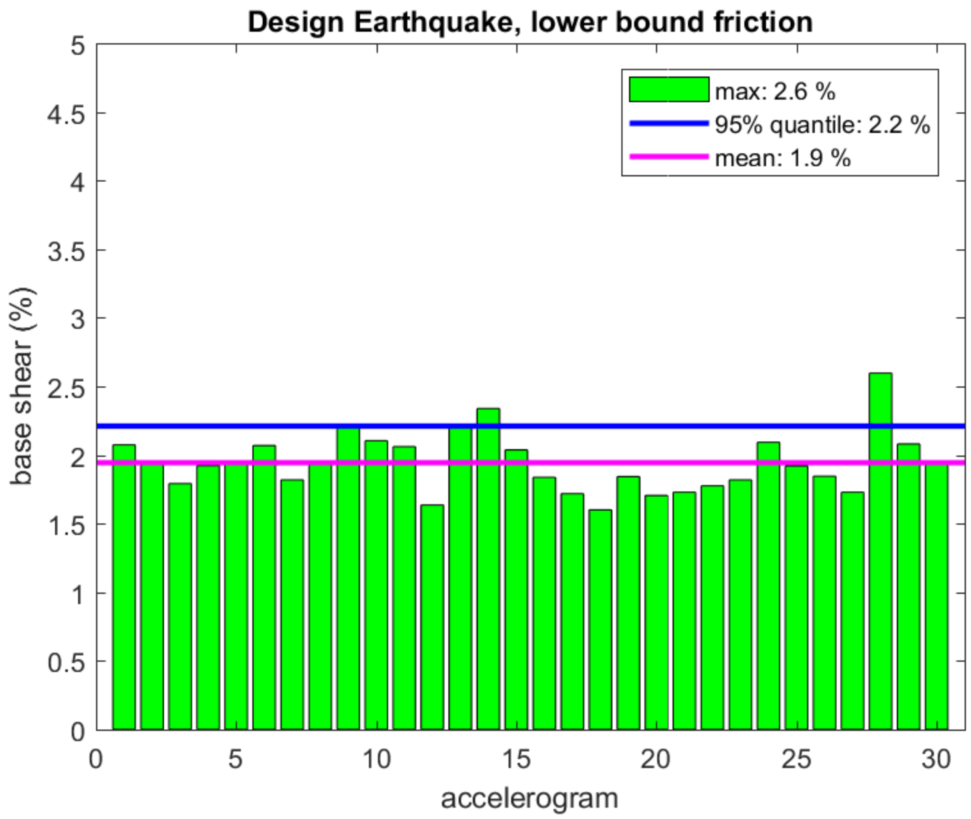


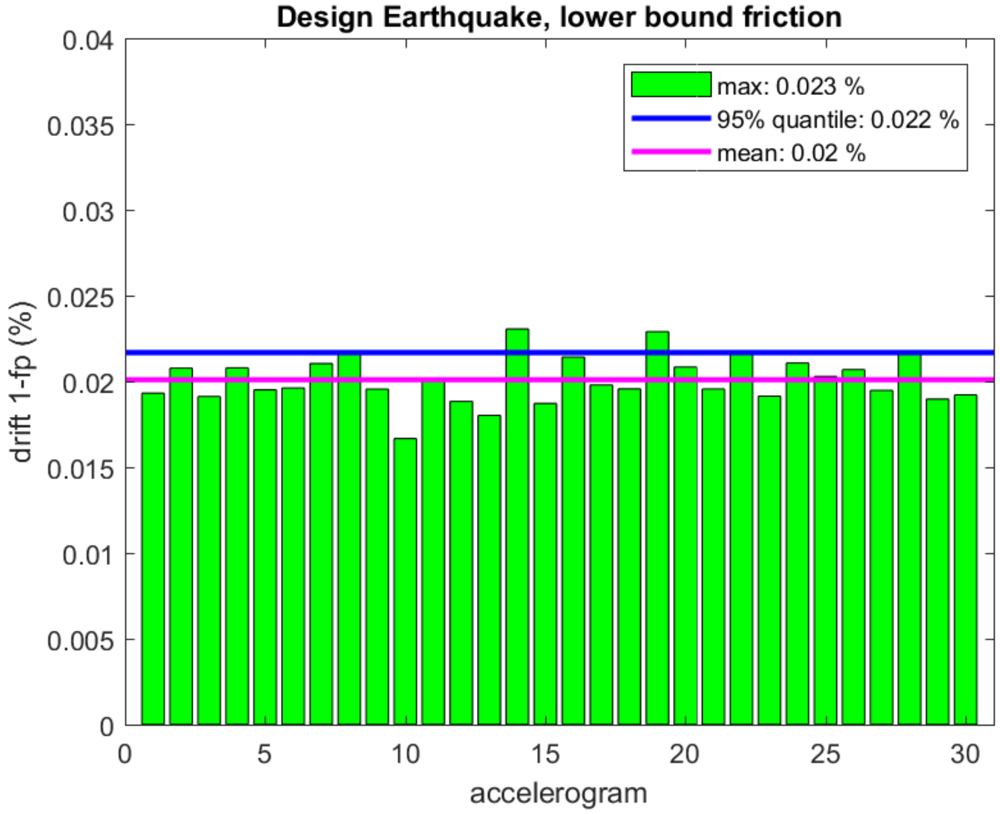


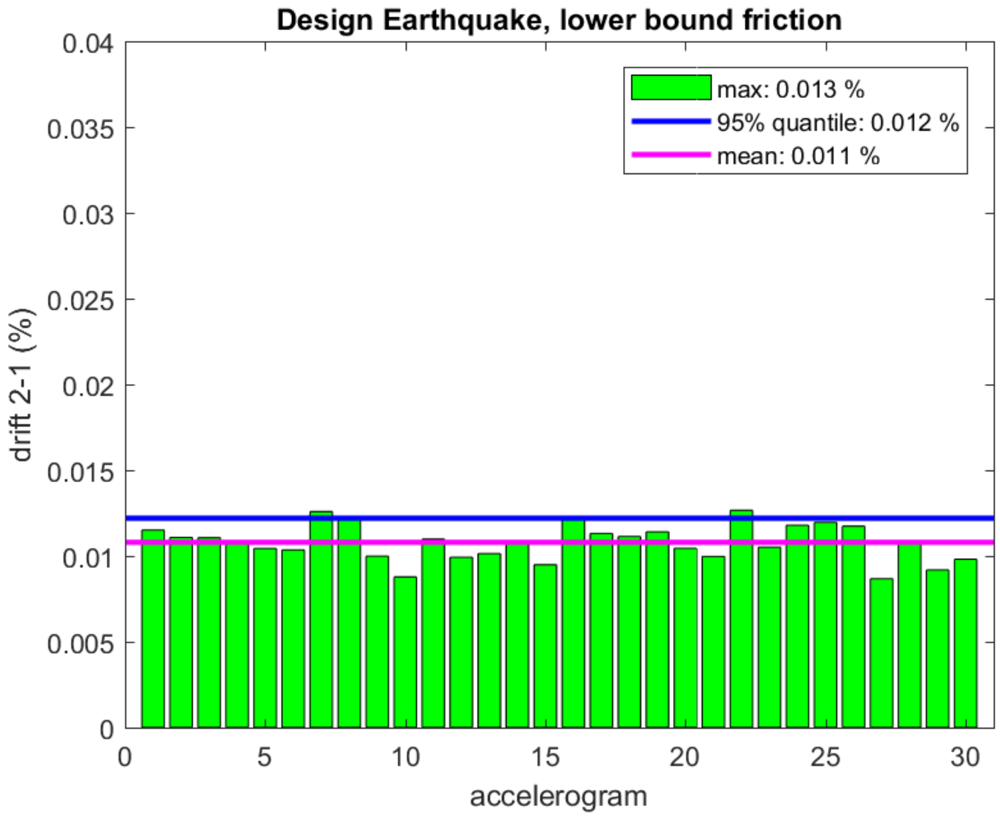

Design Earthquake, lower bound friction
max: 0.051 g
95% quantile: 0.05 g
mean: 0.044 g
absolute accel. storey 3 (g)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
5
10
15
20
25
30
accelerogram

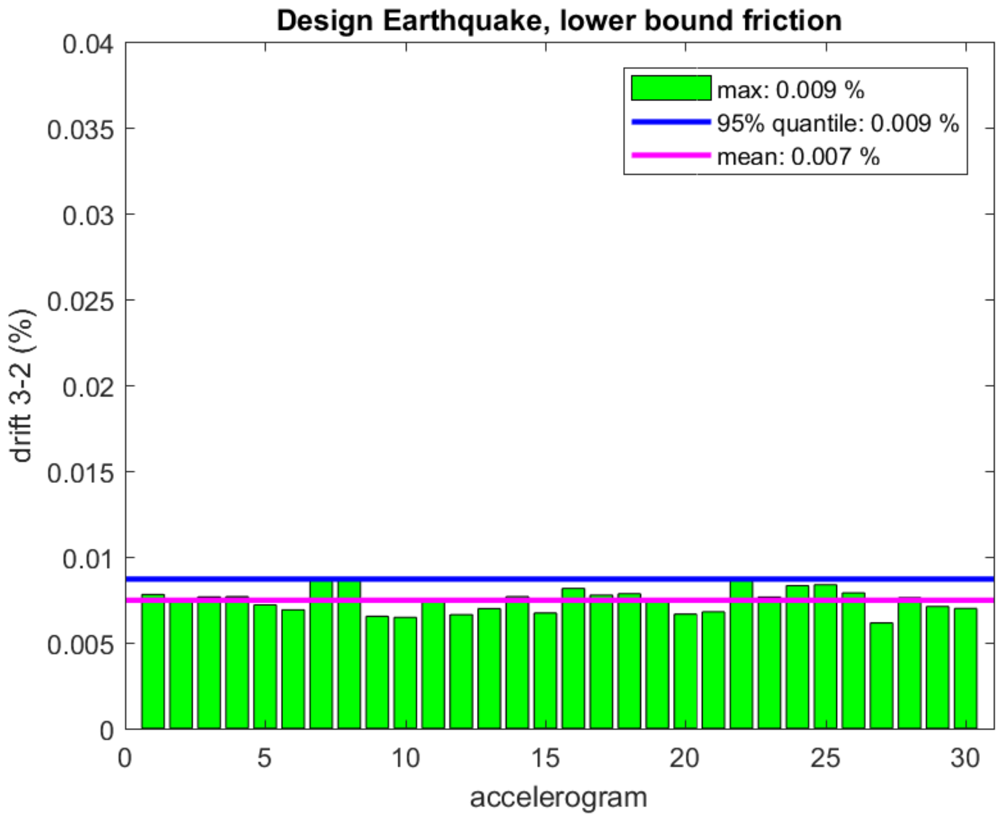

Design Earthquake, lower bound friction
max: 0.065 g
95% quantile: 0.063 g
mean: 0.055 g
absolute accel. storey 4 (g)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
5
10
15
20
25
30
accelerogram

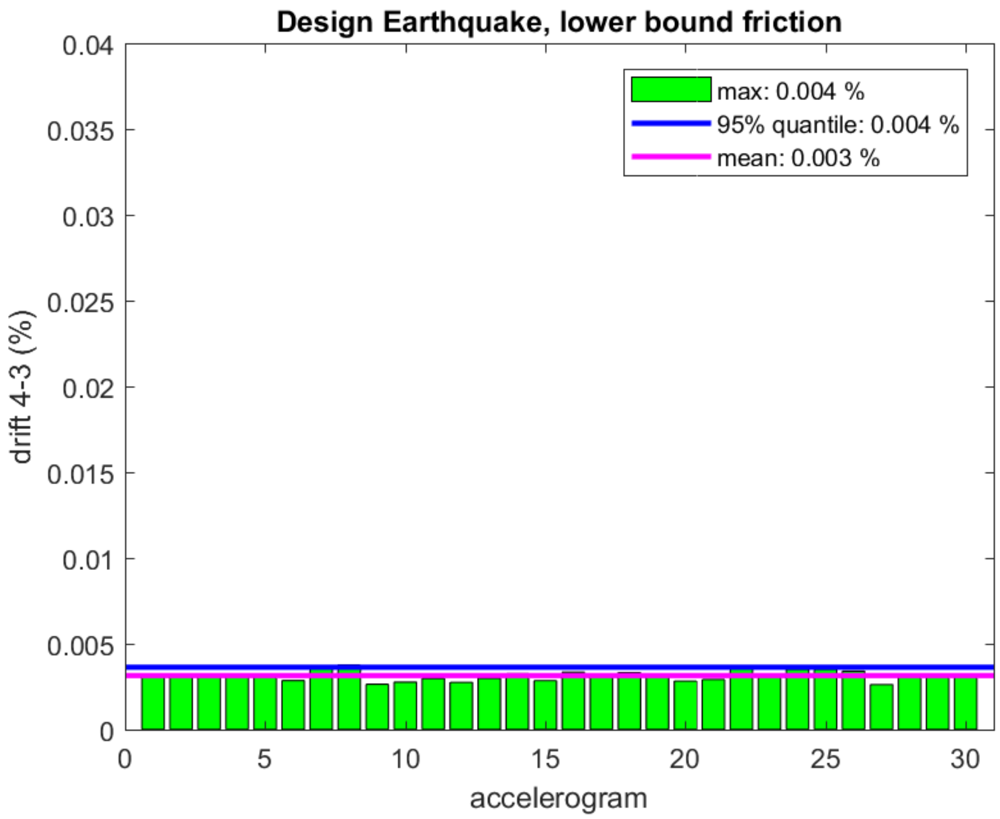

Design Earthquake, lower bound friction
absolute accel. fundament plate (g)
accelerogram
max: 0.098 g
95% quantile: 0.095 g
mean: 0.086 g

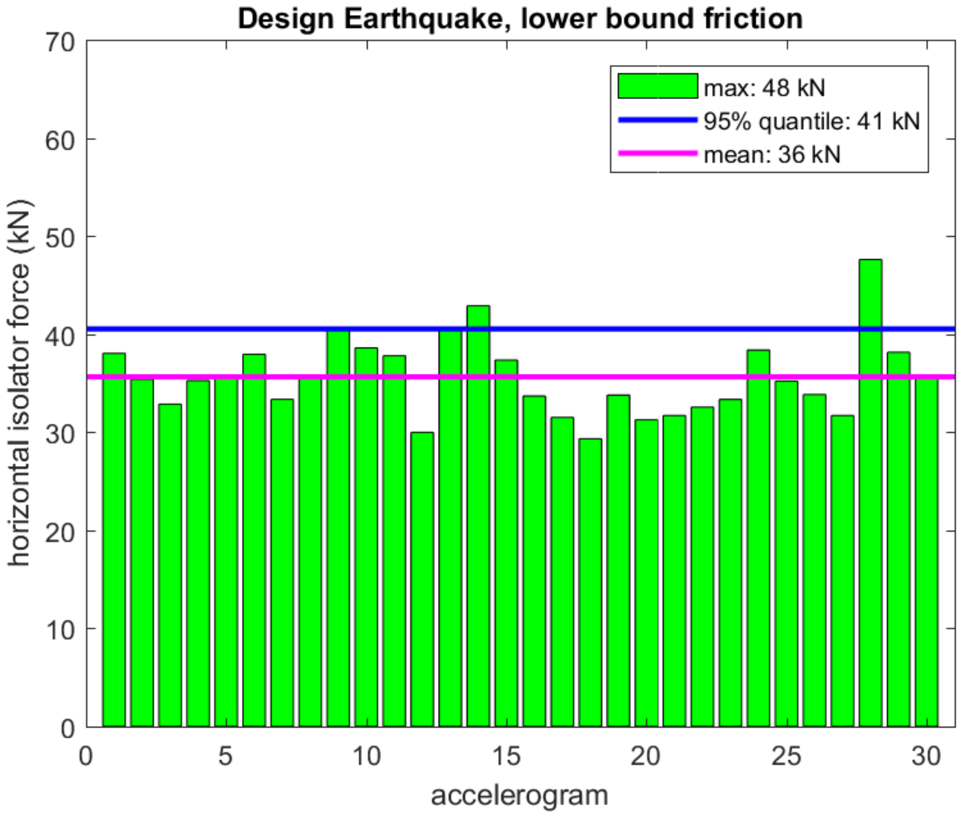

Design Earthquake, lower bound friction
base shear (%)
accelerogram
max: 2.6 %
95% quantile: 2.2 %
mean: 1.9 %

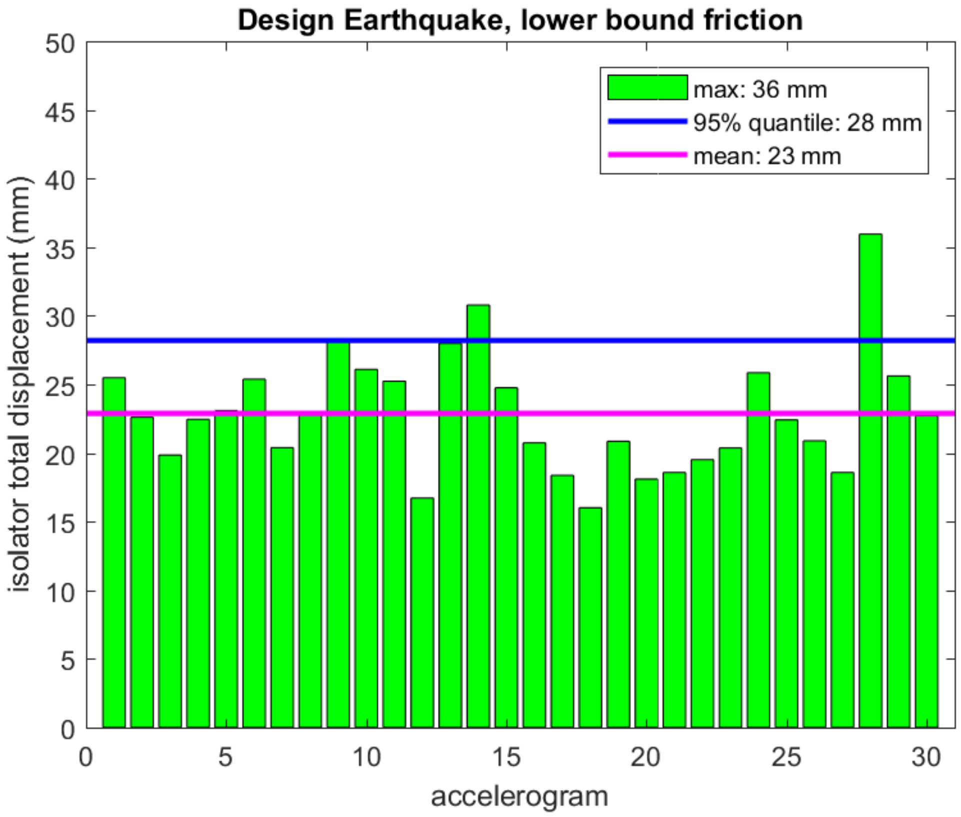

Design Earthquake, lower bound friction
max: 0.023 %
95% quantile: 0.022 %
mean: 0.02 %
drift 1-fp (%)
accelerogram

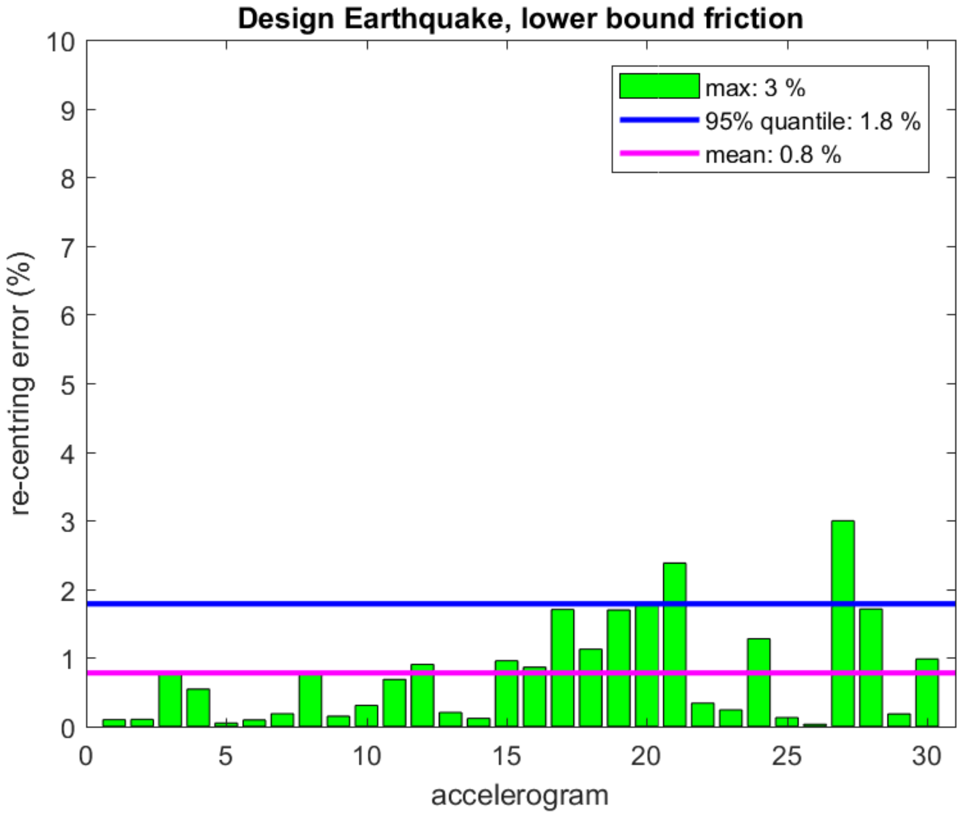

Design Earthquake, lower bound friction
max: 0.013 %
95% quantile: 0.012 %
mean: 0.011 %
drift 2-1 (%)
accelerogram


Design Earthquake, lower bound friction
max: 0.009 %
95% quantile: 0.009 %
mean: 0.007 %
drift 3-2 (%)
accelerogram
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
5
10
15
20
25
30

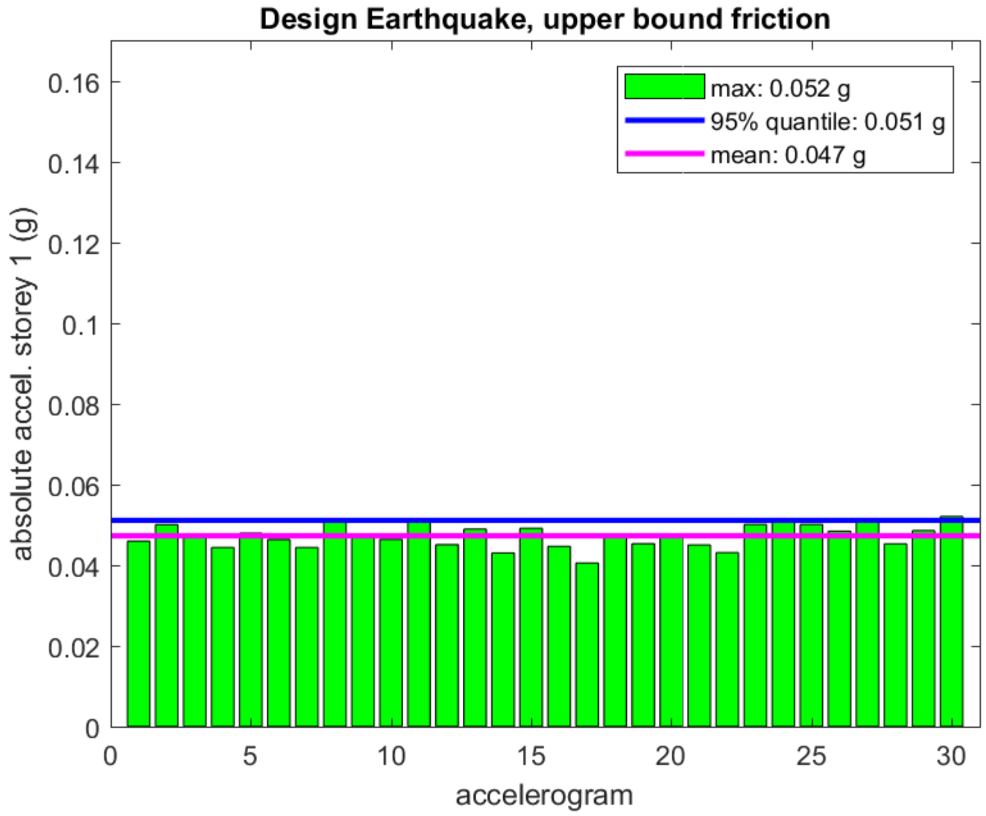

Design Earthquake, lower bound friction
max: 0.004 %
95% quantile: 0.004 %
mean: 0.003 %
drift 4-3 (%)
accelerogram
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
5
10
15
20
25
30

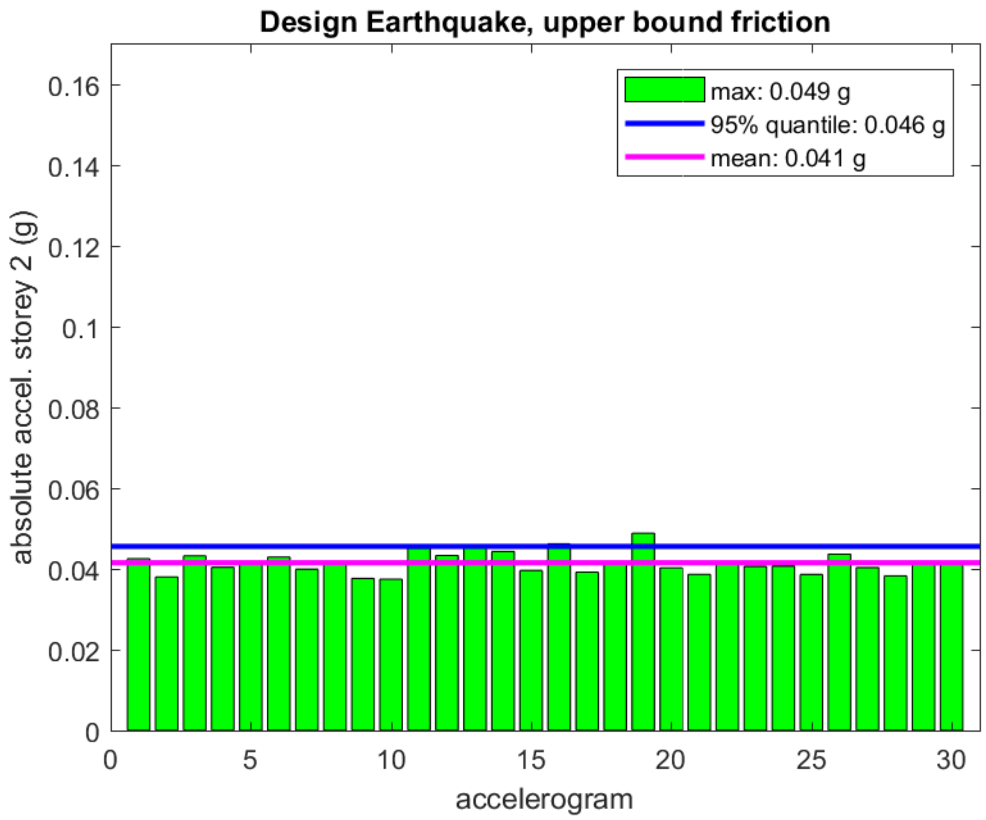

Design Earthquake, lower bound friction
max: 48 kN
95% quantile: 41 kN
mean: 36 kN
horizontal isolator force (kN)
accelerogram
0
10
20
30
40
50
60
70
0
5
10
15
20
25
30

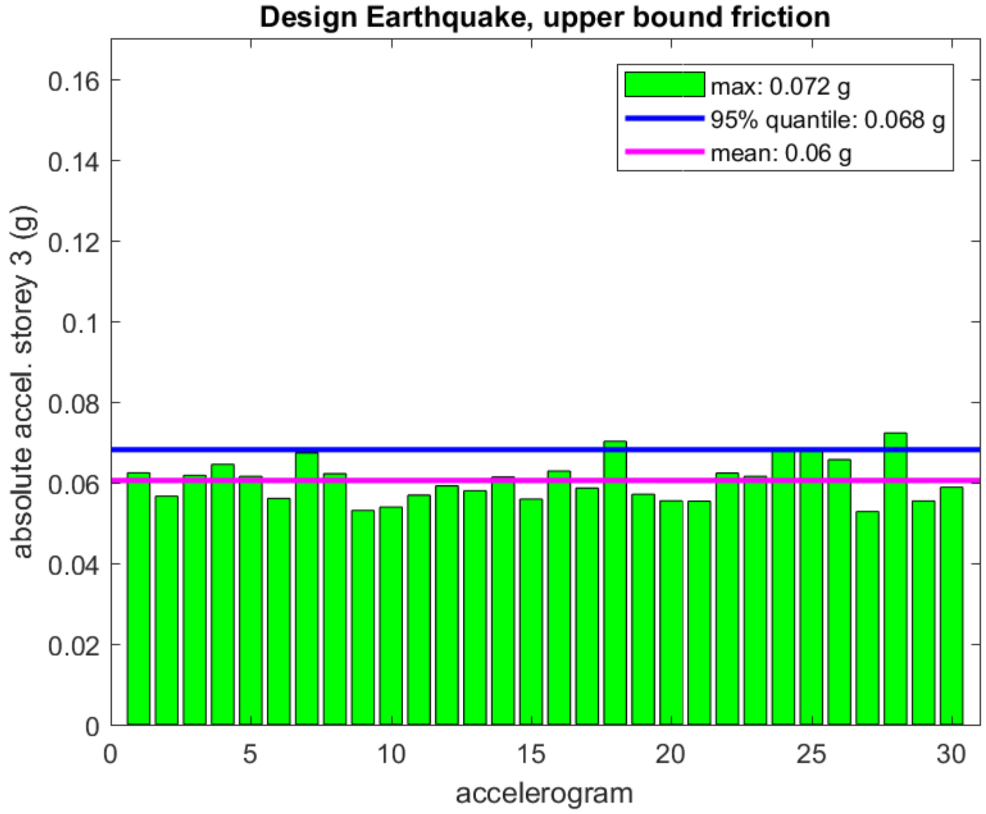

Design Earthquake, lower bound friction
max: 36 mm
95% quantile: 28 mm
mean: 23 mm
isolator total displacement (mm)
accelerogram
0
5
10
15
20
25
30
35
40
45
50
0
5
10
15
20
25
30


Design Earthquake, lower bound friction
max: 3 %
95% quantile: 1.8 %
mean: 0.8 %
re-centring error (%)
accelerogram
0
1
2
3
4
5
6
7
8
9
10
0
5
10
15
20
25
30

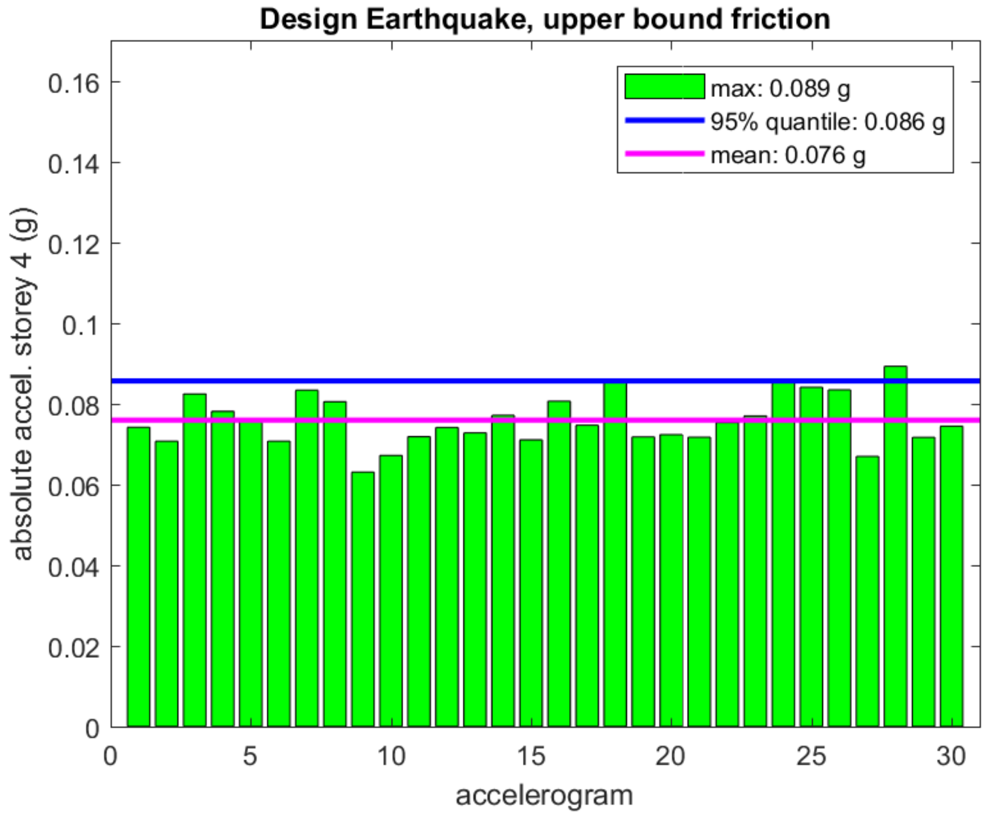
Results for Design Seismic Situation and upper bound friction



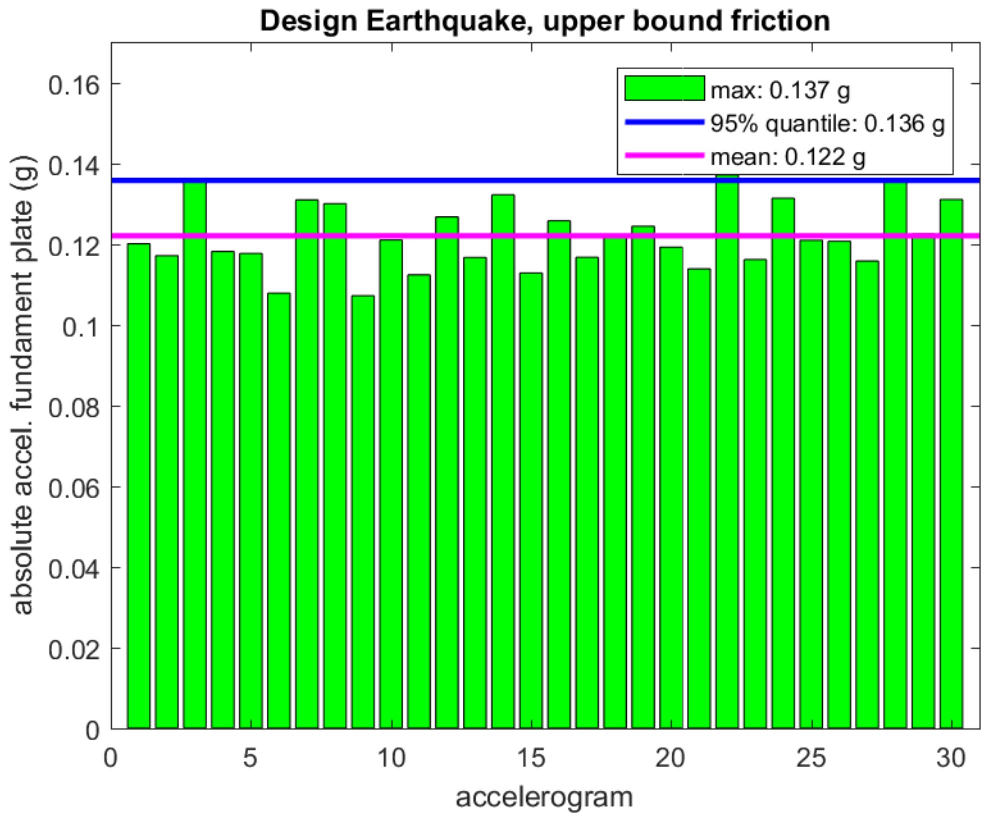


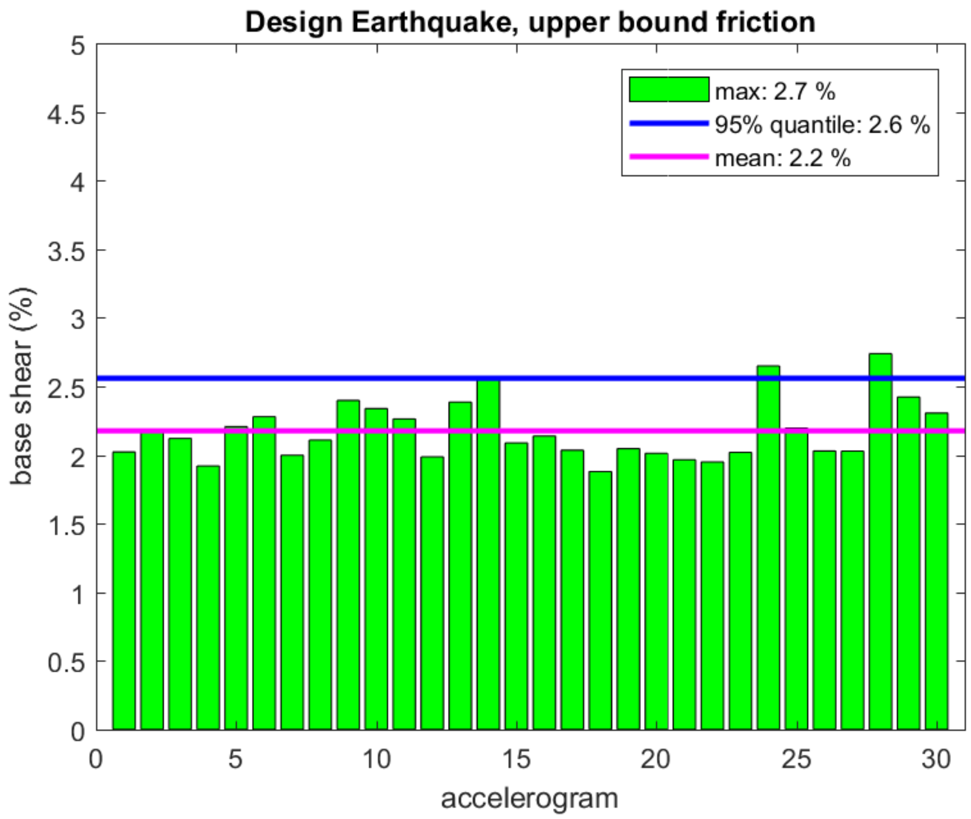


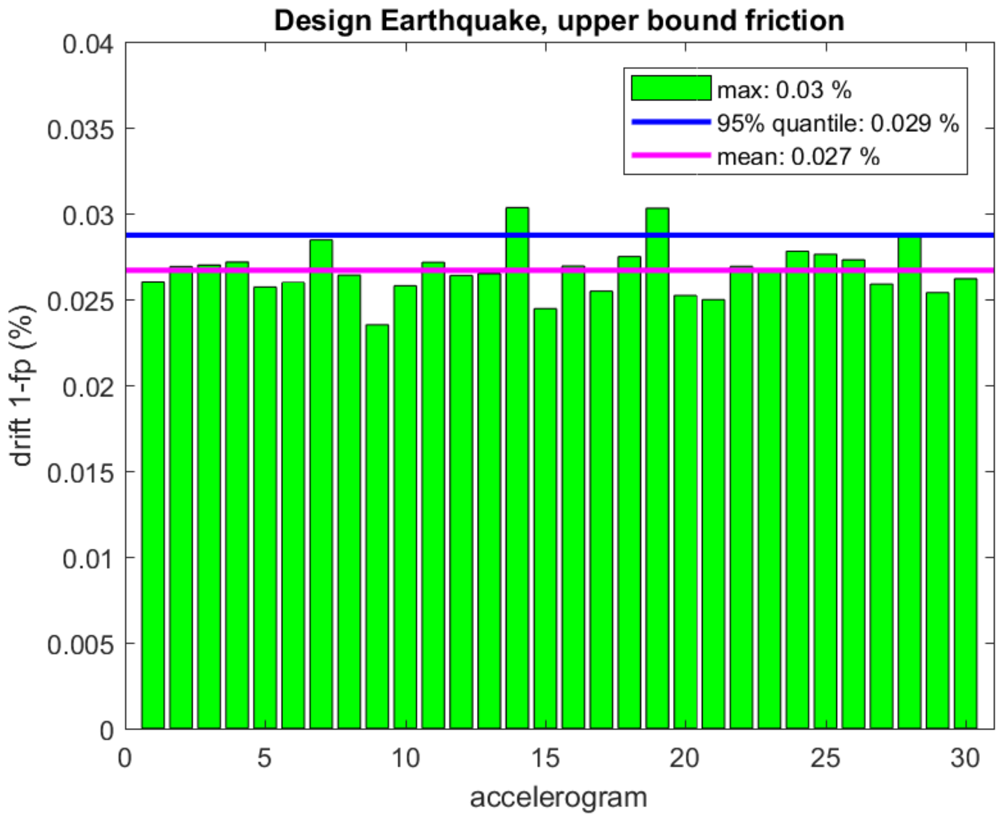
Design Earthquake, upper bound friction
max: 0.072 g
95% quantile: 0.068 g
mean: 0.06 g
absolute accel. storey 3 (g)
accelerogram

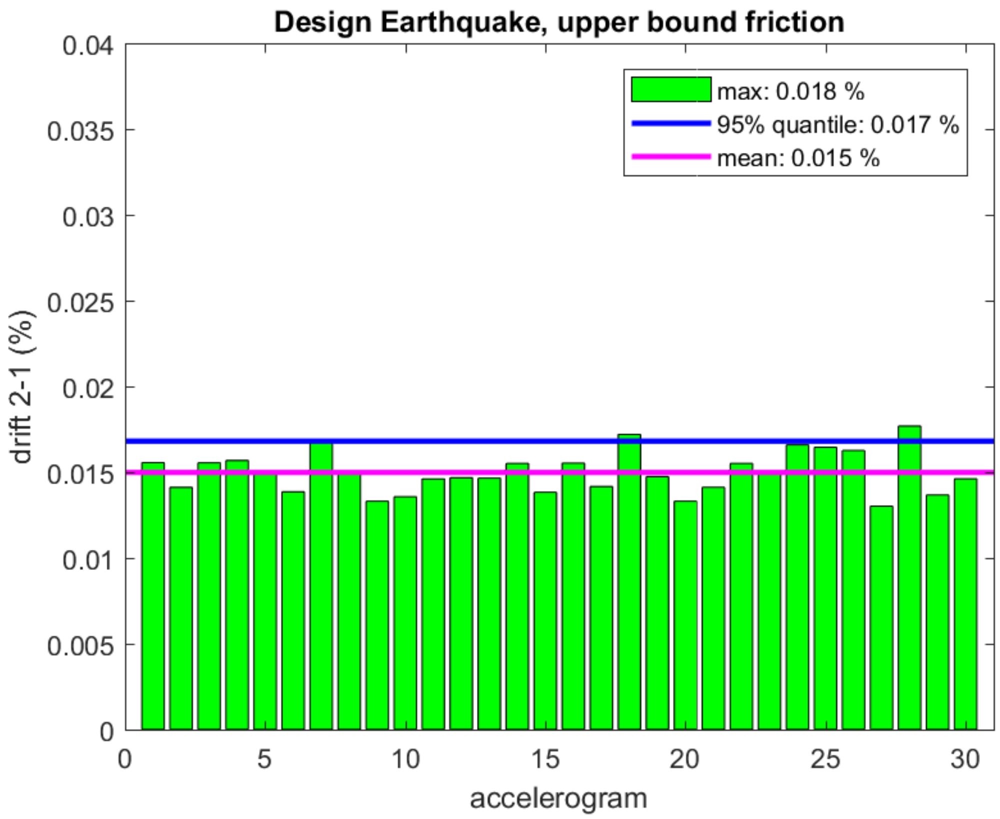


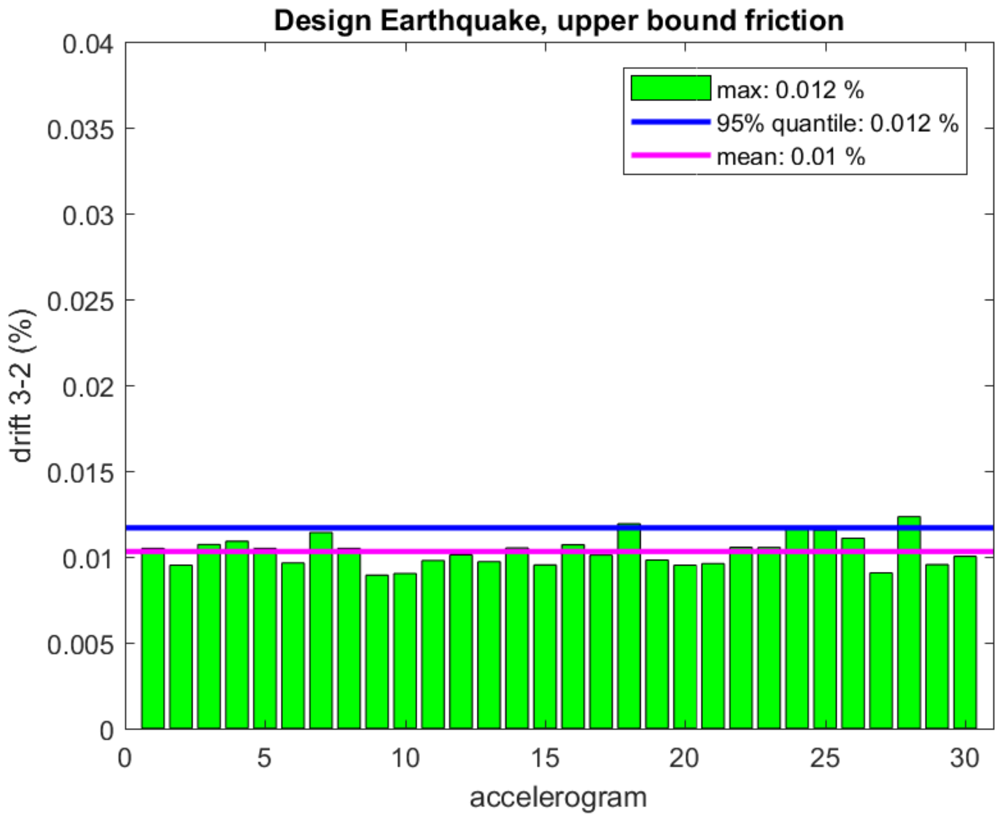
Design Earthquake, upper bound friction
max: 0.089 g
95% quantile: 0.086 g
mean: 0.076 g
absolute accel. storey 4 (g)
accelerogram

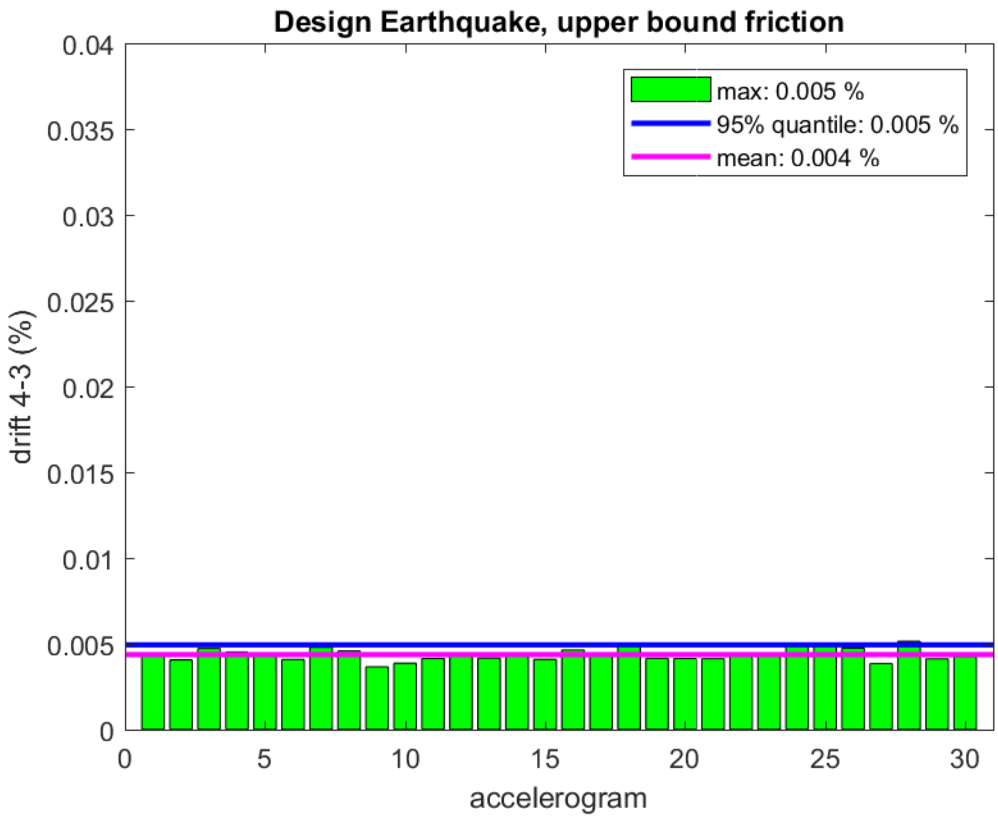

Design Earthquake, upper bound friction
max: 0.137 g
95% quantile: 0.136 g
mean: 0.122 g
absolute accel. fundament plate (g)
accelerogram

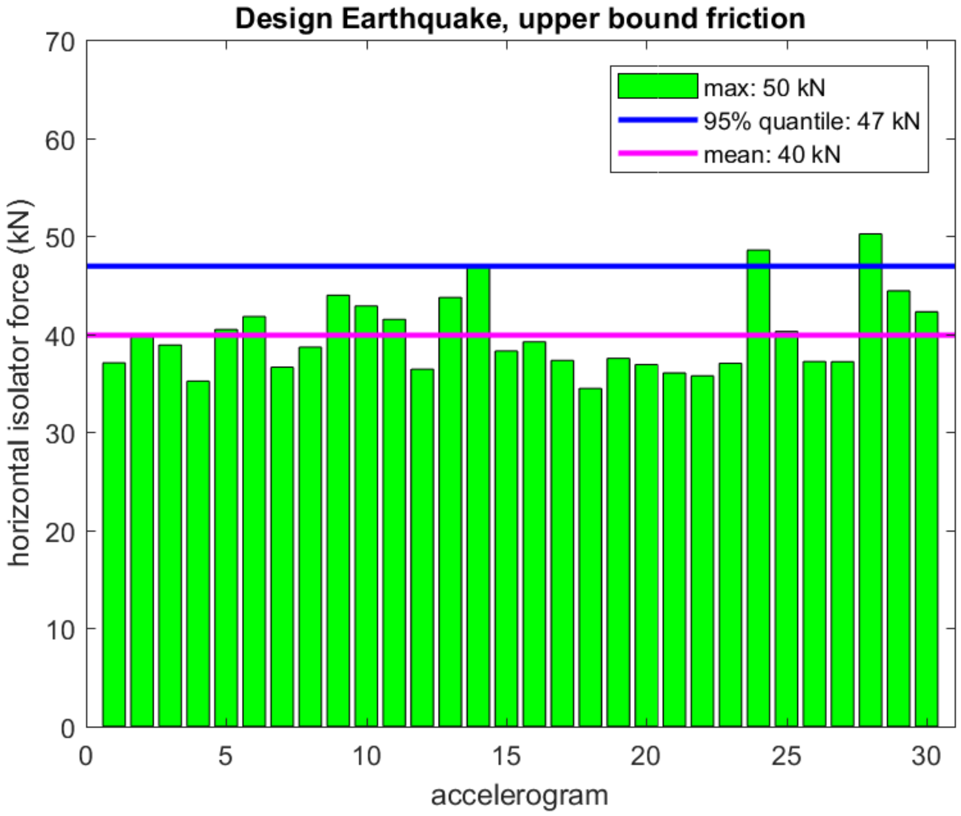

Design Earthquake, upper bound friction
max: 2.7 %
95% quantile: 2.6 %
mean: 2.2 %
base shear (%)
accelerogram

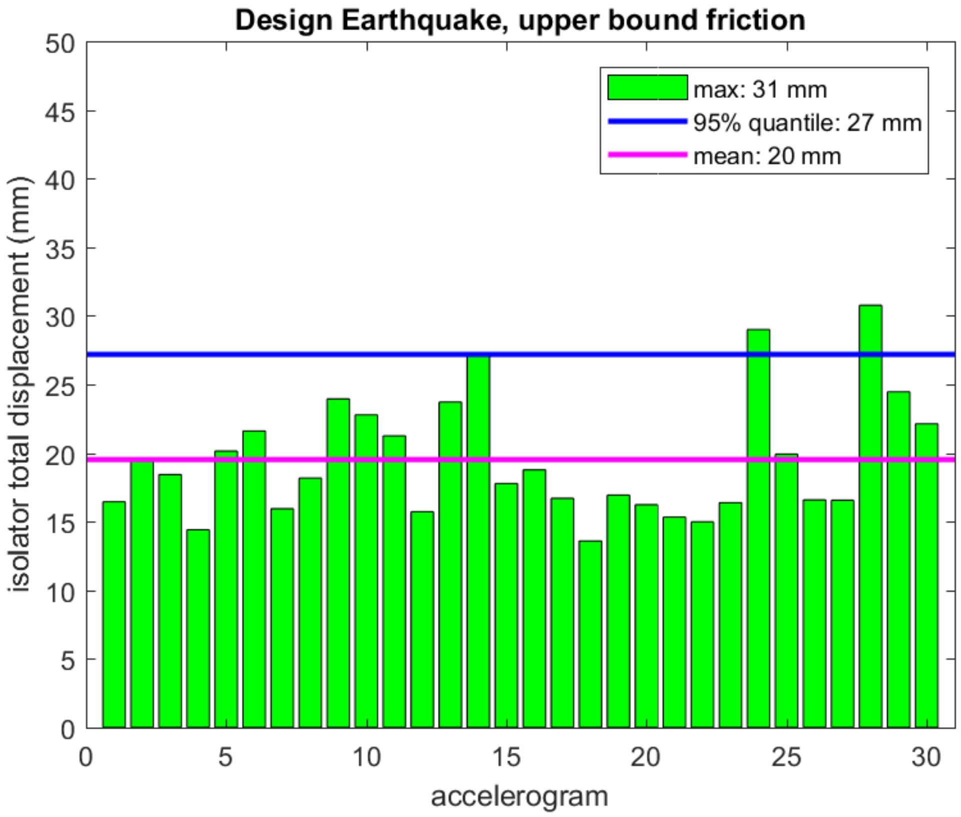

Design Earthquake, upper bound friction
max: 0.03 %
95% quantile: 0.029 %
mean: 0.027 %
drift 1-fp (%)
accelerogram
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
5
10
15
20
25
30

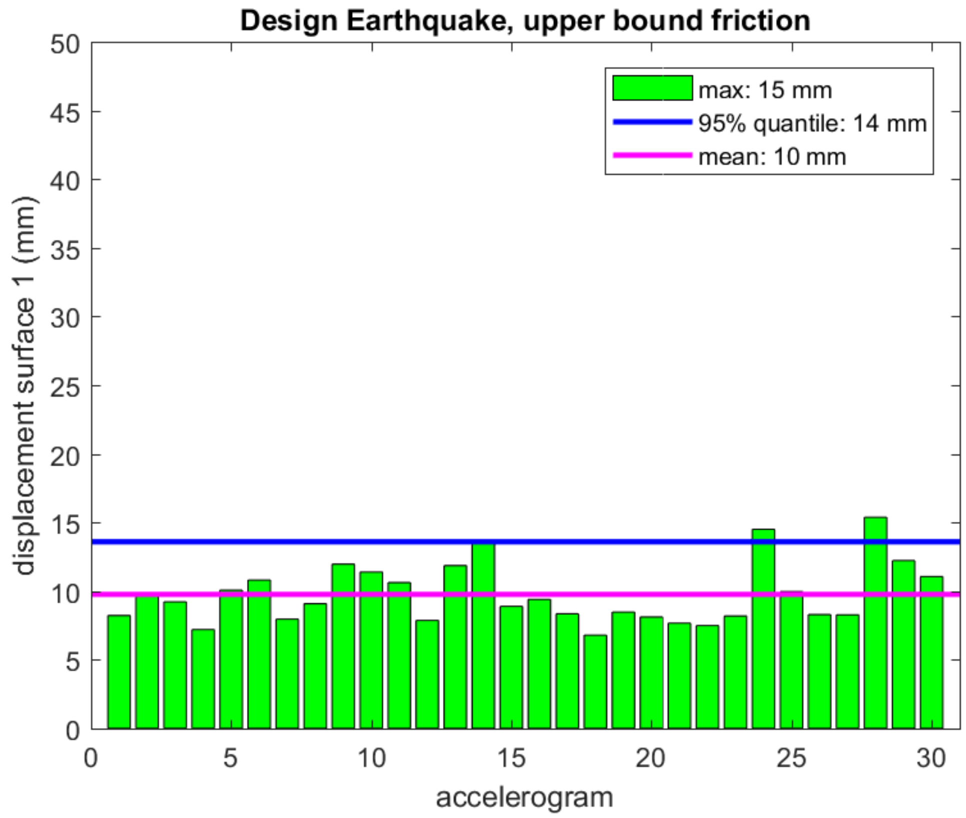

Design Earthquake, upper bound friction
max: 0.018 %
95% quantile: 0.017 %
mean: 0.015 %
drift 2-1 (%)
accelerogram
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
5
10
15
20
25
30


Design Earthquake, upper bound friction
max: 0.012 %
95% quantile: 0.012 %
mean: 0.01 %
drift 3-2 (%)
accelerogram
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
5
10
15
20
25
30

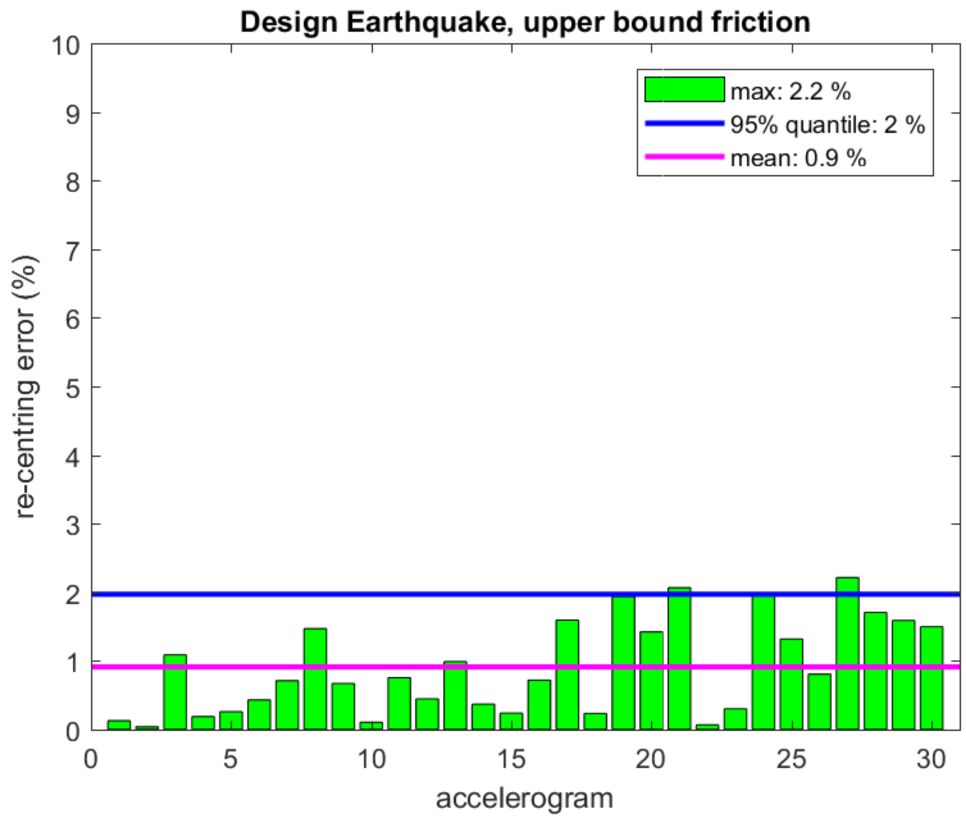

Design Earthquake, upper bound friction
max: 0.005 %
95% quantile: 0.005 %
mean: 0.004 %
drift 4-3 (%)
accelerogram
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
5
10
15
20
25
30


Design Earthquake, upper bound friction
max: 50 kN
95% quantile: 47 kN
mean: 40 kN
horizontal isolator force (kN)
accelerogram
0
10
20
30
40
50
60
70
0
5
10
15
20
25
30


Design Earthquake, upper bound friction
max: 31 mm
95% quantile: 27 mm
mean: 20 mm
isolator total displacement (mm)
accelerogram
0
5
10
15
20
25
30
35
40
45
50
0
5
10
15
20
25
30



Design Earthquake, upper bound friction
max: 15 mm
95% quantile: 14 mm
mean: 10 mm
displacement surface 1 (mm)
accelerogram



Design Earthquake, upper bound friction
max: 2.2 %
95% quantile: 2 %
mean: 0.9 %
re-centring error (%)
accelerogram