

General Meeting




Márcia Gonçalves
Barros Viegas
Romeu Reguengo
Filipe Saraiva
Daniela Finizza

Ema Coelho
Alfredo Campos Costa
Paulo Candeias
Marta Mateus

Athens
27th-28th Sep. 2010

Project Technical Committee (PTC) Meeting

WP2 – Experimental activity on new and existing connections

General Meeting

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WP2 – Experimental activity on new and existing connections (Cladding-to-structure connections)

Summary:

- Review of the experimental tests the 3D Frame Model (Task 4)
- Description of the experimental results and analysis methods
- Presentation of the analysis results
- Conclusions



 <p>General Meeting</p> <p>Márcia Gonçalves Barros Viegas Romeu Reguengo Filipe Saraiva Daniela Finizza</p> <p>Ema Coelho Alfredo Campos Costa Paulo Candeias Marta Mateus</p> <p>Athens 27th, 28th Sep. 2010</p>	<p>SAFECAST Project – General Meeting</p> <p><u>WP2 – Experimental activity on new and existing connections</u> (Cladding-to-structure connections)</p> <p>Review of the experimental tests the 3D Frame Model (Task 4):</p> <p>□ Connection</p> 
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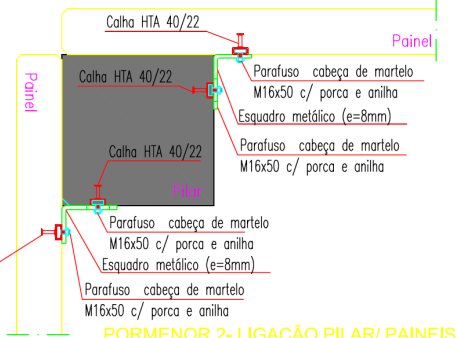
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WP2 – Experimental activity on new and existing connections (Cladding-to-structure connections)

Review of the experimental tests the 3D Frame Model (Task 4):

□ **Connection**

PORMENOR 2- LIGAÇÃO PILAR/ PAINEL

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WP2 – Experimental activity on new and existing connections (Cladding-to-structure connections)

Review of the experimental tests the 3D Frame Model (Task 4):

□ **Two Types of Angles tested**



- Cold-formed ST37 ($f_y=235\text{MPa}$) steel angles (8mm thickness)
- Hot-rolled steel equal angles (L120×10)

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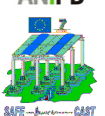
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Review of the experimental tests the 3D Frame Model (Task 4):

❑ **Two Types of Angles tested**

- These types of **galvanized cold formed steel plates (ST37)**. The bending process provokes internal stresses and galvanization makes the steel even more fragile.
- These connections were replaced by **hot rolled steel equal angles**, where no galvanization and no bending.



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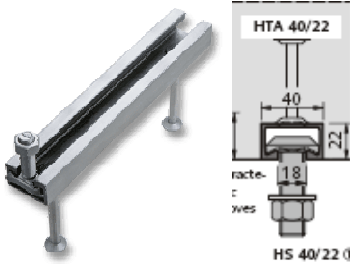
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Review of the experimental tests the 3D Frame Model (Task 4):

❑ **Connection**



- HALFEN HTA 40/22 channels (hot rolled) embedded in both columns and cladding panels
- HALFEN T-head bolts M12x50

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Review of the experimental tests the 3D Frame Model (Task 4):

☐ **Instrumentation**

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Review of the experimental tests the 3D Frame Model (Task 4):

☐ **Seismic Loading**

Portuguese 2010 National Annex:

- > Zone 1.1
- > $T_R = 475$ years
- > $a_{gR} = 2.5\text{m/s}^2$, $S=1.35$, $a_g \approx 3.4\text{m/s}^2$

EC8 pseudo-acceleration response spectrum compatible accelerogram:

- > Soil type B
- > Horizontal component only
- > Importance class II




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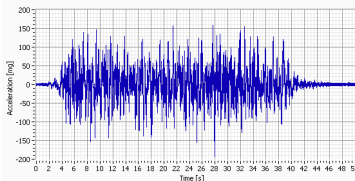
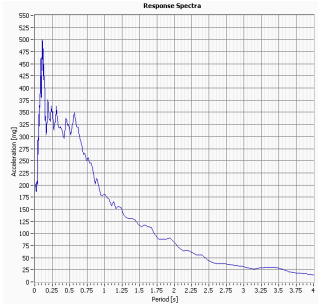
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Review of the experimental tests the 3D Frame Model (Task 4):

□ **Seismic Loading**

Artificial accelerogram referred to elastic spectrum of EC8 for a soil of type B

Elastic response spectrum (5% damping) of the seismic input used in the test

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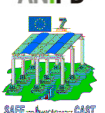
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Test 1 – Stage 5

Cold-formed ST37 ($f_y=235\text{MPa}$) steel angles (8mm thickness)

(video)

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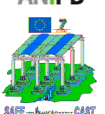
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Test 6 – Stage 8

Hot-rolled steel equal angles (L120×10)

(video)

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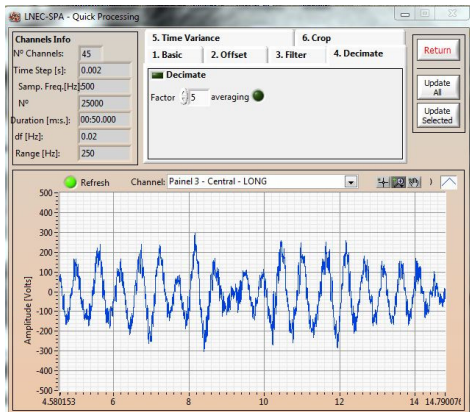
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WP2 – Experimental activity on new and existing connections (Cladding-to-structure connections)

Description of the experimental results and analysis methods:

❑ **Data processing**



- Filtering the acceleration records applying a 50 Hz low pass Fourier Filter,
- Removing the offset
- Applying a decimation factor.

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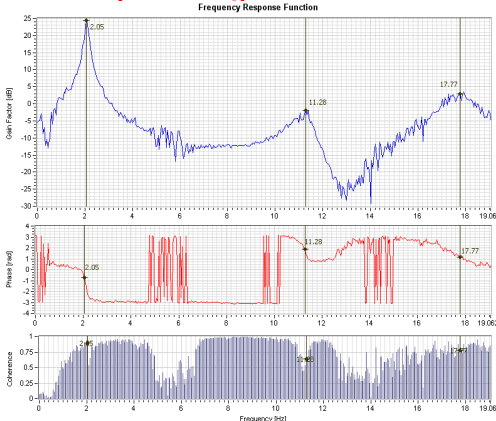
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WP2 – Experimental activity on new and existing connections (Cladding-to-structure connections)

Description of the experimental results and analysis methods:




□ **Data processing**



The estimation of the modal parameters was based on the frequency response function (FRF):

- frequencies ω_n
- modal damping ξ_r and
- modal shape of the model

were identified.

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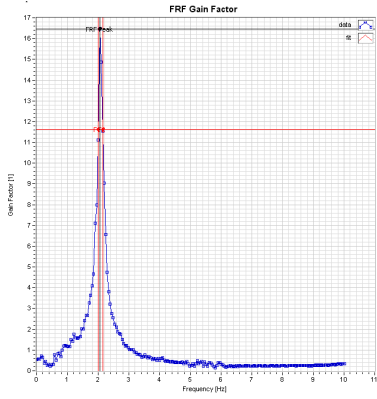
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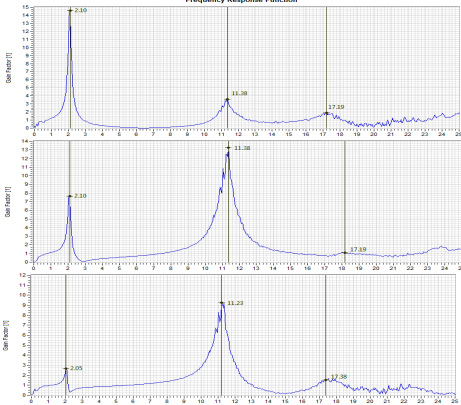
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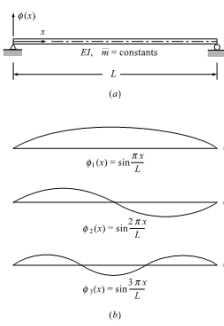
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Description of the experimental results and analysis methods:

□ Structural Vibration Frequency Analysis for determining the frequency of the panel



(a)

(b)

$$\omega_n = (\beta_n)^2 \sqrt{\frac{EI}{\rho AL^4}}$$

β_n : represents the initial constraints of the beam;




E : Young's Modulus;

I : Moment of Inertia;

ρ : Density

A : Area of the transversal section;

L : Length of the beam;

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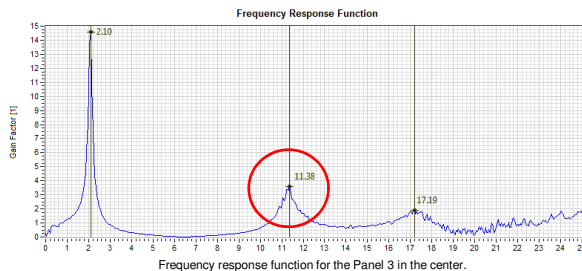
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Description of the experimental results and analysis methods:



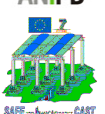
□ **Structural Vibration Frequency Analysis for determining the frequency of the panel**



Frequency response function for the Panel 3 in the center.

$$f_p = \frac{(\pi)^2}{2\pi} \sqrt{\frac{EI}{mL^4}} = 11.07 \text{ Hz}$$

Theoretical frequency of the panel assuming it is simply supported

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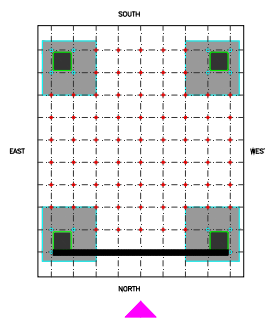
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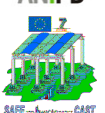
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WP2 – Experimental activity on new and existing connections (Cladding-to-structure connections)

Presentation of the analysis results:

□ **First test: Configuration 1 – Out of plane test**

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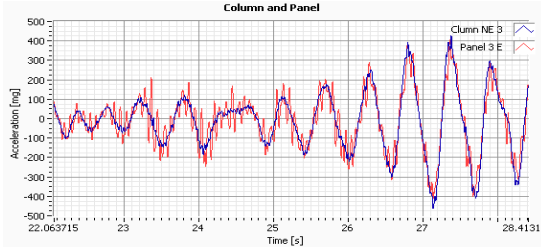
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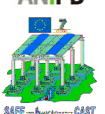
Presentation of the analysis results:

❑ **First test: Configuration 1 – Out of plane test**

Test		PGA
Stage 1	Pink Noise #1	-
Stage 2	Seismic #1	0.17 g
Stage 3	Seismic #2	0.19 g
Stage 4	Seismic #3	0.27 g
Stage 5	Pink Noise #2	-
Stage 6	Seismic #4	0.36 g
Stage 7	Seismic #5	0.43 g

	Stage 1	Stage 5	Var
f1 [Hz]	2.05	1.95	5%
f2 [Hz]	11.38	10.94	4%
f3 [Hz]	17.77	16.00	10%
ζ [%]	3.40	3.40	no var



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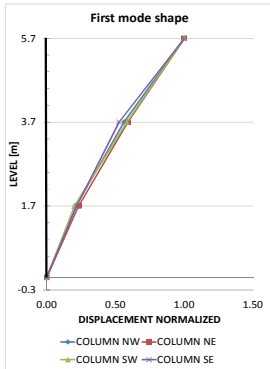
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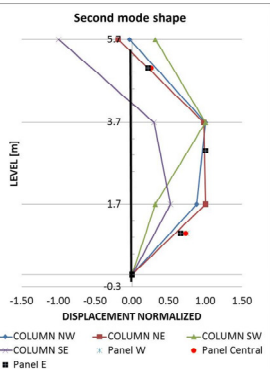
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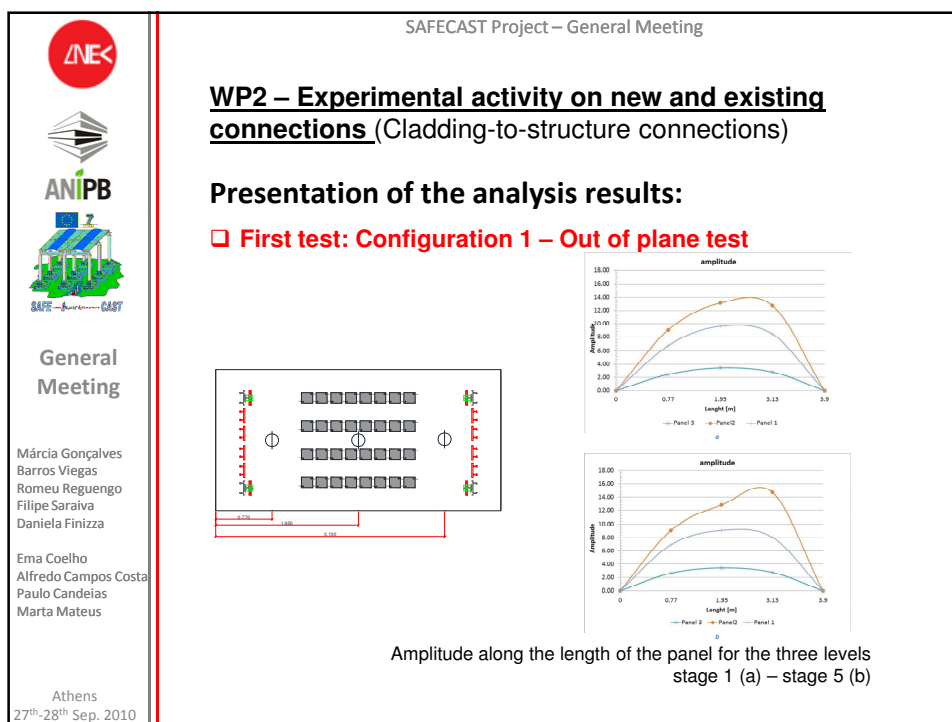
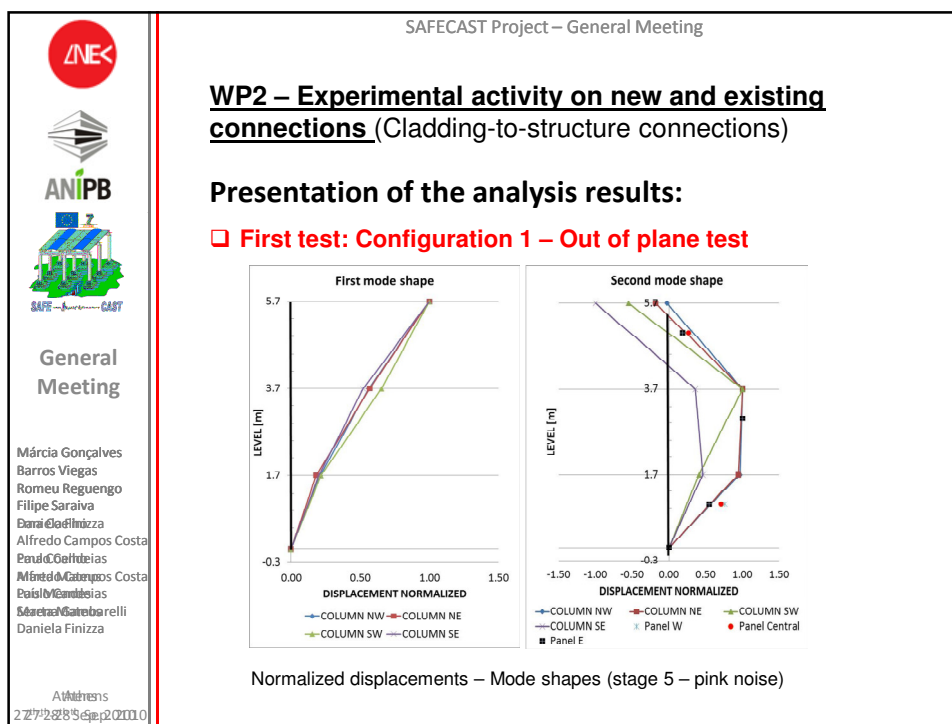
Presentation of the analysis results:




❑ **First test: Configuration 1 – Out of plane test**





Normalized displacements – Mode shapes (stage 1 – pink noise)



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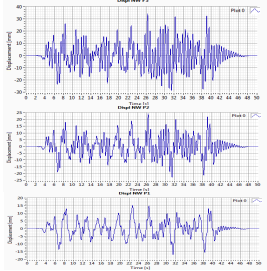
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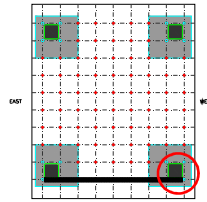
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Presentation of the analysis results:




❑ **First test: Configuration 1 – Out of plane test**



PGA 0.17g					
	Height [m]	Time max [sec]	Max P3 [mm]	Max P2 [mm]	Max P1 [mm]
Column NW	5.70	26.27	34.17	34.15	28.39
	3.70	26.26	24.17	24.27	22.76
	1.70	31.44	14.61	14.77	16.92
	0.00		0.00	0.00	0.00



Displacement for PGA 0.17g

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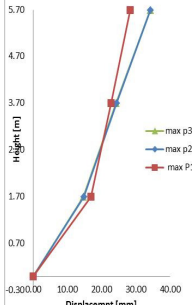
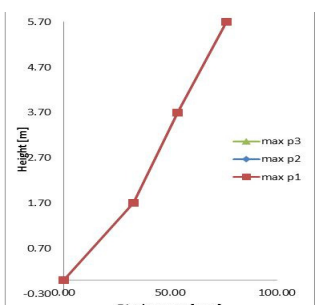
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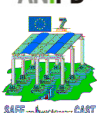
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	3.70	26.26	24.17	24.27	22.76
	1.70	31.44	14.61	14.77	16.92
	0.00		0.00	0.00	0.00

Displacement	Height [m]	Time max [sec]	Max P3	Max P2	Max P1
Column NW	5.70	26.04	76.38	76.34	76.34
	3.70	26.03	53.17	53.19	53.19
	1.70	26.03	32.53	32.69	32.69
	0.00		0.00	0.00	0.00

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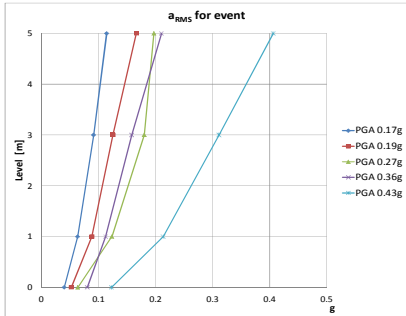
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Presentation of the analysis results:



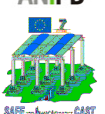
❑ **First test: Configuration 1 – Out of plane test**



- a_{RMS} amplitude increased until 0.122g (ground value)
- For the first two stages a_{RMS} values increase with the height
- After that a_{RMS} increases more at the first and second level respect to the third one (corresponding to an inelastic behavior of the connection in this levels)
- After fastening the connection (PGA=0.36g) the increase of a_{RMS} is the same of the first two stages.

a_{RMS} responses of the test model along the height

Element	$a_{RMS}[g]$ for PGA=0.17g	$a_{RMS}[g]$ for PGA=0.19g	$a_{RMS}[g]$ for PGA=0.27g	$a_{RMS}[g]$ for PGA=0.36g	$a_{RMS}[g]$ for PGA=0.43g
Panel 3	0.114	0.166	0.197	0.272	0.406
Panel 2	0.091	0.125	0.180	0.209	0.311
Panel 1	0.063	0.088	0.123	0.141	0.213
Ground	0.040	0.052	0.063	0.082	0.122

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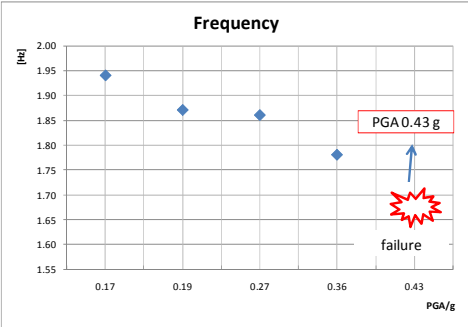
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Presentation of the analysis results:

❑ **First test: Configuration 1 – Out of plane test**



	Stage 2	Stage 3	Stage 4	Stage 6
f_1	1.95	1.87	1.86	1.78

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Presentation of the analysis results:

❑ **First test: Configuration 1 – Out of plane test**



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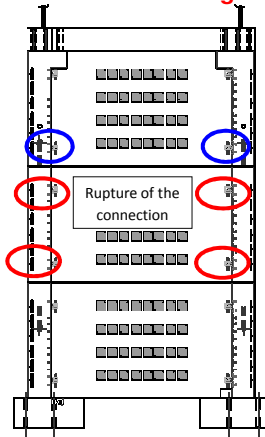

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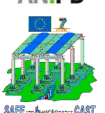
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WP2 – Experimental activity on new and existing connections (Cladding-to-structure connections)

Presentation of the analysis results:

❑ **First test: Configuration 1 – Out of plane test**

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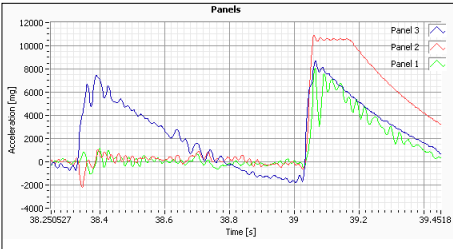
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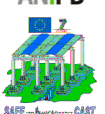
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WP2 – Experimental activity on new and existing connections (Cladding-to-structure connections)

Presentation of the analysis results:

❑ **Comparison of 1st, 2nd and 3rd tests (Configuration 1 – Out of plane test)**

	Stage 1	Stage 5	Var
f1 [Hz]	2.05	1.95	5%
f2 [Hz]	11.38	10.94	4%
f3 [Hz]	17.77	16.00	10%
ζ [%]	3.40	3.40	no var

	Stage 2	Stage 3	Stage 4	Stage 6
f1 [Hz]	1.95	1.87	1.86	1.78

	Stage 1	Stage 5	Var
f1 [Hz]	2.	1.9	5%
f2 [Hz]	12.13	11.28	7%
f3 [Hz]	17.23	16.6	4%
ζ [%]	3.73	4.5	20%



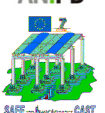
	Stage 2	Stage 3	Stage 4
f1 [Hz]	1.87	1.87	1.86

	Stage 1
f1 [Hz]	2.05
f2 [Hz]	11.93
f3 [Hz]	17.31
ζ [%]	5.07

	Stage 2	Stage 3
f1 [Hz]	2.00	1.82

Connections were fastened

Connections were fastened
Wedges were introduced in the 4 corners

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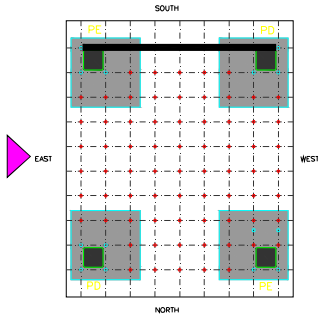
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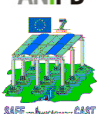
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Presentation of the analysis results:

❑ **Fourth test: Configuration 1 – In plane test**





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Presentation of the analysis results:



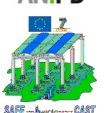
❑ **Fifth test: Configuration 1 – Out of plane test**

	Test	PGA
Stage 1	Pink Noise #1	-
Stage 2	Seismic #1	0.20g
Stage 3	Seismic #2	0.29g
Stage 4	Pink Noise #2	-
Stage 5	Seismic #3	0.25g
Stage 6	Seismic #4	0.38g
Stage 7	Pink Noise #3	-

	Stage 1	Stage 4	Stage 7
f1 [Hz]	2.05	2	1.86
f2 [Hz]	12.45	12.45	10.28
f3 [Hz]	19.33	19.34	16.89
ζ [%]	4.15	4.99	5.95

	Stage 2	Stage 3	Stage 5	Stage 6
f1	1.87	1.83	1.83	1.77

NEW ANGLES WERE USED!!

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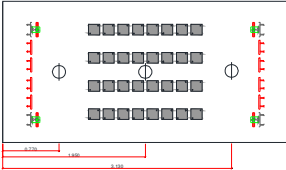
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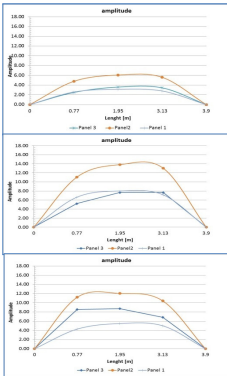
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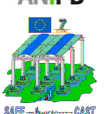
Presentation of the analysis results:

❑ **Fifth test: Configuration 1 – Out of plane test**





Amplitude along the length of the panel for the three levels
stage 1, 4 and 7

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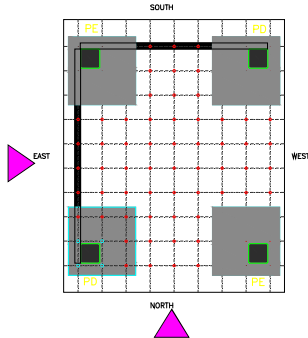
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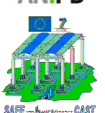
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WP2 – Experimental activity on new and existing connections (Cladding-to-structure connections)

Presentation of the analysis results:

❑ **Sixth test: Configuration 2 – Bi-directional test**

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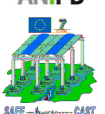
Presentation of the analysis results:

❑ **Sixth test: Configuration 2 – Bi-directional test**

	Test	PGA(long)	PGA(transv)
Stage 1	Pink Noise #1	-	-
Stage 2	Seismic #1	0.08g	0.07g
Stage 3	Seismic #2	0.10g	0.10g
Stage 4	Seismic #3	0.14g	0.14g
Stage 5	Seismic #4	0.22g	0.22g
Stage 6	Pink Noise #2	-	-
Stage 7	Pink Noise #3	-	-
Stage 8	Pink Noise #4	-	-
Stage 9	Seismic #5	0.26g	0.31g
Stage 10	Pink Noise #5	-	-
Stage 11	Seismic #6	0.38g	0.43g
Stage 12	Pink Noise #6	-	-
Stage 13	Seismic #6	0.52g	0.48g
Stage 14	Pink Noise #5	-	-

Remarks (Stage 6):

- Fastening of the connections in panel 3E (North side) and panel 2S (West side),
- Change of the anchoring position in panels 1S and 2S (West side)

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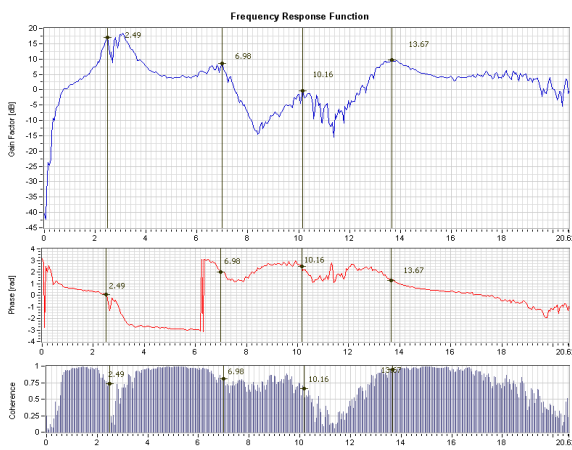
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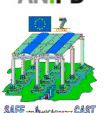
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❑ **Sixth test: Configuration 2 – Bi-directional test**

Frequency Response Function



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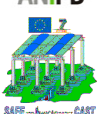
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WP2 – Experimental activity on new and existing connections (Cladding-to-structure connections)

Conclusions:

- Six test runs with peak base accelerations ranging from 0.17g to 1.6g.

Test run	Peak platform acceleration (g)	Test run	Peak platform acceleration (g)
1st out-of-plane north side	-	4th out-of-plane south side - new steel angles	-
	0.17		0.2
	0.19		0.29
	0.27		-
	-		0.25
	0.36		0.38
2nd out-of-plane north side - new position	0.43		-
	-	Bidirectional - new steel angles	-
	0.21		0.07
	0.21		0.1
	0.3		0.14
	-		0.22
	-		-
3rd out-of-plane north side - fastened	-		-
	0.24		-
	0.33		0.31
	1.6		-
1st in-plane south side-signal in transverse direction	-		0.43
	0.35		-
	0.22		0.48
	0.18		-

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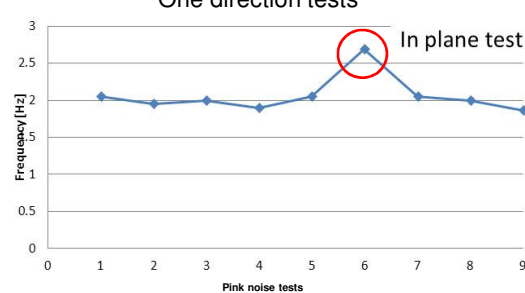
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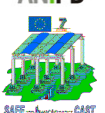
Conclusions:

- The decreasing of the frequencies shows that after the seismic tests the structure was slightly damaged
- Although the stiffness can be improved by fastening well the connection

One direction tests



Pink noise tests	Frequency [Hz]
1	2.1
2	2.0
3	2.0
4	1.9
5	2.1
6	2.7
7	2.1
8	2.0
9	1.8

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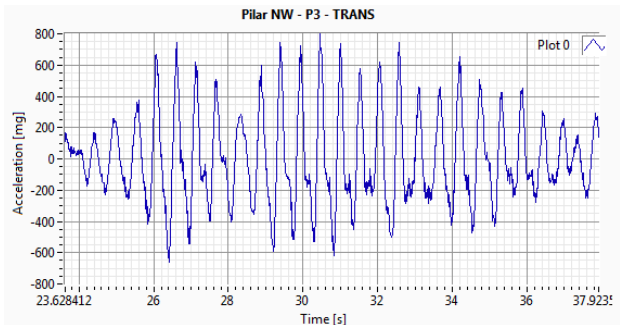
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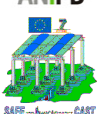
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Conclusions:

- Rattling noise occurs when the connections are not well fastened.
- Improper fastening procedure can lead to an anticipated failure.



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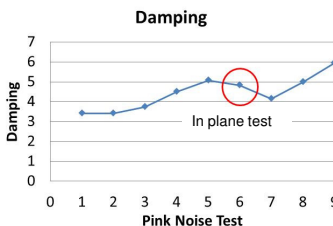
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Conclusions:

- Damping increases during the test run



Test run	Random test	Frequency (Hz)	Damping %
1st out-of-plane north side	Pink noise	2.05	3.4
	Pink noise	1.95	3.4
2nd out-of-plane north side - new position	Pink noise	2	3.73
	Pink noise	1.9	4.49
3rd out-of-plane north side - fastened	Pink noise	2.05	5.07
1st in-plane south side-signal in transverse direction	Pink noise	2.69	4.82
4th out-of-plane south side - new steel angles	Pink noise	2.05	4.15
	Pink noise	2	5
	Pink noise	1.86	5.95

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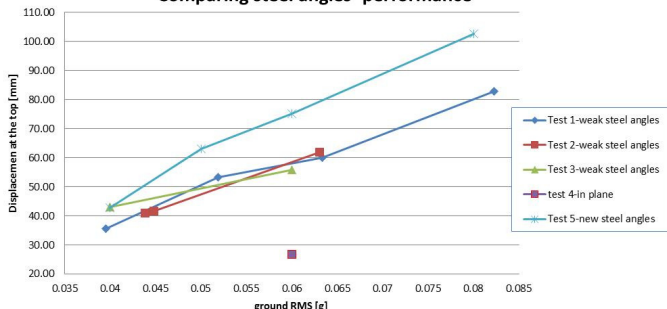
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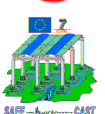
Conclusions:

- New steel angles introduced in the 5th test do not reduce the displacements, so they do not increase stiffness
- The displacements are higher in the 5th test because the structure is already with some damage
- Fastening of the connection can increase stiffness

Comparing steel angles' performance



ground RMS [g]	Test 1-weak steel angles [mm]	Test 2-weak steel angles [mm]	Test 3-weak steel angles [mm]	Test 4-in plane [mm]	Test 5-new steel angles [mm]
0.035	38	42	45	-	40
0.04	40	42	45	-	45
0.045	42	45	48	-	50
0.05	45	48	50	-	65
0.055	50	52	55	-	75
0.06	55	58	60	28	85
0.065	60	62	65	-	95
0.07	65	68	70	-	105
0.075	70	72	75	-	115
0.08	75	78	80	-	125
0.085	80	82	85	-	135

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Conclusions:

- Damage occurs in the connection and in the surrounding concrete

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Thank you for your attention