Development of BRD_Al Prototype

Development of aluminium alloy hysteretic damping system : System configuration and analysis

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Presentation outline

Introduction:

- Objectives

Developments:

- Description of experimental results regarding the mechanical behaviour of aluminium alloys
- Definition and analyses for the BRD_Al device configuration ;
- Definition and analyses for the dissipative bracing;

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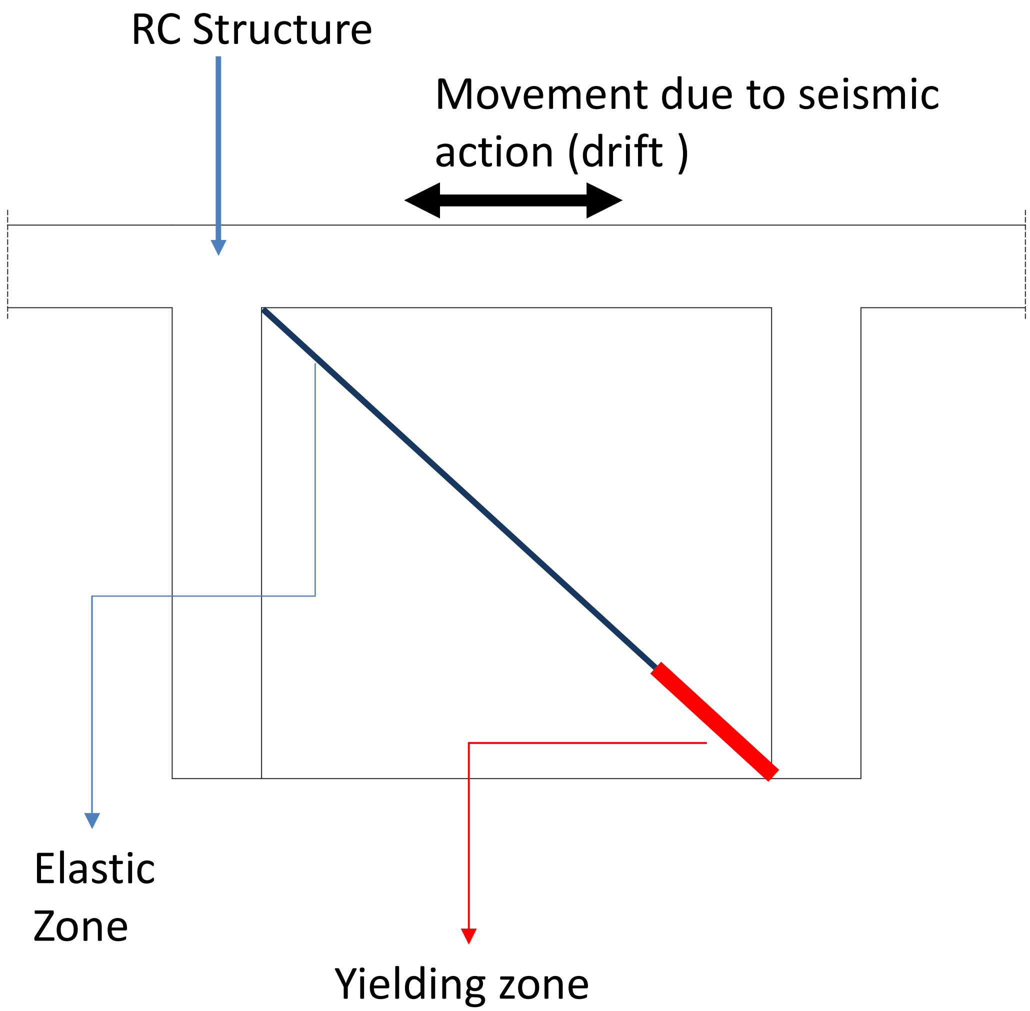
<u>Objectives:</u>

- Alternative to the dissipative bracing device paradigm: use an extruded aluminium alloy member without infill;
- Light-weight and easy to integrate in bracing system;
- Device that is simple to integrate both in new and existing buildings
- Capable of withstanding significant plasticization, hence increasing structural damping due to hysteretic behaviour of the aluminium member;



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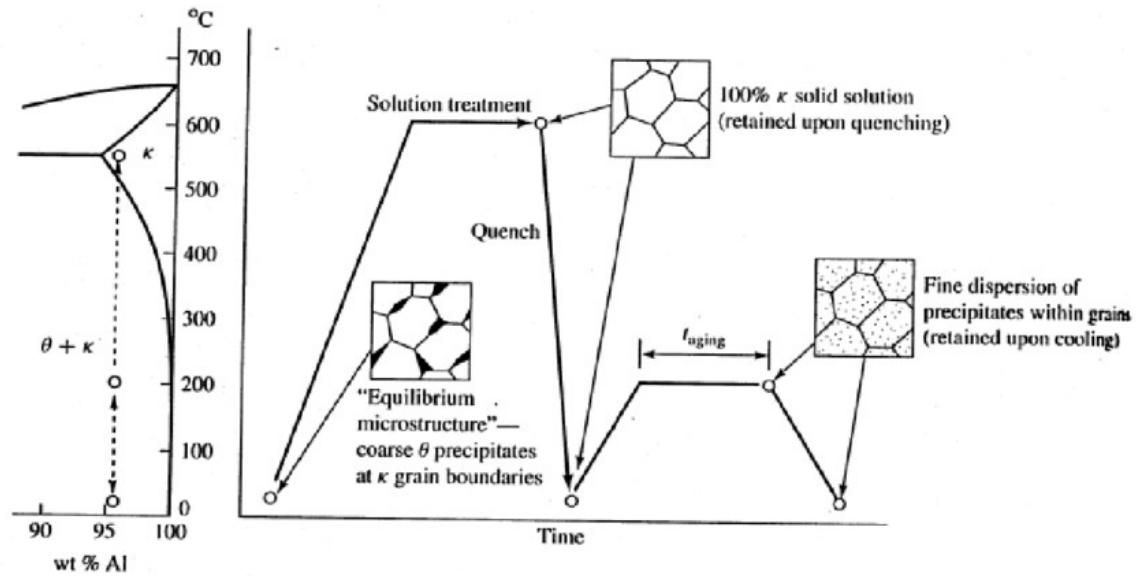
Aluminium Alloy - Thermal treatments



Thermal treatment stages:

- Solution treatment;
- Quenching;
- Artificial ageing

Precipitation transformations can be expressed by

α → α+β

- α: Metastable super saturated solution
- β (with the same crystal structure): More stable with he same crystal structure as α solid solution
- β: Stable or metastable precipitate

<u>Proposed thermal treatments for the 6082 alloy:</u>

1. Solution treatment at 535ºC (45 min)+ageing at 190 ºC (2h);
2. Solution treatment at 535ºC (45 min)+ageing at 100 ºC (32h);
3. No solution treatment +ageing at 350 ºC (2h)
4. No solution treatment + ageing at 280 ºC (8h)

Change precipitates size, shape and distribution
Change grain dimension → Enhance strength and ductility

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Characterization of the mechanical behaviour of the selected alloys

- Uniaxial tension tests
  - Plate specimens
- Uniaxial cyclic tests
  - Rod type specimens (AW 6082 specimens);
  - Squared bars (AW 5083 –H111)

Objectives:

- Assess the mechanical behaviour of the alloys, especially when subjected to cyclic loading;
- Determine the best suited alloy to be used in BRD_AL production;
- Dissemination of experimental results of tested aluminium alloys

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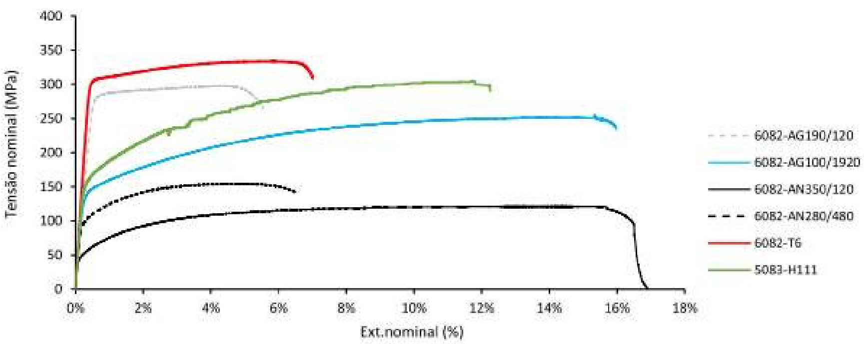
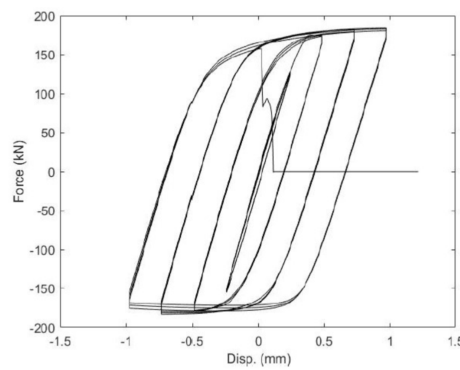
Aluminium alloy selection for the BRB_Al – Experimental campaigns

Results of uniaxial tension tests

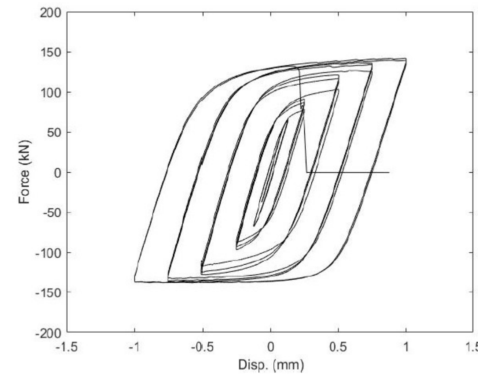


Provete	$E_t(GPa)$	$\sigma_{y0.2}(MPa)$	$\epsilon_y(\%)$	$\sigma_{ult}(MPa)$	$\epsilon_{ult}(\%)$
6082-T6	77	311	0,4	334	6
6082-AG190/120	61	274	0,4	298	4
6082-AG100/1920	63	145	0,2	256	16
6082-AN350/120	69	55	0,1	121	16
6082-AN280/480	67	109	0,2	155	5
5082-H111	67	151	0,2	305	12

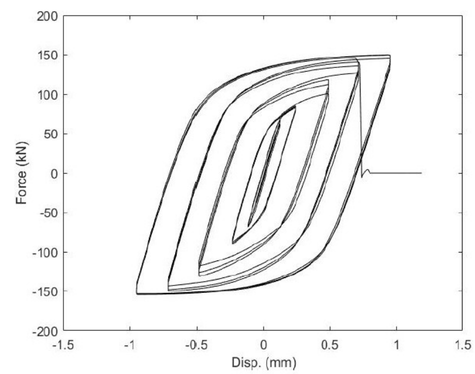
6082 - T6



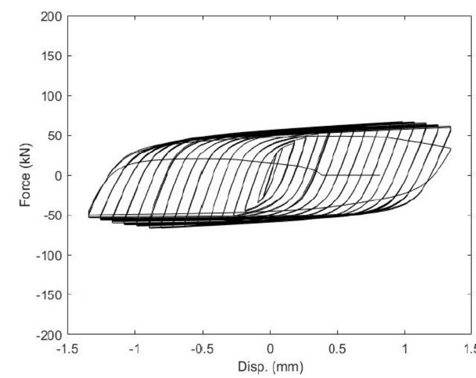
5083-H111



6082-AG100/1920



6082-AN350/120



Beside the reference alloys 6082-T6 and the 5083-H111, the cyclic analyses were carried out considering only the alloys that shown the best performance in terms deformation capacity in the uniaxial tests – the 6082 AG100/1920 and the 6082 - AN350/120 alloys

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Selection of aluminium alloy for the composition of the dissipative components of the BRB_Al

Analyses results– Evaluation parameters

The assessment of the cyclic performance of each alloy was carried out considering specific evaluation parameters recommended by the standard *ATC-24-Guidelines for cyclic testing of components of steel structures.*

The 6082 – AN350/120 has shown the highest values of the deformation capacity ((μ, $\Delta\delta_{cum}$, $\Delta\delta_{cum}^{norm}$, $E_t/\sigma_{y\ 0.2}$) as well has of the energy dissipation parameters (W_{cum}^{norm}). Also, beside these parameters, this alloy has shown the highest number of inelastic cycles until rupture (N_i).

The alloy chosen for the dissipative components of the BRD_Al was the 6082-AN350/120

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Due to the impossibility of carrying out experimental tests, all the analyses and development of the configuration of the BRB_Al device was carried out using the numerical analysis with the ABAQUS software.

Development stages

1. Parametrization of the non linear behavior of the selected alloy when subjected to cyclic loading
   → Combined isotropic and kinematic hardening and damage models for the 6082AN350/120 alloy. The parameters used in those models were calibrated using the experimental results performed on the 6082AG350/120 alloy specimen.

2. Numeric modeling of two idealized configurations for the BRD_Al device
   → The numeric models of the idealized configurations were created using both plate and solid numeric elements

3. Evaluation of the cyclic performance the idealized configurations.
   → The assessment of the cyclic performance of the idealized configurations were carried out considering the evaluation parameters defined in nº45 ECCS bulletin (testing and evaluation of metallic elements subjected to cyclic loading)

4. Selection of the most suited configuration for the BRB_Al device.

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Parametrization of the cyclic performance of the 6082- AN350/120 aluminium alloy

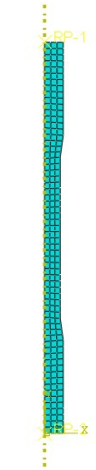
- The cyclic test of the 6082-350/120 specimen was simulated using an axisymmetric numeric model using the ABAQUS software, considering S4R plate type elements with a maximum width/length of 5mm;

- The elasto-plastic behaviour of the material was defined considering the following principles:

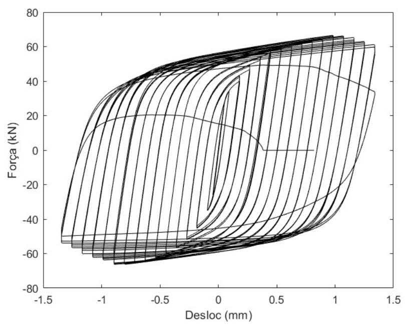
  - Metallic isotropic material assuming the generalized Hooke law in the elastic domain;

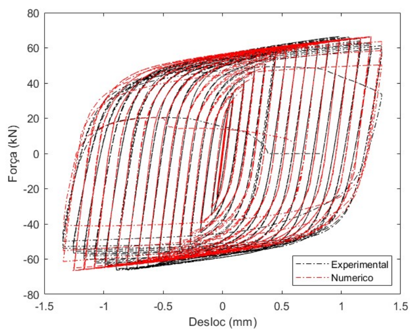
  - Plasticity model assuming a combined non linear isotropic and kinematic hardening (Chaboche Model), considering the Von Mises yielding criterion;

  - Ductile damage – Damage initiation triggered by specific strain equivalent plastic value. Damage evolution was defined by considering a exponential evolution law for the plastic displacement and a limit for the dissipated energy during plastic deformation after damage initiation.



Numeric model of the test specimen used in the cyclic test of the 6082AN350/120 alloy





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Idealized configurations for the BRB_AL device

Configuration T1

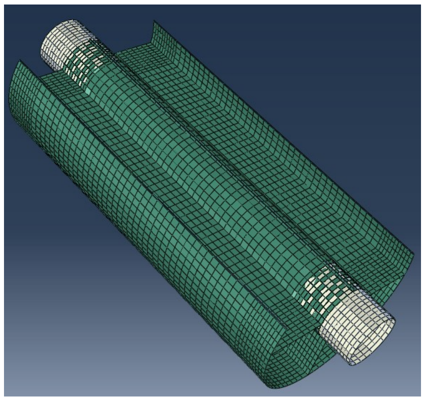


Fig 1.

Configuration T2

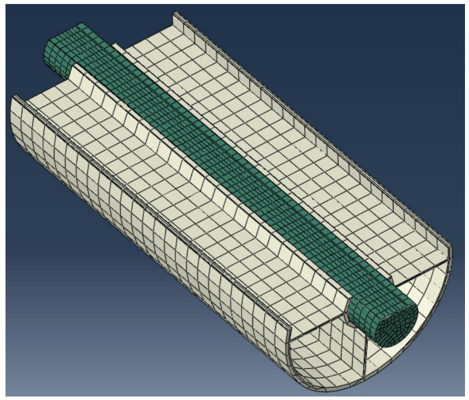
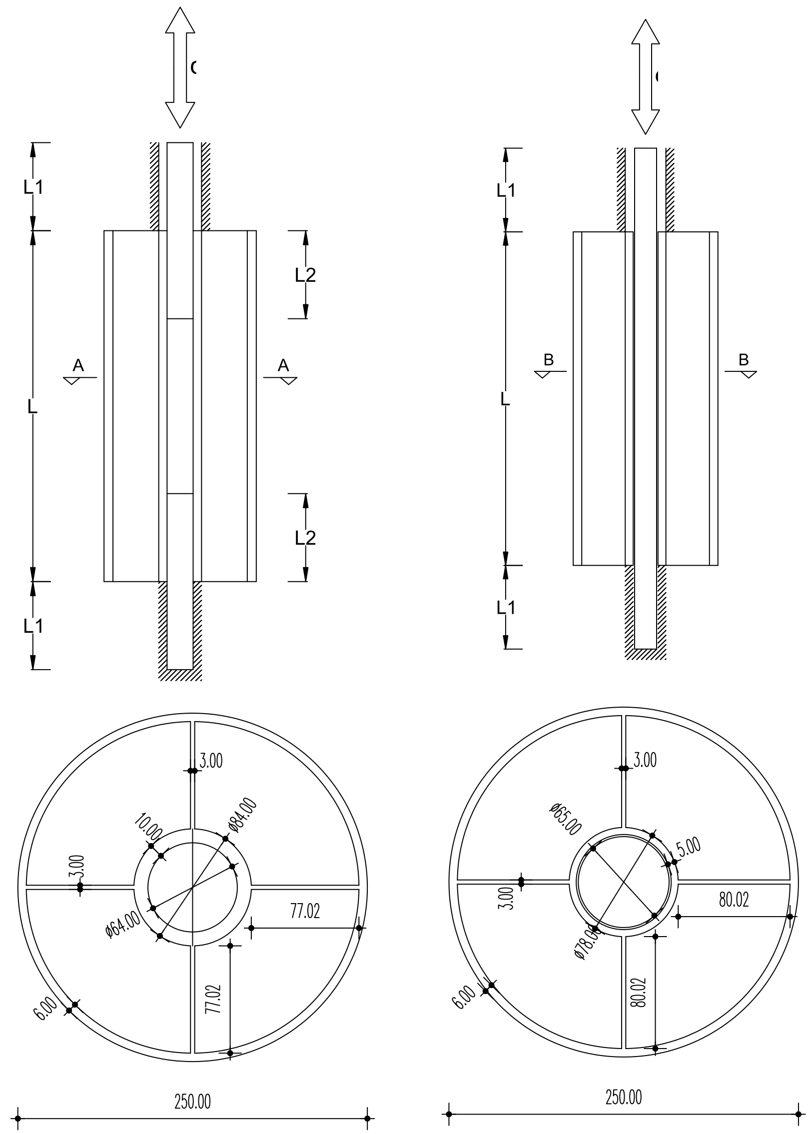


Fig 2.



Config. T1 – Section A-A

Config. T2 – Section B-B

Numerical assessment of two different configurations of the device admitting a reference yielding force of 200 kN

In both configurations, the dissipative components of the device (indicated in green) are composed by the 6082-AN350/120. The non-dissipative parts of the device are composed of the 6082-T6 alloy (indicated in white)

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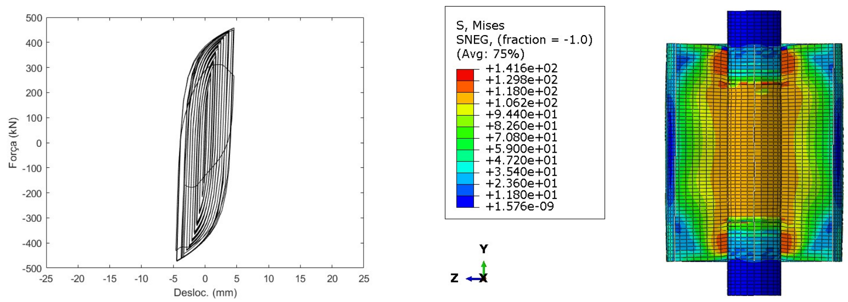
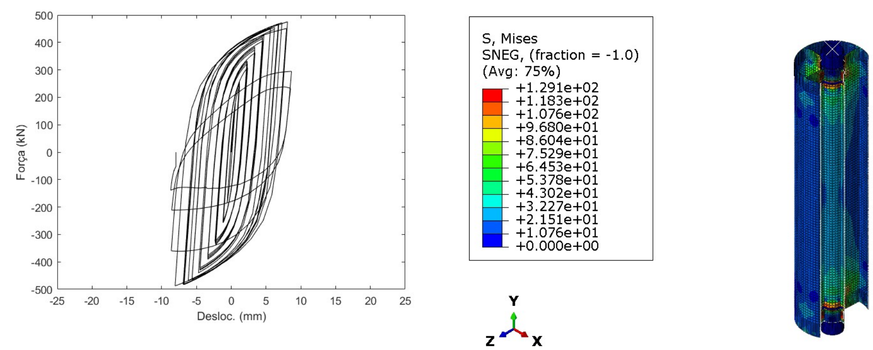
Evaluation of the cyclic performance of the idealized configurations of the BRB_Al device

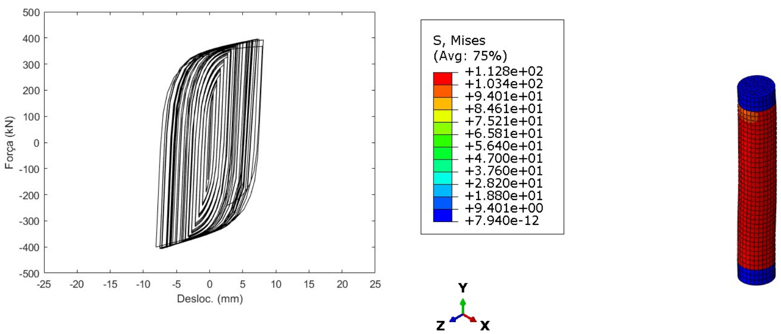
T1-300



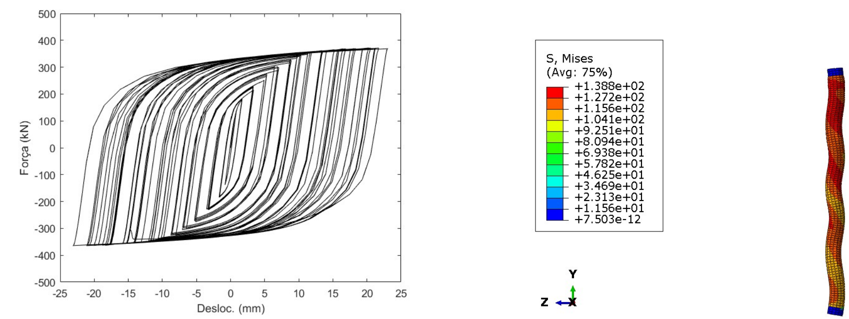
T1-1000



T2-300



T2-1000



Main outcomes:

- Cyclic behaviour of config. T1 is conditioned by local buckling in the lower and upper connection zones (top and bottom of the inner cylinder);
- For config. T2, the restritor components (bi-tubular profile) provides the necessary rigidity to ensure the restriction of buckling of the dissipative component (cylindrical inner shaft);
- For config.T2, was possible to obtain stable plastic deformation for higher values of deformation and greater number of cycles during plastic deformation.

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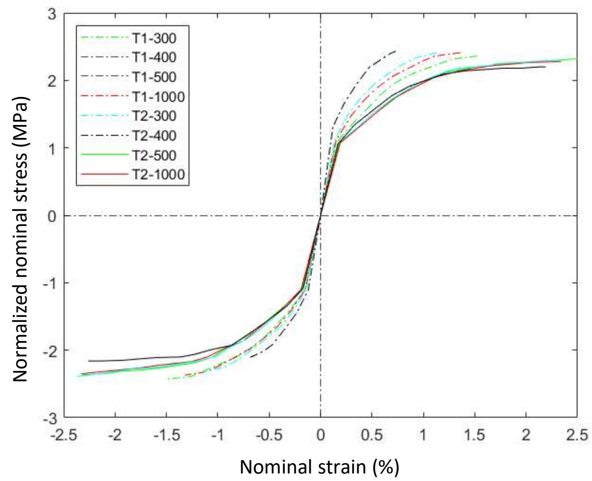
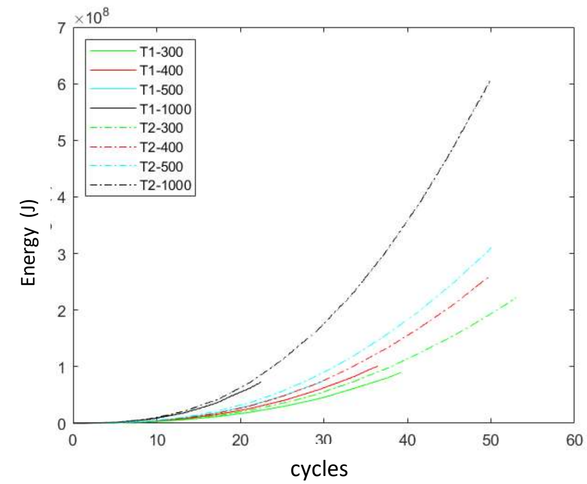
Avaliação de desempenho cíclico das potenciais configurações do elemento BRB_Al

Summary of results:

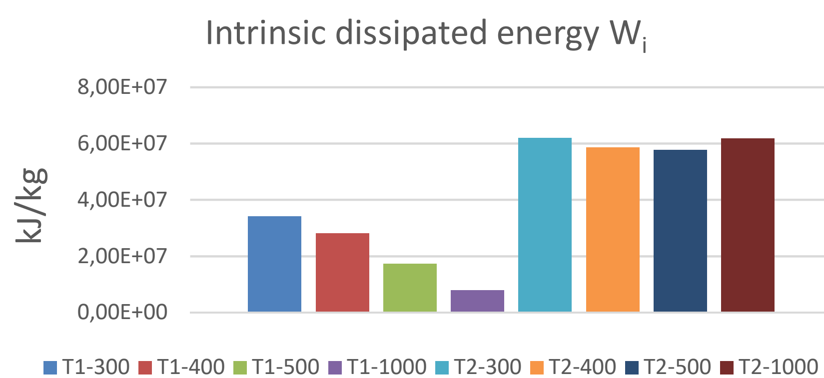
- The dissipative devices with the T2 configuration showed the highest deformation capacity e the highest number of stable cycles under inelastic deformation;
- The devices with the T2 configuration showed the highest values of intrinsic dissipated energy;
- Regardless their of length and the small differences between them, the T2 devices showed relatively stable values of intrinsic dissipated energy;
- Given the results obtained, the T2 configuration was the one chosen for the BRD_Al



Curvas envolventes do comportamento cíclico dos elementos dissipativos



Accumulated dissipated energy during cyclic loading



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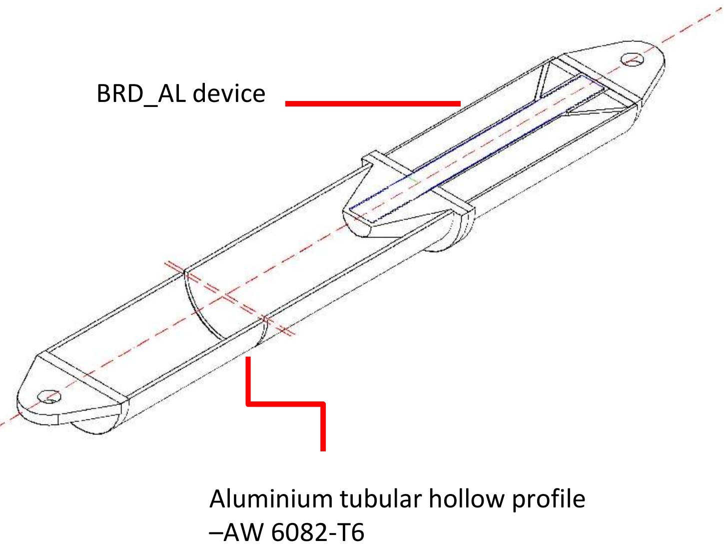
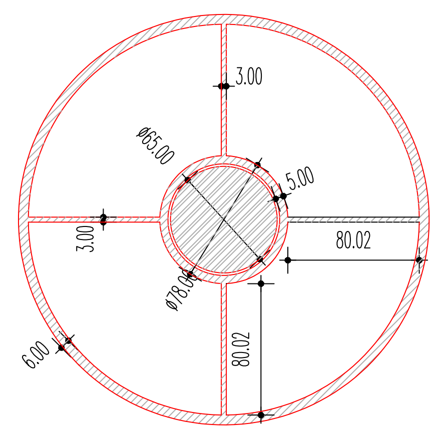
Bracing configuration

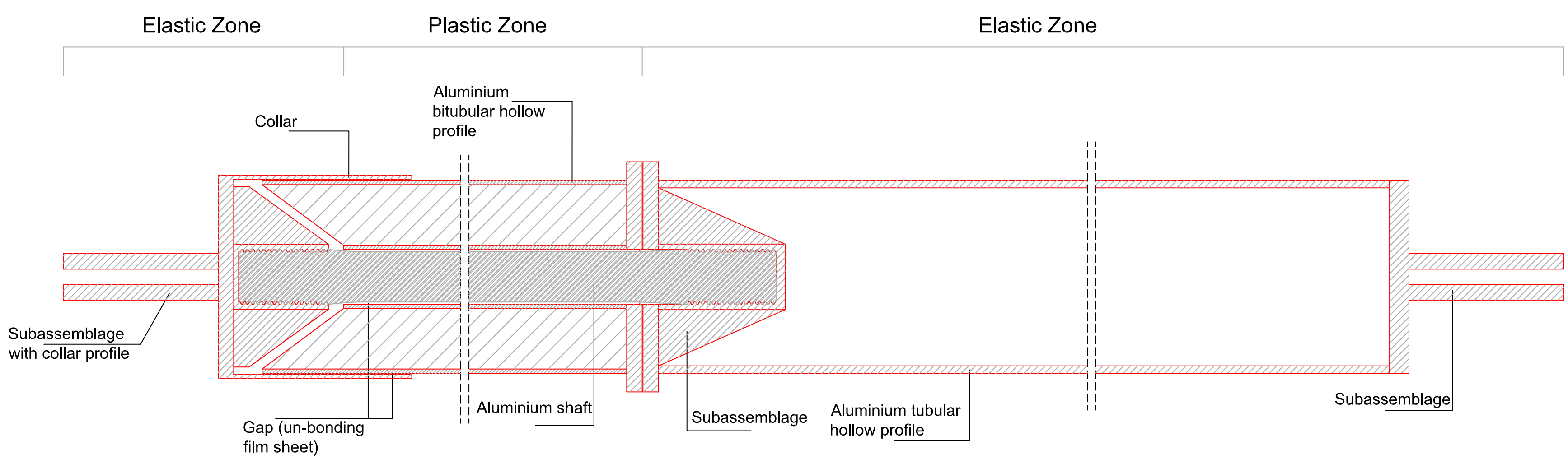
Main assessments:

- The effects of geometric imperfections on the cyclic behaviour of the set hollow profile and the BRD_Al;
- The effects of the length relationship between the shaft and the profile on the cyclical behavior of the set.



Cross section of the BRD-Al device





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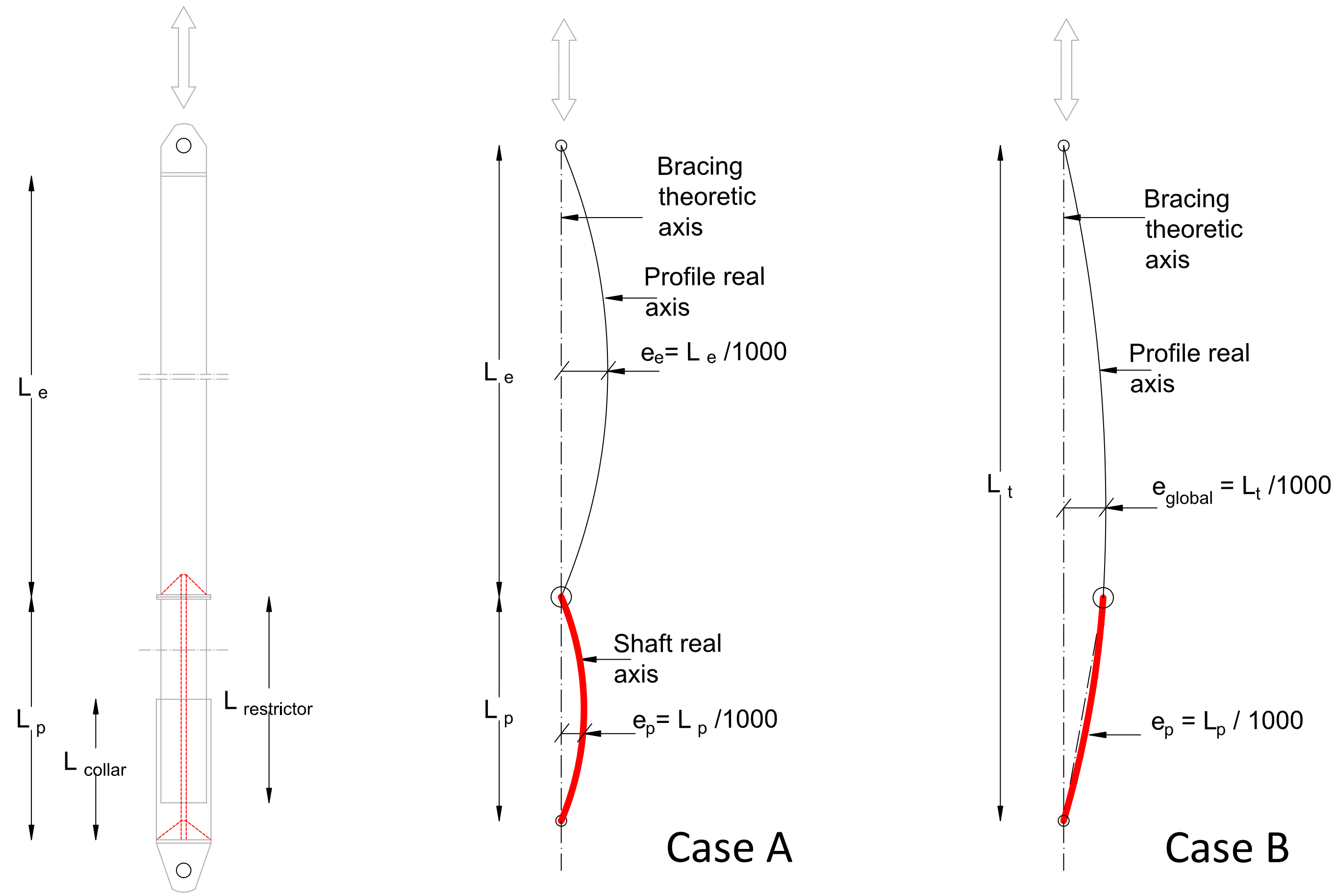
Bracing analyses

- Collar definition using the formulation proposed by Jing-Zhong et al.
- Different cases for the elastic length $\mathbf{L_e}$ and the plastic length $\mathbf{L_p}$ where used for the assessment of their influence on the cycling behavior of the bracing;



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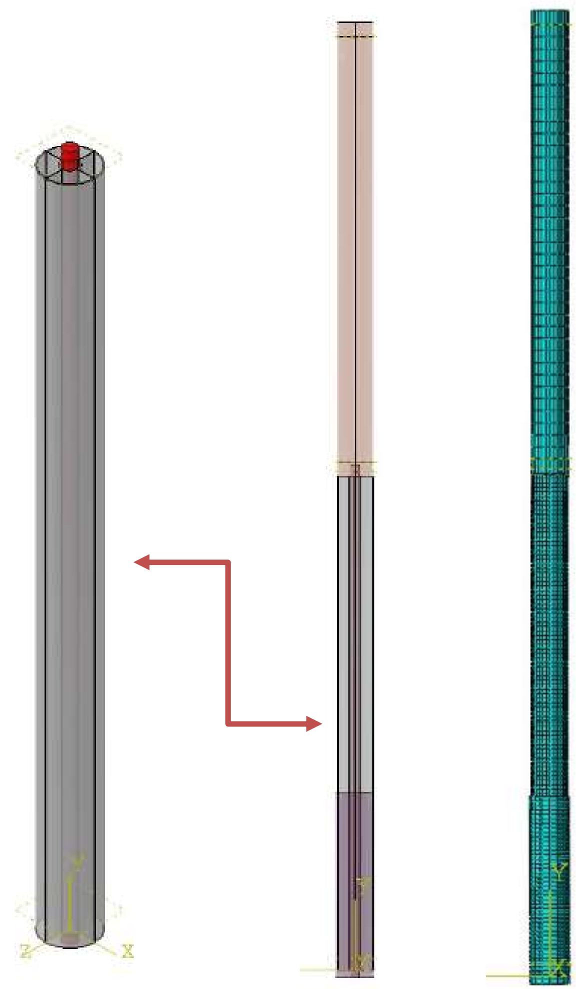
Bracing analyses – Assessment of the global behavior of the bracing system

- Selection of different sizes of the dissipative and elastic components of the bracing – Cases A and B with different L_e and L_p dimensions but maintaining the overall size of the bracing in the 6400 mm of length (reference size for the bracing).

- Definition of the numeric models considering solid elements and using the same material properties considered in the previous BRD_Al analyses.

- Assessment of the cyclic performance of each of these cases considering a cyclic history of increasing displacement amplitude;

- Determination of maximum displacement or extension achieved by the bracing within stable cyclic behavior



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Bracing analyses – Assessment of the global behavior of the bracing system

Case A and B – General dimensions

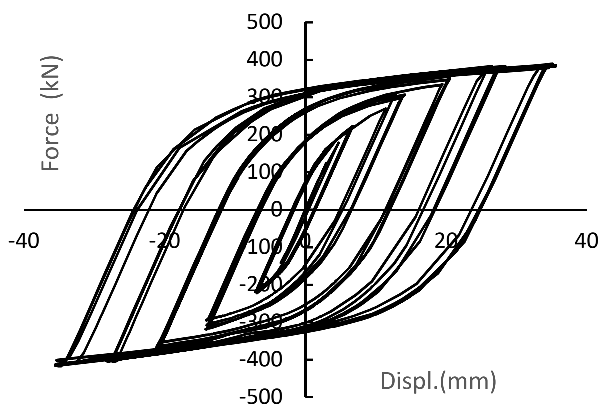
L_t mm	L_p mm	L_e mm	L_{collar} mm
6400	300	6100	1280
	500	5900	
	1000	5400	
	5000	1400	

Case A – Initial imperfections

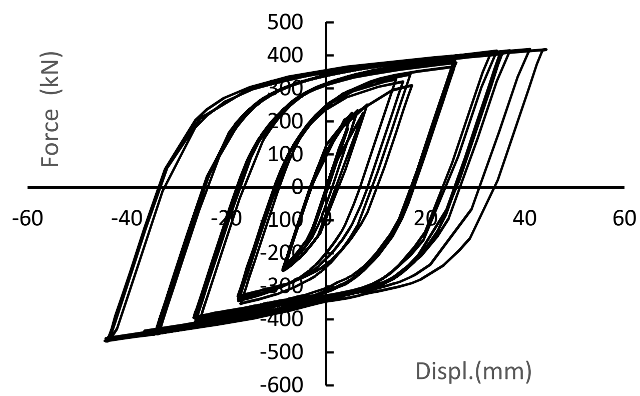
L_p mm	(e_p) mm	(e_e) mm
300	0,3	6,1
500	0,5	5,9
1000	1	5,4
5000	2,49*	1,4

Case B – Initial imperfections

L_p mm	(e_p) mm	(e_{global}) mm
300	0,3	6,4
500	0,5	
1000	1	
5000	2,49*	



Example of the cyclic behaviour of case A with L_P=1000 mm



Example of the cyclic behaviour of case B with L_P=1000 mm

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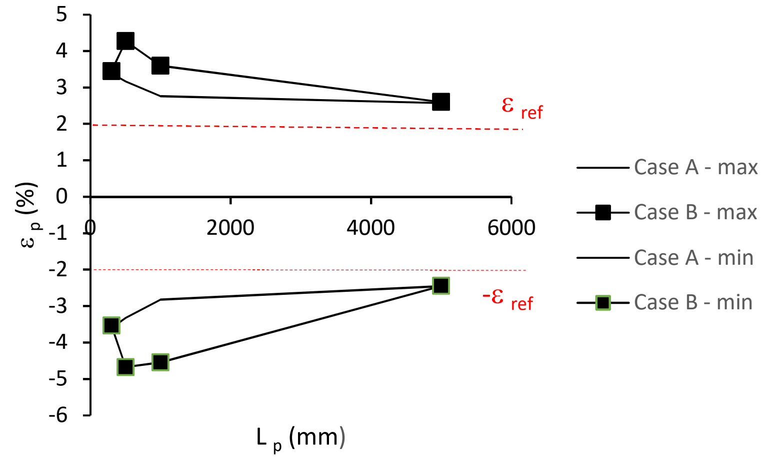
Bracing analyses – Assessment of the global behavior of the bracing system

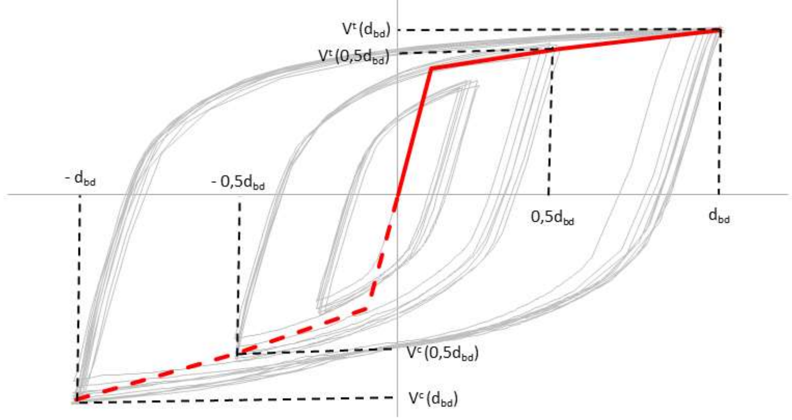
Main outcomes:

- Determination of a reference extension ε_{ref} based on the cyclic analyses of all configurations of cases A and B

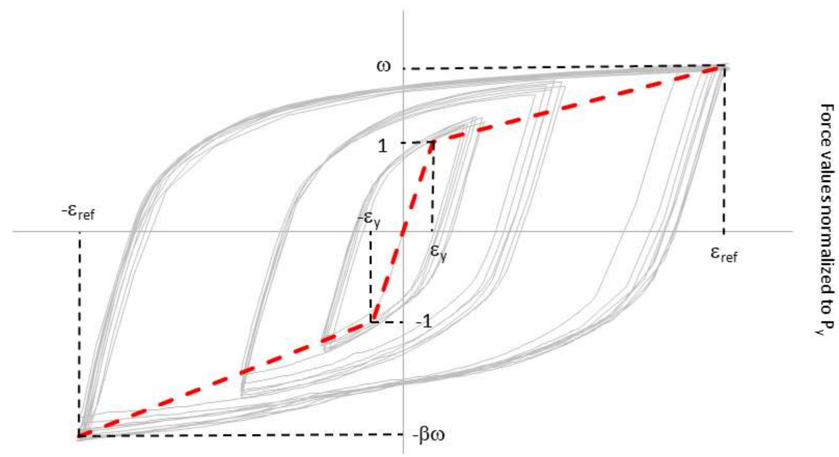
- Definition of the theoretic bilinear curve for the cyclic performance of the bracing, was based on an adaptation of the EN15129 standard suggested by A. Zsarnocsay



EN 15129 definition for Non Linear displacement dependent devices



EN 15129 definition adaptation proposed by Zsarnocsay



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Application of the dissipative bracing in a case study

<u>Information collected</u>:

- Information about the building structure from the municipal archive;
- Geotechnical information from the municipal geotechnical database and also from SPT performed near the building
- Acceleration response signals obtained in the roof of the building in previous observation campaigns.
- Results form previous studies from Furtado, H. and Varum, H.

<u>Objectives:</u>

- Assessment of structural capacity in light of current regulatory requirements for structures subjected to seismic actions. Assessment through static and dynamic non linear analyses;
- Comparison with results obtained by previous works, such as of Furtado, H. and Varum, H.

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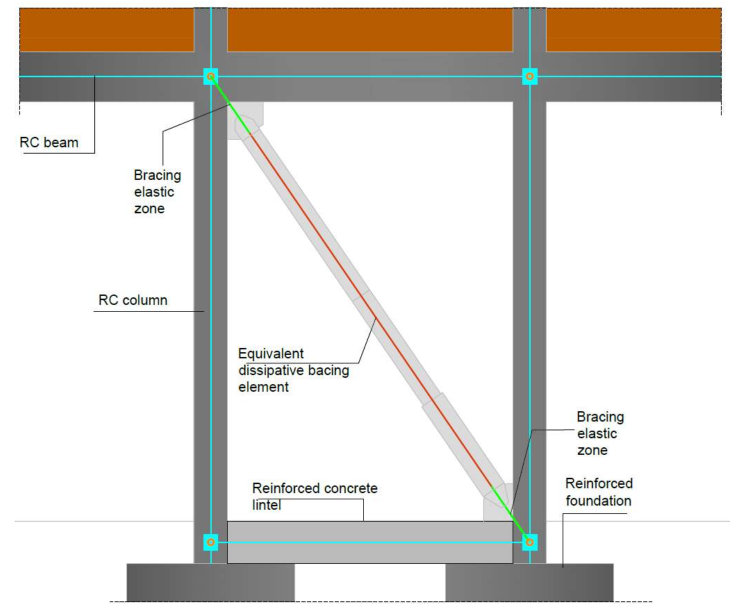
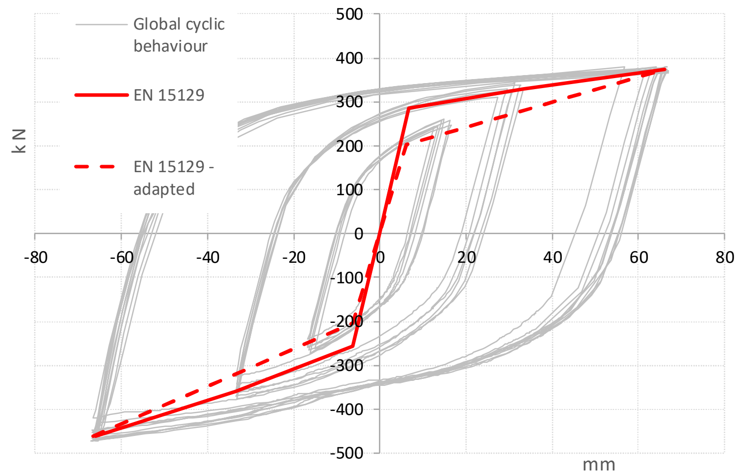
Application of the dissipative bracing in the case study

Definition of the equivalent numeric bracing element bar considering an elasticity modulus E_{eq} and cross-section of the dissipative component of the real brace;

The number of bracings to be applied in the structure was determined considering the methodology proposed by Kasuhiko Kasai et al., even though this methodology was conceived for more traditional configurations of dissipative bracings





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Application of the dissipative bracing in the case study

Definition of the numeric model of the building using the SeismoStruct software, considering the non-linear behaviour of concrete structural elements and the "in frame " infill panels;

Assessment of the seismic behavior of both the original and retrofitted building considering the recommendations by the EN 1998-1 and EN 1998-3

Static non linear static analyses :

Capacity curves; target displacements and evaluation of capacity versus demand of both the original and the retrofitted structure

Dynamic non linear dynamic analyses:

Structural response of both original and retrofitted structure subjected to different pairs of acceleration signals of the reference seismic actions applied in the two main orthogonal directions

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At this time:

- Paper publish on the Journal of Materials and Engineering Performance entitled “Aluminium alloys for hysteretic dissipative devices: mechanical characterization” – ASM International https://doi.org/10.1007/s11665-021-05847-5

- The results of the numeric models of the case study are being processed;

- Follow up assessments on the structural behavior of both original and retrofitted structure will be conducted considering the recommendations of the EN1998-1 and EN 1998-3.

- The structural behavior of both the original structure and the retrofitted structure will also be assessed in terms accelerations, displacements, drifts of the first and top floors and also base shear force.

- Results obtained from these analyses will be compared with the results obtained from previous analysis performed about this case study.

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Thank you for your attention