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EAD 340309-00-0305-v01

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European Assessment Document for

Variant: Non-load-bearing permanent  
shuttering kits or systems  
based on hollow blocks or panels  
of insulating materials and  
sometimes concrete: hollow blocks  
resistant to seismic actions



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## 1 SCOPE OF THE EAD

### 1.1 Description of the construction product

EAD 340309-00-0305 Clause 1.1 applies.

This EAD is a variant to EAD 340309-00-0305 and provides a more detailed specification for hollow blocks resistant to seismic actions, hereinafter called “seismic resistant shuttering kit(s)” (Figure 1.1.1). The hollow blocks of the seismic resistant shuttering kits are characterized by vertical and horizontal holes so that, after the on-site assembling, they are filled with concrete with vertical and horizontal rebars so that they provide a grid of reinforced concrete infilled voids (grid-type wall).

The seismic resistant shuttering kits are composed of: i) hollow blocks (mandatory) and fill-ins of insulating materials (optional); ii) additional components needed for installation and functioning of the kit but which are not subjects of assessments (i.e., filling concrete and reinforcing bars).

In order to cover the load-bearing and seismic performances of the seismic resistant shuttering kits, the set of essential characteristics of the main EAD has been extended and the corresponding additional assessment methods have been introduced.

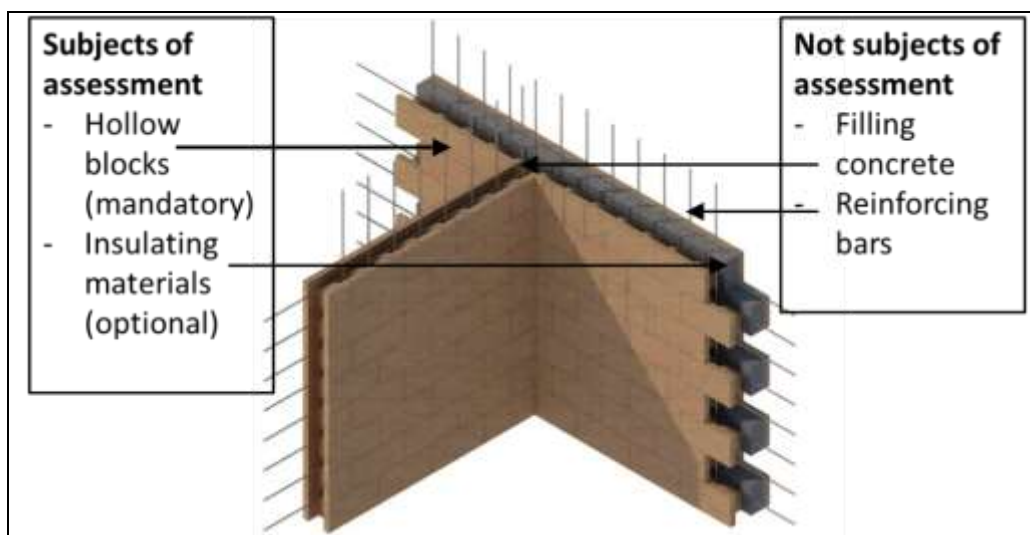


Figure 1.1.1 Seismic resistant shuttering kit's components

### 1.2 Information on the intended use(s) of the construction product

#### 1.2.1 Intended use(s)

EAD 340309-00-0305 Clause 1.2.1 applies.

In particular, this EAD covers permanent shuttering kits based on hollow blocks when used for load-bearing and seismic applications.

#### 1.2.2 Working life/Durability

EAD 340309-00-0305 applies.

### 1.3 Specific terms used in this EAD

EAD 340309-00-0305 applies.

## 2 ESSENTIAL CHARACTERISTICS AND RELEVANT ASSESSMENT METHODS AND CRITERIA

All undated references to standards in this EAD are to be understood as references to the dated versions listed in chapter 4.

### 2.1 Essential characteristics of the product

Table 2.1.1 shows how the performance of the seismic resistant shuttering kits is assessed in relation to the essential characteristics.

**Table 2.1.1 Essential characteristics of the product and methods and criteria for assessing the performance of the product in relation to those essential characteristics**

No	Essential characteristic	Assessment method	Type of expression of product performance
<b>Basic Works Requirement 1: Mechanical resistance and stability</b>			
1	Resulting structural pattern	EAD 340309-00-0305, Clause 2.2.1	Description
2	Efficiency of filling	EAD 340309-00-0305, Clause 2.2.2	Description
3	Possibility of steel reinforcement	EAD 340309-00-0305, Clause 2.2.3	Description
4	Assessment of the monotonic and cyclic structural response of the seismic resistant shuttering kits with and without openings and connections:		
4.1	Elastic modulus E	2.2.1.1	Level $E_m$ [MPa], $\sigma_E$ [MPa]
4.2	Compression strength	2.2.1.2	Level $S_{c,m}$ [MPa], $\sigma_{Sc}$ [MPa]
4.3	Shear strength	2.2.1.3	Level $S_{sv,m}$ [MPa], $\sigma_{Ssv}$ [MPa], $G_m$ [MPa], $\sigma_G$ [MPa]
4.4	Shear strength of the inner horizontal connections	2.2.1.4	Level $S_{sh,m}$ [MPa], $\sigma_{Ssh}$ [MPa]
4.5	Lateral strength	2.2.1.5	Level $F_{u,m}$ [kN], $\sigma_{Fu}$ [kN]
4.6	Elastic and post elastic displacement capacities	2.2.1.6	Level $\delta_{y,m}$ [-], $\sigma_{\delta y}$ [-] $\delta_{pl,m}$ [-], $\sigma_{\delta pl}$ [-]
4.7	Initial stiffness	2.2.1.7	Level $K_{init,m}$ [kN/mm], $\sigma_{Kinit}$ [kN/mm]
4.8	Stiffness secant to yielding	2.2.1.8	Level $K_{y,m}$ [kN/mm], $\sigma_{Ky}$ [kN/mm]
4.9	Ductility	2.2.1.9	Level $\mu_{local,m}$ [-], $\sigma_{\mu local}$ [-]
4.10	Overstrength ratio	2.2.1.10	Level $\rho_{local,m}$ [-], $\sigma_{\rho local}$ [-]
4.11	Dissipated energy	2.2.1.11	Level $E_{diss,m}$ [kN·mm], $\sigma_{Ediss}$ [kN·mm]
4.12	Damping	2.2.1.12	Level $\xi_{eq,m}$ [-], $\sigma_{\xi eq}$ [-]
4.13	Strength of T and L connections	2.2.1.13	Level

No	Essential characteristic	Assessment method	Type of expression of product performance
			$M_{u,conn}^+ [kN \cdot mm]$ , $M_{u,conn}^- [kN \cdot mm]$
4.14	Strength and displacement capacity of a multi-story structure	2.2.1.14	Level $F_u^* [kN]$ , $d_y^* [-]$ , $d_{pl}^* [-]$ $\mu_{global} [-]$ , $\rho_{global} [-]$
<b>Basic Works Requirement 2: Safety in case of fire</b>			
5	Reaction to fire	EAD 340309-00-0305, Clause 2.2.4	Class
6	Influence of the shuttering kit on the fire resistance	EAD 340309-00-0305, Clause 2.2.5	Class
<b>Basic Works Requirement 3: Hygiene, health and the environment</b>			
7	Content, emission and/or release of dangerous substances	EAD 340309-00-0305, Clause 2.2.6	Description
8	Water vapour permeability	EAD 340309-00-0305, Clause 2.2.7	Level
9	Water absorption	EAD 340309-00-0305, Clause 2.2.8	Level
10	Water tightness	EAD 340309-00-0305, Clause 2.2.9	Description
<b>Basic Works Requirement 4: Safety and accessibility in use</b>			
11	Bond strength	EAD 340309-00-0305, Clause 2.2.10	Description
12	Resistance to impact load	EAD 340309-00-0305, Clause 2.2.11	Description
13	Resistance to filling pressure	EAD 340309-00-0305, Clause 2.2.12	Description
14	Safety to personal injuries	EAD 340309-00-0305, Clause 2.2.13	Description
<b>Basic Works Requirement 5: Protection against noise</b>			
15	Airborne sound insulation	EAD 340309-00-0305, Clause 2.2.14	Level
16	Sound absorption	EAD 340309-00-0305, Clause 2.2.15	Level
<b>Basic Works Requirement 6: Energy economy and heat retention</b>			
17	Thermal resistance	EAD 340309-00-0305, Clause 2.2.16	Level
18	Thermal inertia	EAD 340309-00-0305, Clause 2.2.17	Level
<b>Aspects of durability</b>			
19	Resistance to deterioration	EAD 340309-00-0305, Clause 2.2.18	Description

## 2.2 Methods and criteria for assessing the performance of the product in relation to essential characteristics of the product

### 2.2.1 Assessment of the monotonic and cyclic structural response of the seismic resistant shuttering kits with and without openings and connections

#### General requirements

The essential characteristics listed in the following refer to the structural behaviour of the seismic resistant shuttering kits. For this reason, the assessment methods shall always be performed on specimens which include concrete pouring and steel reinforcement. Normal weight concrete with concrete strength grade equal to C25/30 shall be used for assessment. Concrete properties shall be in accordance with EN 206 and considering the indications of Table 2.2.1.1. Specifications about flow classes, maximum aggregates size (mm) and fresh concrete consistency shall be reported in ETA. For all the patterns, the maximum aggregate size shall be assumed at least 8mm.

**Table 2.2.1.1 Concrete properties**

Minimum dimension of the filling section(s)	Concrete properties
<12 cm	maximum aggregate size 8 mm, flow class $\geq$ F5 (Table 5, EN 206)
12 cm $\leq$ s < 14 cm	maximum aggregate size 16 mm, flow class $\geq$ F3 (Table 5, EN 206)
$\geq$ 14 cm	maximum aggregate size 32 mm, flow class $\geq$ F2 (Table 5, EN 206)

Steel reinforcement  $f_{yk}=430$  MPa shall be adopted, with light geometrical percentage for vertical ( $\rho_{vert}$ ) and horizontal ( $\rho_{horiz}$ ) reinforcement for all the test specimens, i.e.,  $\rho_{vert}=\rho_{horiz}=0.15\% \cdot A_c$  given  $A_c=t_c \cdot b$  where  $t_c$  is the concrete core thickness according to Figure 2.2.1.1(a) and  $b$  is the specimen width (Figure 2.2.1.1(b)).

The experimental assessment methods described in the following consider pseudo-static load applications, in which the external loads (in terms of forces and/or displacements) shall be applied with low rate in order to reduce the dynamic effects during the test. Acceptable rates for displacement control tests shall be not higher than 0.1 mm/s. Acceptable rates for force control tests shall be not higher than 0.1 KN/s.

The experimental assessments shall be performed according to the test methods listed in Table 2.2.1.2 and described in the Annexes. In Table 2.2.1.2, specimens' geometry, number of tests and loading conditions are specified.

For the assessment of each essential characteristic listed in the following, at least one thickness value  $t_{cm}$  of the seismic resistant shuttering kits shall be tested, assuming  $t_{cm}$  as a medium value of  $t_c$  in the range of the available product size. The thickness of the seismic resistant shuttering kits  $t_{cm}$  (Figure 2.2.1.1) shall be stated in ETA.

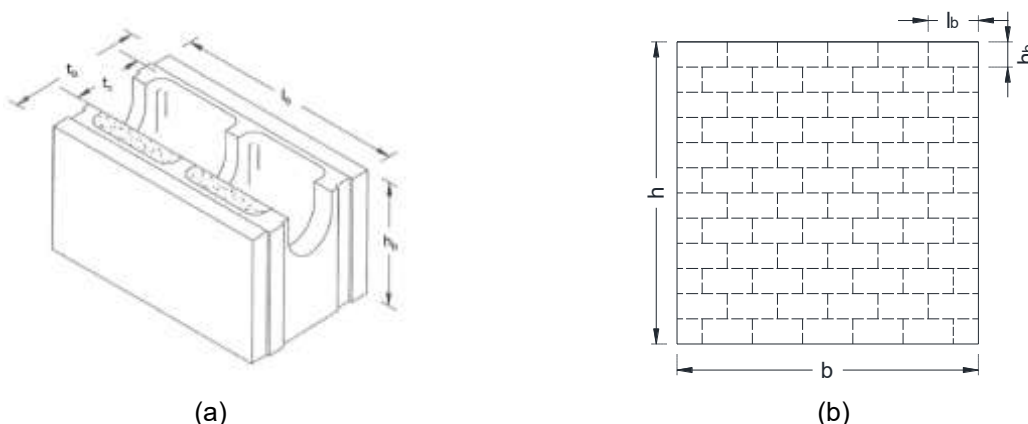
Assessment for thickness values in the range of  $\pm 15\%$  of  $t_{cm}$  can be obtained through linear extrapolation, as described in the following.

Given  $p_{EC_i}^{tested}$  the experimental value of a product performance parameter, obtained after the assessment for the generic essential characteristic  $EC_i$  corresponding to  $t_{cm}$ , the numerical value of  $p_{EC_i}^{num}$ , obtained for the generic thickness value  $t_{ci}$  by linear extrapolation, shall be calculated as in the following:

$$p_{EC_i}^{num} = n \cdot p_{EC_i}^{tested}$$

In which  $n = \frac{t_{ci}}{t_{cm}}$ .

For variations of the thickness value  $t_{ci}$  higher than  $\pm 15\%$  of  $t_{cm}$ : a) the monotonic response of the seismic resistant shuttering kits (0, 2.2.1.2, 2.2.1.3, 2.2.1.4) shall be obtained through further experimental tests; b) the cyclic response of the seismic resistant shuttering kits (2.2.1.5 to 2.2.1.14) shall be assessed by experimental tests or by proven validity numerical models, calibrated on the experimental tests performed on the specimens with thickness equal to  $t_{cm}$  and documented in ETA.



(a) (b)  
Figure 2.2.1.1 Dimensions: (a) single block; (b) specimen

**Table 2.2.1.2 Specimens and experimental setup of the required tests (h=specimen height, b=specimen width, t=specimen thickness)**

Specimen characteristics		Purpose of the test	Test Method	Loading	Testing protocol	N° of specimens
Small specimens $b = h = 1.0 \pm 0.01 \text{ m}$ $t = t_{cm}$ Concrete grade C25/30 Steel grade $f_{yk} = 430 \text{ MPa}$ $(\rho_{vert} = \rho_{horiz} = 0.15\% \cdot A_c)$		<ul style="list-style-type: none"> <li>Elastic modulus E (2.2.1.1)</li> <li>Compression strength <math>S_c</math> (2.2.1.2)</li> </ul>	Annex A, Clause A.4.1	Axial compression	Pseudo-static, monotonic	2
		<ul style="list-style-type: none"> <li>Elastic modulus G</li> <li>Shear strength <math>S_{sv}</math> (2.2.1.3)</li> </ul>	Annex A, Clause A.4.2	Diagonal compression	Pseudo-static, monotonic	2
		<ul style="list-style-type: none"> <li>Shear strength of the inner horizontal connections <math>S_{sh}</math> (2.2.1.4)</li> </ul>	Annex B	Axial compression	Pseudo-static, monotonic	2
Full-scale specimens $h = b = 3.0 \pm 0.04 \text{ m}$ $t = t_{cm}$ Concrete grade C25/30 Steel grade $f_{yk} = 430 \text{ MPa}$ $(\rho_{vert} = \rho_{horiz} = 0.15\% \cdot A_c)$	Without openings (Figure C.3.1)	<ul style="list-style-type: none"> <li>Lateral strength (2.2.1.5)</li> <li>Lateral stiffness (2.2.1.7 and 2.2.1.8)</li> <li>Displacement capacity (2.2.1.6) and ductility (2.2.1.9)</li> <li>Dissipation (2.2.1.10, 2.2.1.11 and 2.2.1.12)</li> </ul>	Annex C	Axial compression and in plan horizontal shear force	Pseudo-static, monotonic, Pseudo-static, cyclic (horizontal)	2
	With door (Figure C.3.2(a))					1
	With window (Figure C.3.2(b))					1
Joints between walls at least 1 m of linear connection Concrete grade C25/30 Steel grade $f_{yk} = 430 \text{ MPa}$ $(\rho_{vert} = \rho_{horiz} = 0.15\% \cdot A_c)$	L-shaped (Figure E.2.1(a,b))	Connection strength (2.2.1.13)	Annex E	Bending moment	Pseudo-static, cyclic (bending moment)	1
T-shaped (Figure E.2.1(c,d))	1					
H-shaped building Concrete grade C25/30 Steel grade $f_{yk} = 430 \text{ MPa}$ $(\rho_{vert} = \rho_{horiz} = 0.15\% \cdot A_c)$		Lateral strength, lateral stiffness, displacement capacity, ductility, dissipation (2.2.1.14)	Annex D	Gravity axial and combined in plane load	Pseudo-static, cyclic (horizontal)	1

### 2.2.1.1 Elastic modulus E

#### Purpose of the assessment

The purpose of the test is the assessment of the elastic modulus E (Young's modulus) of the seismic resistant shuttering kits.

#### Assessment method

The elastic modulus E shall be obtained through the test procedure listed in Table 2.2.1.2 and described in Annex A, Clause A.4.1.

#### Expression of results

The elastic modulus  $E_i$  for each  $i^{\text{th}}$  tested specimen shall be evaluated as the slope of the initial portion of the stress-strain diagram obtained after a compression test, according to the test procedure described in Annex A, Clause A.4.1.

In particular:

$$E_i [\text{MPa}] = \sigma_{0i} / \varepsilon_{0i} \quad (2.2.1.1.1)$$

$$\sigma_{0i} [\text{MPa}] = N_{0i} / A_{ci} \quad (2.2.1.1.2)$$

$$\varepsilon_{0i} [-] = \frac{\varepsilon_{1,0i} + \varepsilon_{2,0i} + \varepsilon_{4,0i} + \varepsilon_{5,0i}}{4} = \frac{\Delta_{1,0i}/l_{1i} + \Delta_{2,0i}/l_{2i} + \Delta_{4,0i}/l_{4i} + \Delta_{5,0i}/l_{5i}}{4} \quad (2.2.1.1.3)$$

In which, for the  $i^{\text{th}}$  specimen:

- $N_{0i}$  [N] is the initial axial force value applied at the beginning of the compression test;
- $A_{ci} = b_i \cdot t_{cm,i}$  is the load application area, given  $b_i = i^{\text{th}}$  specimen width,  $t_{cm,i} = i^{\text{th}}$  specimen thickness as described in Annex A, Clause A.3;
- $\varepsilon_{j,0i}$  [-] is the initial strain of the  $j^{\text{th}}$  measurement line (i.e., 1-1', 2-2', 4-4' or 5-5' in Figure A.2.1(a));
- $\Delta_{j,0i}$  [mm] is the initial relative displacement of the  $j^{\text{th}}$  measurement line (i.e., 1-1', 2-2', 4-4' or 5-5' in Figure A.2.1(a));
- $l_{ji}$  [mm] is the length of the  $j^{\text{th}}$  measurement line (i.e., 1-1', 2-2', 4-4' or 5-5' in Figure A.2.1(a));

Given the total number of executed tests  $n$ , the average value (arithmetic mean) of the elastic modulus  $E_m$  [MPa] and the standard deviation  $\sigma_E$  shall be determined and given in the ETA.

### 2.2.1.2 Centred axial compression strength

#### Purpose of the assessment

The purpose of the test is the assessment of the centred axial compression strength of the seismic resistant shuttering kits.

#### Assessment method

The centred axial compression strength shall be obtained through the test procedure listed in Table 2.2.1.2 and described in Annex A, Clause A.4.1.

#### Expression of results

The compression strength  $S_{c,i}$  of each  $i^{\text{th}}$  tested specimen shall be evaluated by using the following expression:

$$S_{c,i} [\text{MPa}] = \frac{N_{max,i}}{A_{c,i}} \quad (2.2.1.2.1)$$

In which

- $N_{\max,i}$  [N] corresponds to the maximum axial compression force identified on force-displacement curve obtained through the test procedure described in Annex A, Clause A.4.1;
- $A_{c,i}$  [mm<sup>2</sup>] =  $b_i \cdot t_i$  is the load application area, given  $b_i$  [mm] =  $i^{\text{th}}$  specimen base,  $t_i$  [mm] =  $i^{\text{th}}$  specimen thickness as described in Annex A, Clause A.3.

Given the total number of executed tests  $n$ , the average value (arithmetic mean) of the compression strength  $S_{c,m}$  [MPa] and the standard deviation  $\sigma_{Sc}$  shall be determined and given in the ETA.

### 2.2.1.3 Shear strength

#### Purpose of the test

The purpose of the proposed test method is the evaluation of the shear strength  $S_{sv}$  and of the elastic shear modulus  $G$  of the seismic resistant shuttering kits, which is obtained through a diagonal compression test.

#### Assessment method

The shear strength  $S_{sv}$  and the elastic shear modulus  $G$  shall be obtained through the test procedure listed in Table 2.2.1.2 and described in Annex A, Clause A.4.2.

#### Expression of results

The shear strength  $S_{sv,i}$  of each  $i^{\text{th}}$  tested specimen shall be evaluated by using the following expression:

$$S_{sv,i}[\text{MPa}] = \frac{0.7P_{\max,i}}{A_{n,i}} \quad (2.2.1.3.1)$$

$$A_{n,i}[\text{mm}^2] = \left( \frac{b_i + h_i}{2} \right) t_i \quad (2.2.1.3.2)$$

In which, for the  $i^{\text{th}}$  specimen:

- $P_{\max,i}$  [N] is the peak value of the diagonal compression force identified on force-displacement curve obtained through the test procedure described in Annex A, Clause A.4.2;
- $b_i$  [mm] is the specimen width;
- $h_i$  [mm] is the specimen height;
- $t_i$  [mm] is the specimen thickness;

Given the total number of executed tests  $n$ , the average value (arithmetic mean) of the shear strength  $S_{sv,m}$  [MPa] and the standard deviation  $\sigma_{Sv}$  shall be determined and given in the ETA.

The elastic shear modulus  $G_i$ , of each  $i^{\text{th}}$  tested specimen, shall be evaluated by using the following expression, according to the test procedure described in Annex A, Clause A.4.2

$$G_i[\text{MPa}] = \frac{S_{sv,i}}{\gamma_i} \quad (2.2.1.3.3)$$

$$\gamma_i[-] = \left( \frac{\Delta V_i + \Delta H_i}{l_{g,i}} \right) \quad (2.2.1.3.4)$$

In which, for the  $i^{\text{th}}$  specimen:

- $\gamma_i$  [-] is the shear strain;
- $\Delta V_i = \frac{\Delta V_{1,\max,i} + \Delta V_{3,\max,i}}{2}$  [mm] is the vertical shortening, corresponding to  $P_{\max,i}$ , averaged on the measurement line 1-1' and 3-3' in Figure A.2.1(b);
- $\Delta H_i = \frac{\Delta H_{2,\max,i} + \Delta H_{4,\max,i}}{2}$  [mm] is the horizontal extension, corresponding to  $P_{\max,i}$ , averaged on the measurement line 2-2' and 4-4' in Figure A.2.1(b);
- $l_{g,i}$  [mm] is the vertical gage length obtained as  $(l_{g1,i} + l_{g3,i})/2$  for measurement lines 1-1' and 3-3' at the Figure A.2.1(b).

Given the total number of executed tests  $n$ , the average value (arithmetic mean) of the shear modulus  $G_m$  [MPa] and the standard deviation  $\sigma_G$  shall be determined and given in the ETA.

#### 2.2.1.4 Shear strength of the inner horizontal connections

##### Purpose of the assessment

The purpose of the proposed test method is the evaluation of the shear strength of the inner horizontal connections  $S_{sh}$  formed by concrete filling the hollow blocks.

##### Assessment method

Connection shear strength  $S_{sh}$  shall be obtained through the test procedure listed in Table 2.2.1.2 and described in Annex B.

##### Expression of results

The connection shear strength  $S_{sh,i}$  for each  $i^{\text{th}}$  tested specimen shall be evaluated by using the following expression:

$$S_{sh,i} [\text{MPa}] = \frac{N_{crack,i}}{A_{c,i}} \quad (2.2.1.4.1)$$

In which:

- $N_{crack,i}$  [N] is the axial compression load at the formation of the diagonal cracks in the inner horizontal connections, identified on force-displacement curve obtained through the test procedure described in Annex B, Clause B.4;
- $A_{c,i}$  [mm<sup>2</sup>] is the loading application area according to Clause 2.2.1.

Given the total number of executed tests  $n$ , the average value (arithmetic mean) of the shear strength of the inner horizontal connections  $S_{sh,m}$  [MPa] and the standard deviation  $\sigma_{Ssh}$  shall be determined and given in the ETA.

#### 2.2.1.5 Lateral strength

##### Purpose of the assessment

The purpose of the proposed test method is the evaluation of the lateral strength of the seismic resistant shuttering kits under vertical and lateral (in plane) loads.

##### Assessment method

The lateral strength  $F_u$  [kN] shall be obtained through the test procedure listed in Table 2.2.1.2 and described in Annex C.

##### Expression of results

The lateral strength  $F_{u,i}$  of each  $i^{\text{th}}$  tested specimen corresponds to the reaction force at 15% degradation of the maximum lateral load ( $F_{max,i}$ ) on the mean envelope curve obtained during the test according to Annex C.

Given the total number of executed tests  $n$ , the average value (arithmetic mean) of the lateral strength  $F_{u,m}$  [kN] and the standard deviation  $\sigma_{F_u}$  shall be determined and given in the ETA.

#### 2.2.1.6 Elastic and post elastic displacement capacities

##### Purpose of the assessment

The purpose of the proposed test method is the evaluation of the seismic resistant shuttering kits' displacement capacities under vertical and lateral (in plane) loads.

Assessment method

Displacement capacities in both elastic and inelastic field, shall be estimated on the experimental curves obtained from the test procedure listed in Table 2.2.1.2 and described in Annex C.

Expression of results

The elastic displacement capacity  $\delta_{y,i}$  for each  $i^{\text{th}}$  tested specimen corresponds to the horizontal drift at which yielding occurs.  $\delta_{y,i}$  shall be obtained as in the following:

$$\delta_{y,i}[-] = \frac{d_{y,i}}{h_i} \quad (2.2.1.6.1)$$

in which:

- $d_{y,i}$  [mm] is the horizontal displacement at yielding (i.e., corresponding to  $F_{y,i}$  in Figure C.5.1(b));
- $h_i$  [mm] is the specimen height.

Given the total number of executed tests  $n$ , the average value (arithmetic mean) of the elastic displacement capacity  $\delta_{y,m}$  [-] and the standard deviation  $\sigma_{\delta y}$  shall be determined and given in the ETA.

The post elastic displacement  $\delta_{pl,i}$  for each  $i^{\text{th}}$  tested specimen shall be obtained as in the following:

$$\delta_{pl,i}[-] = \frac{d_{u,i} - d_{y,i}}{h_i} \quad (2.2.1.6.2)$$

in which  $d_{u,i}$  is the horizontal displacement recorded during the test when collapse occurs, that is the horizontal displacement which corresponds to the lateral strength  $F_{u,i}$  (Figure C.5.2).

Given the total number of executed tests  $n$ , the average value (arithmetic mean) of the post elastic displacement capacity  $\delta_{pl,m}$  [-] and the standard deviation  $\sigma_{\delta pl}$  shall be determined and given in the ETA.

## 2.2.1.7 Initial stiffness

Purpose of the assessment

The purpose of the proposed test method is the evaluation of the seismic resistant shuttering kits' initial stiffness  $K_{init}$  under vertical and lateral (in plane) loads.

Assessment method

The initial stiffness  $K_{init,i}$  for each  $i^{\text{th}}$  tested specimen shall be estimated on the experimental skeleton curve obtained from the test procedure listed in Table 2.2.1.2 and described in Annex C.

Expression of results

The initial stiffness  $K_{init,i}$  for each  $i^{\text{th}}$  tested specimen corresponds to the slope of the initial branch, up to the cracking point of the skeleton curve as shown in Annex C (Figure C.5.2). It shall be calculated as in the following:

$$K_{init,i}[\text{kN/mm}] = \frac{F_{crack,i}}{d_{crack,i}} \quad (2.2.1.7.1)$$

In which:

- $d_{crack,i}$  [mm] represents the minimum lateral displacement, on the skeleton curve obtained with test procedure described in Annex C (Figure C.5.2), for which cracks occur.  $d_{crack,i}$  shall be assumed as  $d_{crack,i} = d_{crack,s-i}$  or  $d_{crack,i} = d_{crack,f-i}$ , if shear or flexural cracks occur, respectively, for the  $i^{\text{th}}$  specimen.
- $F_{crack,i}$  [kN] represents the lateral force corresponding to  $d_{crack,i}$ , on the skeleton curve obtained with test procedure described in Annex C (Figure C.5.2). Assuming  $F_{crack,s-i}$  as the lateral force corresponding to  $d_{crack,s-i}$  on the skeleton curve in Figure C.5.2 and  $F_{crack,d-i}$  as the lateral force

corresponding to  $d_{\text{crack},f-i}$  on the skeleton curve in Figure C.5.2,  $F_{\text{crack},i}$  shall be assumed as  $F_{\text{crack},i} = F_{\text{crack},s-i}$  or  $F_{\text{crack},i} = F_{\text{crack},f-i}$  when shear or flexural cracks occur, respectively, for the  $i^{\text{th}}$  specimen;

Given the total number of executed tests  $n$ , the average value (arithmetic mean) of the initial stiffness  $K_{\text{init},m}$  [kN/mm] and the standard deviation  $\sigma_{K_{\text{init}}}$  shall be determined and given in the ETA.

#### 2.2.1.8 Stiffness secant to yielding

##### Purpose of the assessment

The purpose of the proposed assessment method is the evaluation of the seismic resistant shuttering kits' secant stiffness to yielding  $K_y$  under vertical and lateral (in plane) loads.

##### Assessment method

The secant stiffness at yielding  $K_{y,i}$  for each  $i^{\text{th}}$  tested specimen shall be estimated on the experimental skeleton curve obtained from the test procedure listed in Table 2.2.1.2 and described in Annex C.

##### Expression of results

The secant stiffness at yielding  $K_{y,i}$  for each  $i^{\text{th}}$  tested specimen corresponds to the slope of the secant at yielding point of the skeleton curve as shown in Annex C (Figure C.5.2).

It shall be calculated as in the following:

$$K_{y,i} [\text{kN} / \text{mm}] = \frac{F_{y,i}}{d_{y,i}} \quad (2.2.1.8.1)$$

In which:

- $F_{y,i}$  [kN] represents the lateral force on the skeleton curve obtained with test procedure described in Annex C, corresponding to the yielding, for the  $i^{\text{th}}$  specimen;
- $d_{y,i}$  [mm] represents the lateral displacement, on the skeleton curve obtained with test procedure described in Annex C, corresponding to the yielding (i.e., corresponding to  $F_{y,i}$ ), for the  $i^{\text{th}}$  specimen.

Given the total number of executed tests  $n$ , the average value (arithmetic mean) of the secant stiffness to yielding  $K_{y,m}$  [kN/mm] and the standard deviation  $\sigma_{K_y}$  shall be determined and given in the ETA.

#### 2.2.1.9 Ductility

##### Purpose of the assessment

The purpose of the proposed assessment is the evaluation of the seismic resistant shuttering kits' behaviour after yielding, under vertical and lateral loads.

##### Assessment method

The local ductility  $\mu_{\text{local},i}$  of each  $i^{\text{th}}$  tested specimen shall be determined on the experimental curves obtained from the test procedure listed in Table 2.2.1.2 and described in Annex C.

##### Expression of results

The local ductility  $\mu_{\text{local},i}$  for the  $i^{\text{th}}$  tested specimen is defined as:

$$\mu_{\text{local},i} [-] = \frac{d_{pl,i}}{d_{y,i}} \quad (2.2.1.9.1)$$

In which:

- $d_{pl,i}$  [mm] is the plastic displacement obtained as  $d_{pl,i} = d_{u,i} - d_{y,i}$ ;

- $d_{u,i}$  [mm] in the collapse displacement obtained from the test procedure listed in Table 2.2.1.2 and described in Annex C (Figure C.5.2);
- $d_{y,i}$  [mm] is the yielding displacement obtained from the test procedure listed in Table 2.2.1.2 and described in Annex C (Figure C.5.1(b) and Figure C.5.2).

Given the total number of executed tests  $n$ , the average value (arithmetic mean) of the local ductility  $\mu_{local,m}$  [-] and the standard deviation  $\sigma_{\mu_{local}}$  shall be determined and given in the ETA.

#### 2.2.1.10 Overstrength ratio

##### Purpose of the assessment

The purpose of the proposed test method is the evaluation of the overstrength ratio  $\rho_{local}$  for the seismic resistant shuttering kits, under vertical and lateral loads.

##### Assessment method

The overstrength ratio  $\rho_{local,i}$  of each  $i^{\text{th}}$  tested specimen shall be determined on the experimental curves obtained from the test procedure listed in Table 2.2.1.2 and described in Annex C.

##### Expression of results

The overstrength ratio  $\rho_{local,i}$  for the  $i^{\text{th}}$  tested specimen is defined as:

$$\rho_{local,i} [-] = \frac{F_{max,i}}{F_{y,i}} \quad (2.2.1.10.1)$$

In which  $F_{max,i}$  [kN] and  $F_{y,i}$  [kN] shall be obtained on the skeleton curve referring to the test procedure listed in Table 2.2.1.2 and described in Annex C (Figure C.5.1(b) and Figure C.5.2).

Given the total number of executed tests  $n$ , the average value (arithmetic mean) of the overstrength ratio  $\rho_{local,m}$  [-] and the standard deviation  $\sigma_{\rho_{local}}$  shall be determined and given in the ETA.

#### 2.2.1.11 Dissipated energy

##### Purpose of the assessment

The purpose of the proposed test method is the evaluation of the dissipated energy  $E_{diss}$ , when the seismic resistant shuttering kits are subjected to vertical and lateral loads.

##### Assessment method

Dissipated energy  $E_{diss,i}$  of each  $i^{\text{th}}$  tested specimen shall be calculated using the experimental curve obtained from the test procedure listed in Table 2.2.1.2 and described in Annex C.

##### Expression of results

The dissipated energy  $E_{diss,i}$  for each  $i^{\text{th}}$  tested specimen shall be calculated using the experimental curve obtained from the test procedure listed in Table 2.2.1.2 and described in Annex C, as specified in Clause C.5.

Given the total number of executed tests  $n$ , the average value (arithmetic mean) of the dissipated energy  $E_{diss,m}$  [kN·mm] and the standard deviation  $\sigma_{E_{diss}}$  [kN·mm] shall be determined and given in the ETA.

#### 2.2.1.12 Damping

##### Purpose of the assessment

The purpose of the proposed test method is the evaluation of the equivalent damping ratio for the seismic resistant shuttering kits.

Assessment method

The equivalent damping ratio is defined with reference to the experimental curve obtained from the test listed in Table 2.2.1.2 and described in Annex C.

Expression of results

Equivalent damping coefficient  $\xi_{eq,i}$  for each  $i^{\text{th}}$  tested specimen shall be calculated according to the Jacobsen model as in the following equation:

$$\xi_{eq,i} = \frac{1}{4\pi} \cdot \frac{E_{diss,i}}{E_{S,i}} \quad (2.2.1.12.1)$$

in which:

- $E_{diss,i}$  [kN·mm] is the dissipated energy (Clause 2.2.1.11 and C.5.1);
- $E_{S,i}$  [kN·mm] is the elastic strain energy (Clause C.5.1).

Given the total number of executed tests  $n$ , the average value (arithmetic mean) of the equivalent damping ratio  $\xi_{eq,m}$  [-] and the standard deviation  $\sigma_{\xi_{eq,m}}$  shall be determined and given in the ETA.

## 2.2.1.13 Strength of T and L connections

Purpose of the assessment

The purpose of the proposed assessment method is the evaluation of the mutual connections' strengths.

Assessment method

The connections' strengths shall be evaluated on the experimental curves obtained from the test procedure listed in Table 2.2.1.2 and described in Annex E.

Expression of results

The connections' strengths shall be expressed in terms of ultimate moment  $M_{u,conn}^{\pm}$  (corresponding to the connection ultimate bending force  $F_{u,conn}$  defined in Clause E.5), obtained for the L or T connection, respectively, as in the following. Positive values of the ultimate moments correspond to clockwise rotations; negative values of the ultimate moments correspond to counter clockwise rotations.

$$M_{u,L}^{\pm} [kN \cdot mm] = \frac{\sqrt{2}}{2} F_{u,conn} \cdot l_{w,L} \quad (2.2.1.13.1)$$

$$M_{u,T}^{\pm} [kN \cdot mm] = F_{u,conn} \cdot l_{w,T} \quad (2.2.1.13.2)$$

in which  $l_{w,L}$  and  $l_{w,T}$  correspond to the wings' dimensions defined in Clause E.3 (Figure E.3.1).

## 2.2.1.14 Strength and displacement capacity of a multi-story structure

Purpose of the assessment

The purpose of the proposed assessment method is the evaluation of the seismic resistant shuttering kits behaviour when assembled in a multi-story structure, under vertical and lateral (horizontal) loads.

Assessment method

The seismic resistant shuttering kits behaviour, when assembled in a multi-story structure, shall be estimated referring to the experimental curves obtained from the test procedure listed in Table 2.2.1.2 and described in Annex D.

Expression of results

The seismic resistant shuttering kits behaviour, when assembled in a multi-story structure, shall be expressed in terms of lateral strength, displacement capacity, ductility and overstrength ratio.

The lateral strength  $F_u^*$  [kN] of the whole structure specimen corresponds to the base reaction force at 15% degradation of the maximum lateral load ( $F_{max}^*$ ) on the global force-displacement curve obtained during the test according to Annex D.

The elastic displacement capacity  $\delta_y^*$  of the whole structure specimen shall be obtained as in the following:

$$\delta_y^*[\text{mm}] = d_y^* \quad (2.2.1.14.1)$$

in which  $d_y^*$  [mm] represents the horizontal displacement at the top floor, in the direction of the applied lateral load, for which yielding occurs (i.e., corresponding to  $F_y^*$  that is the lateral force in the loading point at the top floor corresponding to yielding in the bilinear curve obtained on the global envelope curve, according to Annex D);

The post elastic displacement capacity  $\delta_{pl}^*$  of the whole structure specimen shall be obtained as in the following:

$$\delta_{pl}^*[\text{mm}] = d_{pl}^* \quad (2.2.1.14.2)$$

in which  $d_{pl}^*$  [mm] represents the global post elastic displacement capacity.  $d_{pl}^*$  shall be obtained as in the following:

$$d_{pl}^*[\text{mm}] = d_u^* - d_y^* \quad (2.2.1.14.3)$$

in which  $d_u^*$  [mm] represents the horizontal displacement of the loading point at the top floor, in the direction of the applied lateral load, for which collapse occurs (i.e., when  $F_u^*$  is reached, according to Annex D).

The global ductility  $\mu_{global}$  of the whole structure specimen is defined as:

$$\mu_{global}[-] = \frac{d_{pl}^*}{d_y^*} \quad (2.2.1.14.4)$$

The overstrength ratio  $\rho_{global}$  for the whole structure specimen is defined as:

$$\rho_{global}[-] = \frac{F_{max}^*}{F_y^*} \quad (2.2.1.14.5)$$

In which  $F_{max}^*$  [kN] and  $F_y^*$  [kN] shall be obtained on the global skeleton curve referring to the test procedure listed in Table 2.2.1.2 and described in Annex D.

### 3 ASSESSMENT AND VERIFICATION OF CONSTANCY OF PERFORMANCE

#### 3.1 System(s) of assessment and verification of constancy of performance to be applied

EAD 340309-00-0305 applies.

#### 3.2 Tasks of the manufacturer

EAD 340309-00-0305 applies.

Additional cornerstones of the actions to be undertaken by the manufacturer of the product in the procedure of assessment and verification of constancy of performance are laid down in Table 3.2.1.

**Table 3.2.1 Control plan for the manufacturer; cornerstones**

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
<b>Factory production control (FPC)</b> [including testing of samples taken at the factory in accordance with a prescribed test plan]					
1	<i>Block</i> /Weight	Measurement-scale	Control plan	1	Each week
2	<i>Block concrete</i> /Mix design	Control plan	Control plan	-	Every batch
3	<i>Block</i> /Temperature	Measurement-thermometer	Control plan	All	Every four hours
4	<i>Block</i> /Surfaces in-plane alignment	Visual inspection	Accepted according to the production documentation	All	Each week
5	<i>Block</i> /Mechanical strength	Measurement	Accepted according to the production documentation	1	Each year

#### 3.3 Tasks of the notified body

EAD 340309-00-0305 applies.

## 4 REFERENCE DOCUMENTS

EAD 340309-00-0305 applies.

In addition, the following reference documents shall be considered.

EAD 340309-00-0305	Non load-bearing permanent shuttering kits/systems based on hollow blocks or walls of insulating materials and sometimes concrete
EN 206:2013+A2:2021	Concrete - Specification, performance, production and conformity
ISO 1920-4:2020	Testing of concrete - Part 4: Strength of hardened concrete

## ANNEX A: COMPRESSION TEST

### A.1 Summary of Test Method

This test consists in the application of a monotonic compression load, under displacement control, in the axial or diagonal direction (Figure A.1.1), in quasi-static conditions (i.e., load application rate lower than 0.1 mm/s). Varying the test setup and the specimen characteristics, the test method aims to define the elastic moduli (0, 2.2.1.3), the seismic resistant shuttering kit's centred axial compression (2.2.1.2) and shear strength (2.2.1.3).

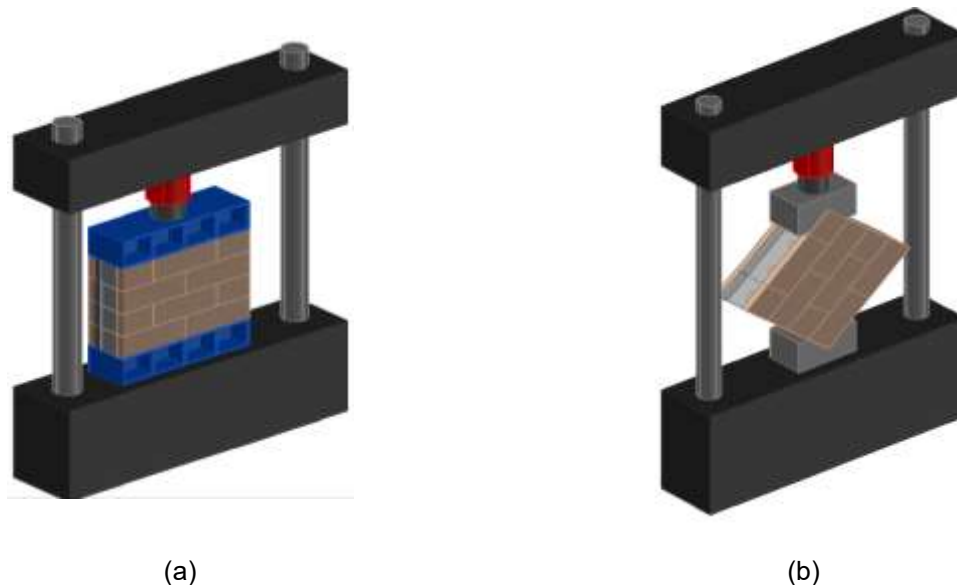


Figure A.1.1 Test setup schemes for (a) axial and (b) diagonal compression

### A.2 Apparatus

The test setup shall allow in-plane vertical displacements and end rotations (double-hinged system) and shall prevent out-of-plane displacements. The monotonic compression shall be uniformly applied on the loading surface. For this reason, actuators shall transfer compression loads to concrete blocks properly connected to the specimen, as described in the following for axial and diagonal compression test.

Centred compression test: all the specimens shall be coupled with upper and lower steel rigid plates or beams to ensure a uniform distribution of the compression stress applied during the test execution; the specimens shall be bedded with rapid setting mortar on the contact surfaces between specimen and steel plates/beams.

Diagonal compression test: the specimen shall be bedded with rapid setting mortar on one corner into a steel or high strength concrete block formed into a 45° vee in the upper and lower surfaces and dimensioned such that the sides of the vee are one tenth of the height of the specimen (i.e., the length of the side). A plumb line and bob shall be used to ensure that the diagonal is exactly vertical in both orthogonal planes. Alternatively, an equivalent block may be cast in place using a high strength polymer concrete and a suitable mould.

The testing machine shall be suitable for use with stiff materials (ISO 1920-4) and shall be regularly calibrated. In particular, the following shall be matched:

- maximum permissible error of repeatability of forces as percentage of nominal force = 1%
- maximum permissible mean error of forces as percentage of nominal force =  $\pm 1\%$
- maximum permissible error of zero force as percentage of maximum range force =  $\pm 0.2\%$

Deformation and displacements shall be monitored by adopting a network of deformation/displacement transducers (linear potentiometers or Linear Variable Displacement Transducers) as shown in Figure A.2.1. All transducers included in the monitoring system shall have an accuracy class equal or lower than 1%.

The applied forces shall be measured by load cells.

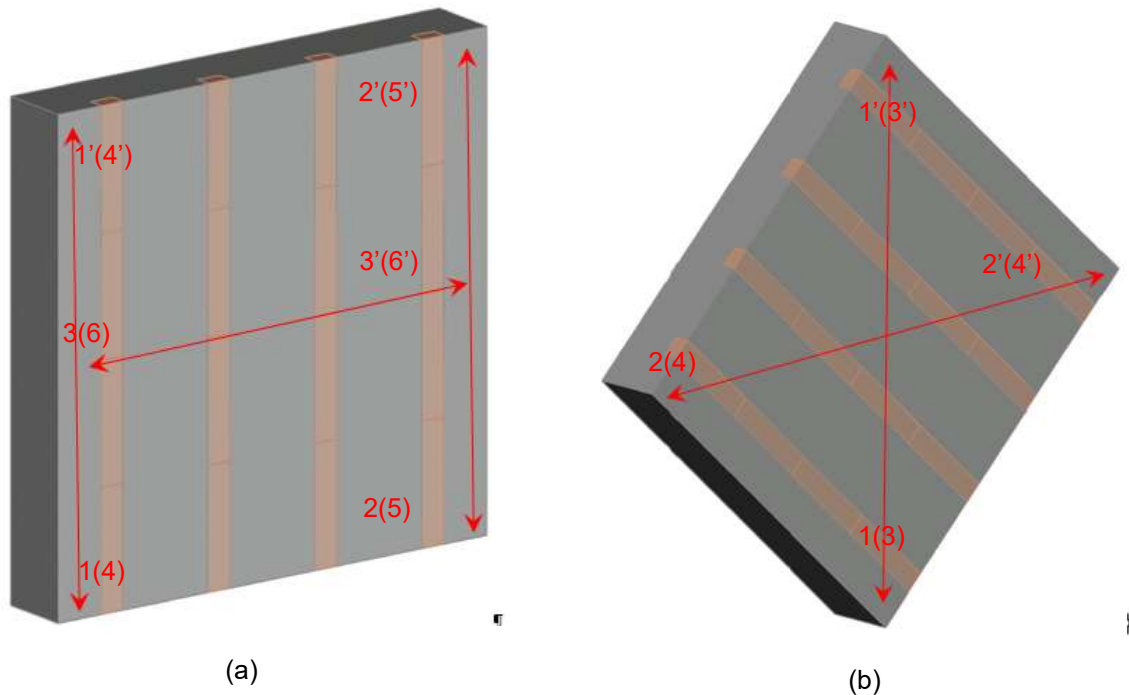


Figure A.2.1 Displacements/deformations positioning scheme to be installed both on front and (back) specimens faces for (a) axial and (b) diagonal compression specimen

### A.3 Test Specimen

The test shall be performed on two specimens of small size walls, at least. Small size walls shall be made by hollow blocks resulting in specimens with the following dimensions, assuming  $t_{cm}$  as a medium value in the range of available product size:

- specimen base  $b = 1.0 \pm 0.01$  m
- specimen height  $h = 1.0 \pm 0.01$  m
- specimen thickness (concrete core depth) =  $t_{cm}$

Longitudinal and transversal reinforcement ( $f_{yk}=430$  MPa) passes through the vertical and horizontal holes ( $\rho_{vert}=\rho_{horiz}=0.15\% A_c$ ), filled by cast-in-situ concrete (C25/30), in order to perform vertical columns and horizontal connections. Insulating material layers can be arranged before concrete filling.

### A.4 Test Procedure

The vertical load shall be applied smoothly and the application rate shall not exceed 0.1 mm/s, as described in the following for centred axial and diagonal compression tests, respectively.

#### A.4.1 Centred Axial Compression Test

An axial compression load  $N$  shall be applied in the loading point which corresponds to the geometric barycentre of the load application area  $A_c$  ( $A_c$  according to Clause 2.2.1) (Figure A.1.1(a)). An initial static load  $N_0$  shall be assumed not lower than  $N_0=0.02A_c f_{ck}$ . The same initial load shall be applied for all the specimens to be tested. Then, at least two loading-unloading cycles shall be performed for a compression load not lower than  $N=0.2A_c f_{ck}$ . Finally, a monotonic load shall be applied until the collapse of the specimen is reached.

#### A.4.2 Diagonal compression test

A diagonal compression load  $P$  shall be applied according to Figure A.1.1(b). The diagonal compression load shall be incrementally applied up to the maximum load, that is the load after which the compression strength decreases. At each step, the compression load shall be increased of 5 kN at most.

Collapse condition corresponds to a decrease of 15% of the maximum compression load.

### A.5 Test Report

As a minimum requirement, the report shall include at least the following information:

#### General

- Description of the specimens in terms of dimensions and used materials (geometry of the used shuttering blocks, arrangement and amount of reinforcement, type of concrete at the age of testing, consistence, maximum aggregate size)
- Description of the test setup (geometry)
- Description of the testing equipment: load cells, displacement transducers, software, hardware, data recording system
- Number of executed tests

#### Measured values

- Parameters of load application (e.g., rate of increase of load or size of load increase steps)
- Cyclic force-displacement curves for each test. The force values correspond to the measured compression load at each loading step. The displacement values correspond to the average value of the measured vertical displacements by multiple measurement lines, at each loading step
- Relevant parameters for the  $i^{\text{th}}$  specimen:

#### *Centred axial compression tests*

- $N_{0i}$  [kN] is the initial axial (compression) force value
- $\Delta_{j,0i}$  [mm] is the initial relative displacement of the  $j^{\text{th}}$  measurement line corresponding to  $N_{0,i}$
- $N_{\max,i}$  [kN] is the maximum axial compression force reached for the  $i^{\text{th}}$  specimen under centred axial compression
- $\Delta_{j,\max,i}$  [mm] is the axial compression (vertical) displacement of the  $j^{\text{th}}$  measurement line, corresponding to  $N_{\max,i}$  during each test

#### *Diagonal compression test*

- $P_{\max,i}$  [kN] is the maximum diagonal (vertical) compression load
- $\Delta V_{j,\max,i}$  [mm] is the diagonal vertical shortening, corresponding to  $P_{\max,i}$ , on the  $j^{\text{th}}$  measurement line
- $\Delta H_{j,\max,i}$  [mm] is the diagonal horizontal extension, corresponding to  $P_{\max,i}$ , on the  $j^{\text{th}}$  measurement line

## ANNEX B: SHEAR TEST

### B.1 Summary of Test Method

This test consists in the application of a monotonic compression load, under displacement control, in the axial direction (Figure B.4.1), in quasi-static conditions (i.e., load application rate lower than 0.1 mm/s). The test aims to the definition of the shear strength of the inner horizontal connections of the walls (2.2.1.4).

### B.2 Apparatus

The test specimen shall be arranged in a double-supported configuration (Figure B.4.1). Increasing of local stresses shall be avoided at the supporting points (e.g., using neoprene pads).

Actuators shall be sized to provide reserve capacity for both force and displacement beyond the maximum anticipated as necessary for the test. Actuator mounting shall be designed in order to create loading in the desired direction only. During the loading cycles, off-axis forces and displacements created by rotations of the actuator or component under test shall be minimized.

The applied centred axial load shall be uniformly distributed on a specimen portion of length equal to 50 cm, through a HEA steel profile.

Horizontal and vertical Linear Variable Displacement Transducers shall be arranged, in order to measure displacements and deformations. A load cell shall be arranged at the application point of the actuator, in order to measure applied force.

### B.3 Test Specimen

The specimen used in the experimental assessment is the wall represented in the following Figure B.4.1. Due to the adopted static scheme, the horizontal connections are subjected to a pure shear. The specimens to be adopted shall have the following dimensions, assuming  $t_{cm}$  as a medium value in the range of available product size:

- specimen base  $b = 1.0 \pm 0.01$  m
- specimen height  $h = 1.0 \pm 0.01$  m
- specimen thickness (concrete core depth) =  $t_{cm}$

Longitudinal and transversal reinforcement ( $f_{yk}=430$  MPa) passes through the vertical and horizontal holes ( $\rho_{vert}=\rho_{horiz}=0.15\% A_c$ ), filled by cast-in-situ concrete (C25/30), in order to perform vertical columns and horizontal connections. Insulating material layers can be arranged before concrete filling.

### B.4 Test Procedure

Force control test is performed in quasi-static conditions. Increasing loading steps are applied up to the failure. One loading-unloading cycle is performed at each step. The maximum load at each step is equal to  $n \cdot N_0$ , considering that  $n$  is the number of the current step and  $N_0$  is the initial static axial load. An initial static axial load  $N_0$  shall be assumed not lower than  $N_0=0.02 A_c f_{ck}$ . The unloading phase ends when the applied external force is equal to zero.

Collapse condition corresponds to a decrease of 15% of the maximum compression load.

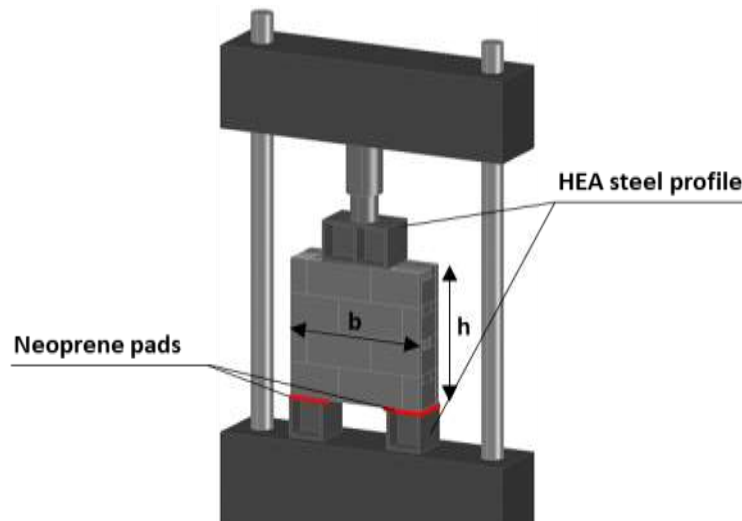


Figure B.4.1 Experimental setup for shear test

## B.5 Test Report

As a minimum requirement, the report shall include at least the following information:

### General

- Description of the specimens in terms of dimensions and used materials (geometry of the used shuttering blocks, arrangement and amount of reinforcement, type of concrete at the age of testing, consistence, maximum aggregate size)
- Description of the test setup (geometry)
- Description of the testing equipment: load cells, displacement transducers, software, hardware, data recording system
- Number of executed tests

### Measured values

- Parameters of load application (e.g., rate of increase of load or size of load increase steps)
- Cyclic force-displacement curves. The force values correspond to the measured axial compression load at each loading step. The displacement values correspond to the measured vertical displacements, at each loading step, averaged on the measurement lines
- Relevant parameters for the  $i^{\text{th}}$  specimen:
  - $N_0$  [kN] is the initial static axial load
  - $N_{\text{crack},i}$  [kN] is the axial load at the formation of the diagonal cracks in the horizontal connections during the test

## **ANNEX C: COMBINED AXIAL AND LATERAL (IN PLANE) LOAD TEST**

### **C.1 Summary of Test Method**

The test consists in the application of combined axial and lateral loads, in quasi-static conditions, on full-scale specimens, with and without openings. The test aims to the definition of the lateral strength (2.2.1.5), lateral stiffness (2.2.1.7, 2.2.1.8), elastic and post elastic displacement capacity (2.2.1.6, 2.2.1.9), and dissipation capacity (2.2.1.10, 2.2.1.11, 2.2.1.12).

### **C.2 Apparatus**

Actuators shall be sized to provide reserve capacity for both force and displacement beyond the maximum anticipated as necessary for the test. Actuator mounting shall be designed in order to create loading in the desired direction only.

The specimens shall be completed with the connection elements to the testing system that shall guarantee the correct application of horizontal and vertical forces eliminating any slipping, off-axis displacements or end rotations. More specifically, the following additional elements shall be provided:

1. Foundation slab at the base of the seismic resistant shuttering kit, which connects the specimen to the laboratory strong floor. The foundation slab shall be fixed with post-tensioned bars, passing through the thickness of the slab. To avoid slipping of the foundation slab with respect to the laboratory strong floor, the total anchoring force shall be at least 10 times the value of the maximum horizontal force applied to the specimen during the test.
2. Top reinforced concrete beam, connecting the top of the seismic resistant shuttering kit to the in plane horizontal hydraulic actuators and to the vertical jacks used to apply vertical forces during the test. It shall guarantee a uniform distribution of the axial load and shall be anchored to the specimen through bars able to transfer the horizontal loads without damage and avoiding slippage.
3. Two self-balanced systems to apply the vertical load, each one of them consisting of a steel transversal beam and a couple of vertical bars connected to the foundation slab through a pair of hooks.

In order to avoid out of plane displacements during the combined application of in plane horizontal and vertical loads, a reaction steel frame shall be adopted (Figure C.2.1): it shall be connected to the laboratory strong floor and it shall be composed by vertical columns and horizontal beams. It shall restrain the specimen in the out-of-plane direction allowing the in-plane displacements through two supporting horizontal beams guiding sliders (2 sliders per side, as reported in Figure C.2.1). PTFE or other low friction material plates shall be mounted on the floor beam to provide a contact friction force lower than 1% with respect to the applied in-plane horizontal load. Preliminary test on sliders shall be performed in order to measure the effective friction force developed during the displacement application.

In order to ensure an accurate control of the test, particularly when approaching the collapse condition, the reaction systems shall provide an adequate stiffness.

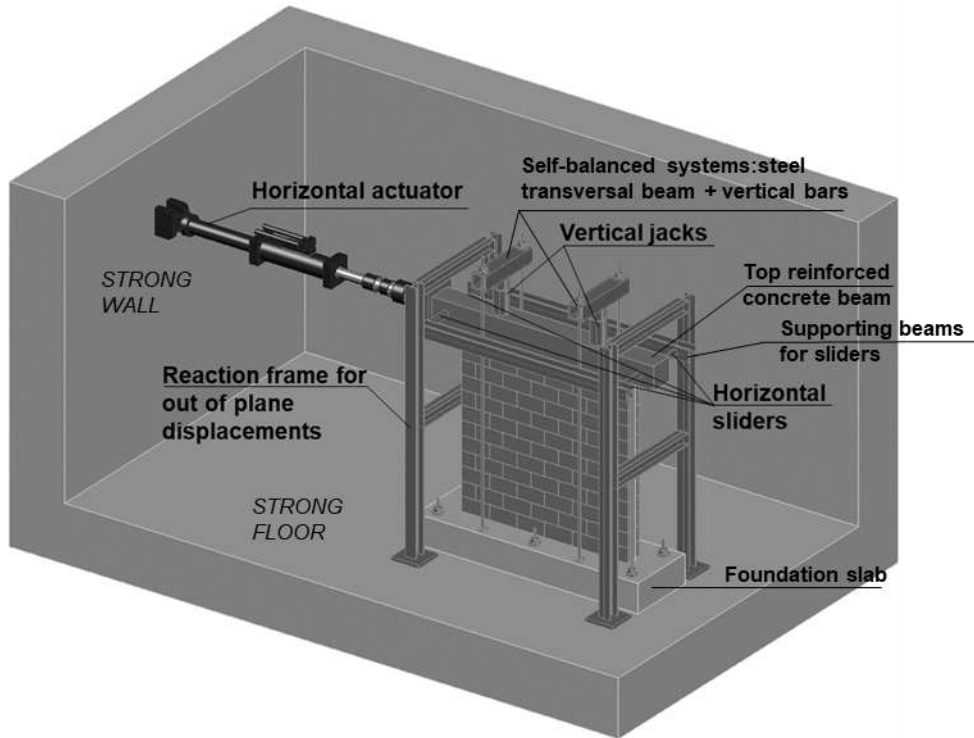


Figure C.2.1 Testing layout of the full-scale specimen

The behaviour of the seismic resistant shuttering kit shall be monitored by using a data acquisition system and a network of transducers capable to capture deformations and displacements correlated to the applied forces.

Deformation and displacements shall be monitored by adopting a network of deformation/displacement transducers (linear potentiometers or Linear Variable Displacement Transducers) as shown in Figure C.2.2. All transducers included in the monitoring system shall have an accuracy class equal or lower than 1%.

The applied forces shall be measured by load cells.

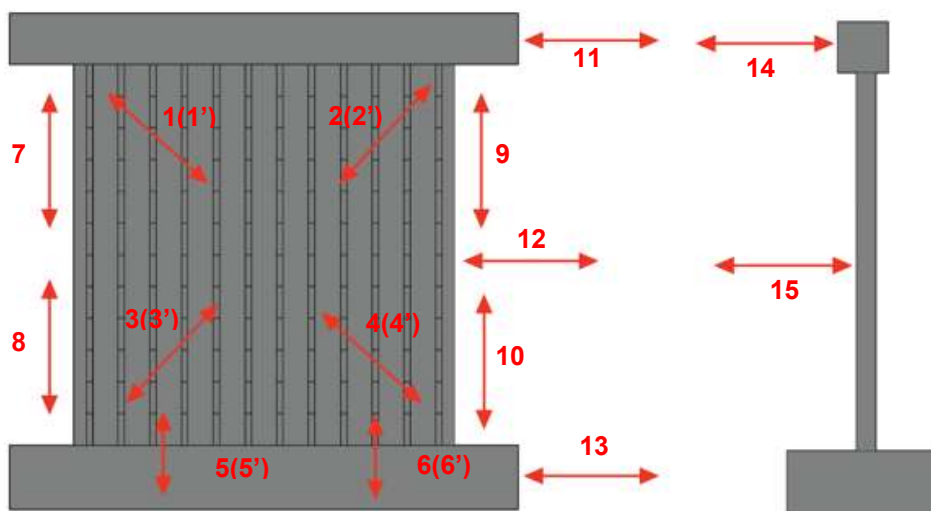


Figure C.2.2 Displacements/deformations transducers positioning scheme on wall specimen without openings

### C.3 Test Specimen

The specimens to be adopted in the experimental assessment shall replicate typical real applications, as indicated in the following assuming  $t_{cm}$  as a medium value in the range of available product size:

1. Wall without openings: wall base =  $3 \pm 0.04$  m, wall height =  $3 \pm 0.04$  m, wall thickness =  $t_{cm}$
2. Wall with door opening: wall base =  $3 \pm 0.04$  m, wall height =  $3 \pm 0.04$  m, wall thickness =  $t_{cm}$ , door base =  $1 \pm 0.01$  m, door height =  $2 \pm 0.02$  m;
3. Wall with window opening: wall base 3 m, wall height 3 m, wall thickness =  $t_{cm}$ , window opening =  $1 \pm 0.01$  m x  $1 \pm 0.01$  m

The door openings shall be positioned in the middle of the wall so that the specimens will satisfy symmetry with respect to its vertical axis. The window openings shall be positioned in the middle of the wall so that the specimens will satisfy symmetry with respect to its vertical and horizontal axis.

Adopted specimens' dimensions shall be reported in ETA.

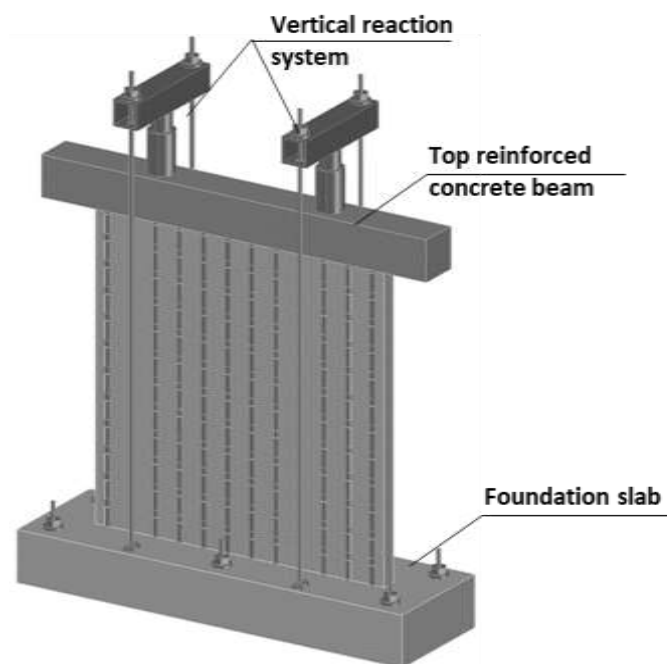


Figure C.3.1 Full-scale specimens of seismic resistant shuttering kit without openings

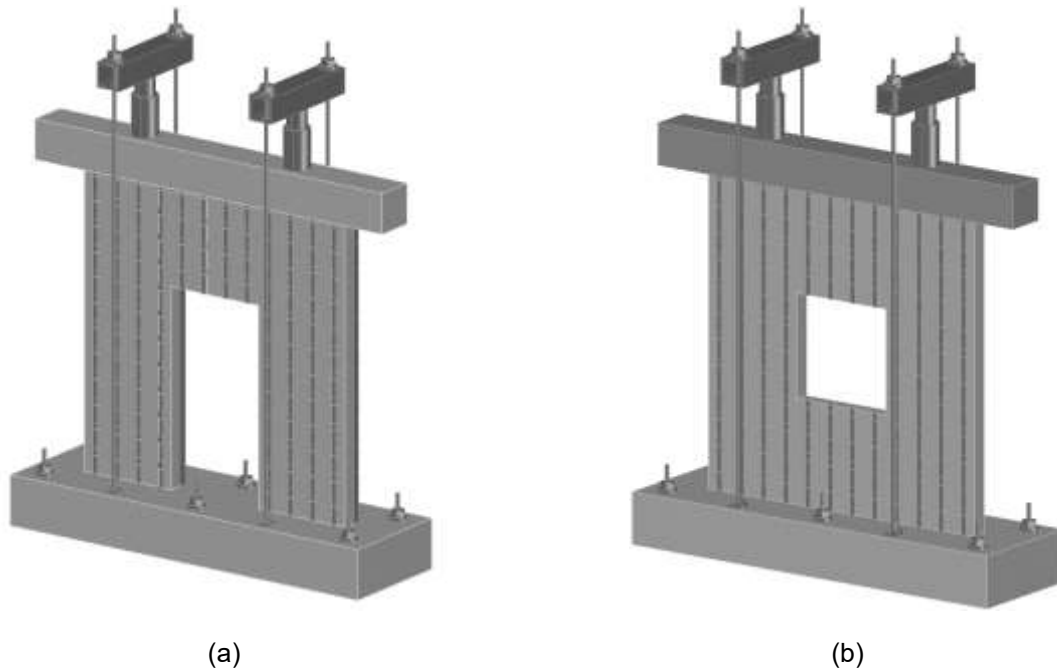


Figure C.3.2 Full-scale specimen of seismic resistant shuttering kit with openings: (a) door; (b) window

#### C.4 Test Procedure

The test protocol consists of slow monotonic application of axial vertical load and of slow cyclic application of lateral force or displacement with a predetermined loading pattern.

The test shall be carried according to the following steps:

1. Application of the vertical load in force control and pseudo-static conditions (i.e., load application rate not exceeding 0.1 kN/s). Pressure drops which may occur, due to settling of the restraining system, shall be compensated by the control system both in the pre-test and test phase. Each test shall be performed for two different axial (vertical) load levels,  $N_1$  and  $N_2$ . The vertical load shall be monotonically applied and shall remain constant during the test. The two axial (vertical) load levels shall be assumed so that:
  - $N_1$  [kN] =  $A_c \cdot f_{ck}$ ;
  - $N_2$  [kN]  $\geq 2N_1$ .
2. Application of the horizontal cyclic loads in displacement control and pseudo-static conditions (i.e., load application rate not exceeding 0.1 mm/s). The horizontal action shall be applied by assuming increasing displacement targets and performing 3 total push-pull cycles for each displacement target. Pushing force/displacement values shall be assumed as positive (+). Pulling force/displacement values shall be assumed as negative (-).

The application of the horizontal cyclic loads consists of two phases:

- 2.a. Pre-damage phase up to the triggering of the yielding deformation of the steel reinforcement. In this phase, the test shall be performed with not less than 3 target displacements including:
  - a target displacement which corresponds to the uncracked behaviour of the specimen ( $d_{t1}$  in Figure C.4.1);
  - a target displacement which corresponds to the theoretical value for the triggering of the permanent damage ( $d_m$  in Figure C.4.1).
- 2.b. Post-damage phase. In this phase, tests shall be performed with no less than 4 target displacements until the collapse condition is reached ( $d_{IN}$  in Figure C.4.1). Collapse corresponds to a degradation of the maximum lateral force equal to 15%.

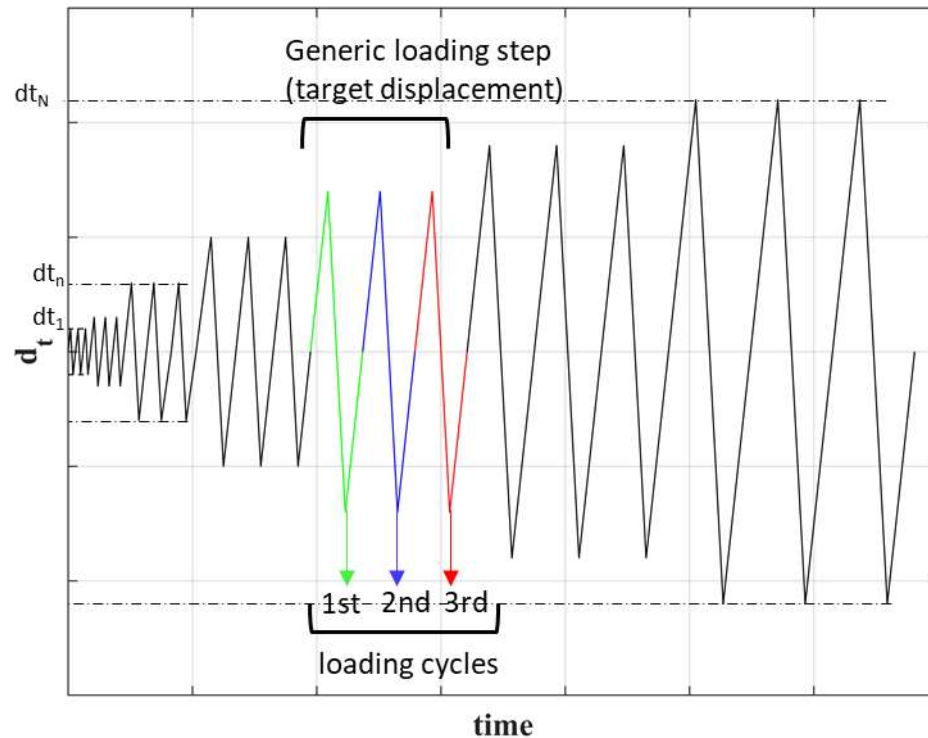


Figure C.4.1 Schematic loading protocol diagram

## C.5 Test Report

As a minimum requirement, the report shall include at least the following information:

### General

- Description of the specimens in terms of dimensions and used materials (geometry of the used shuttering blocks, arrangement and amount of reinforcement, type of concrete at the age of testing, consistence, maximum aggregate size)
- Description of the test setup (geometry)
- Description of the testing equipment: load cells, displacement transducers, software, hardware, data recording system
- Number of executed tests

### Measured values, for each $i^{\text{th}}$ tested specimen

- Parameters of load application (e.g., rate of increase of load or size of load increase steps);
- Cyclic force-displacement curves: force values correspond to the applied in plane lateral loads at each step, displacements correspond to the in plane horizontal displacement recorded at the top of the specimen;
- Area enclosed by the force-displacement curve for each  $c^{\text{th}}$  cycle, at each  $t^{\text{th}}$  displacement target,  $\Omega_{c,t}$ . The area enclosed by each force-displacement curve shall be obtained using the trapezoid rule.
- The mean value of the areas enclosed by the force-displacement curves for the three cycles, at each  $t^{\text{th}}$  displacement target,  $\overline{\Omega}_t$

$$\overline{\Omega}_t = \sum_{c=1}^3 \Omega_{c,t}$$

- Dissipated energy  $E_{diss}$  [kN·mm], obtained as the sum over all the displacement targets of  $\overline{\Omega}_t$ :

$$E_{diss} = \sum_t \overline{\Omega}_t$$

- Envelope curves for each cycle connecting points with maximum forces at each step (Figure C.5.1(a)); mean envelope curve obtained as the mean of the envelope curves for each cycle (Figure C.5.1(b));
- Elastic strain energy  $E_s$  [kN·mm] obtained as:

$$E_s = \frac{F_{final} \cdot d_{final}}{2}$$

In which  $d_{final}$  [mm] is the final point of the mean envelope curve and  $F_{final}$  [kN] is the corresponding force value (Figure C.5.1(b));

- Bilinear curve in which  $F_y = K_{init} d_y$  and  $d_y$  are obtained by equating the area under the mean envelope curve and the area under the bilinear curve.

The area under the mean envelope curve can be obtained by using the trapezoid rule.

The area under the bilinear curve shall be calculated as in the following:

$$A_{bil} = \frac{F_y \cdot d_y}{2} + F_y \cdot (d_u - d_y) = \frac{K_{init} \cdot d_y^2}{2} + K_{init} d_y \cdot (d_u - d_y)$$

Assuming  $K_{init}$  [kN/mm] as the slope of the first branch of the mean envelope curve, as defined in Clause 2.2.1.7;  $d_u$  [mm] as the lateral displacement corresponding to 15% reduction of  $F_{max}$  on the mean envelope curve (Figure C.5.1(b)).

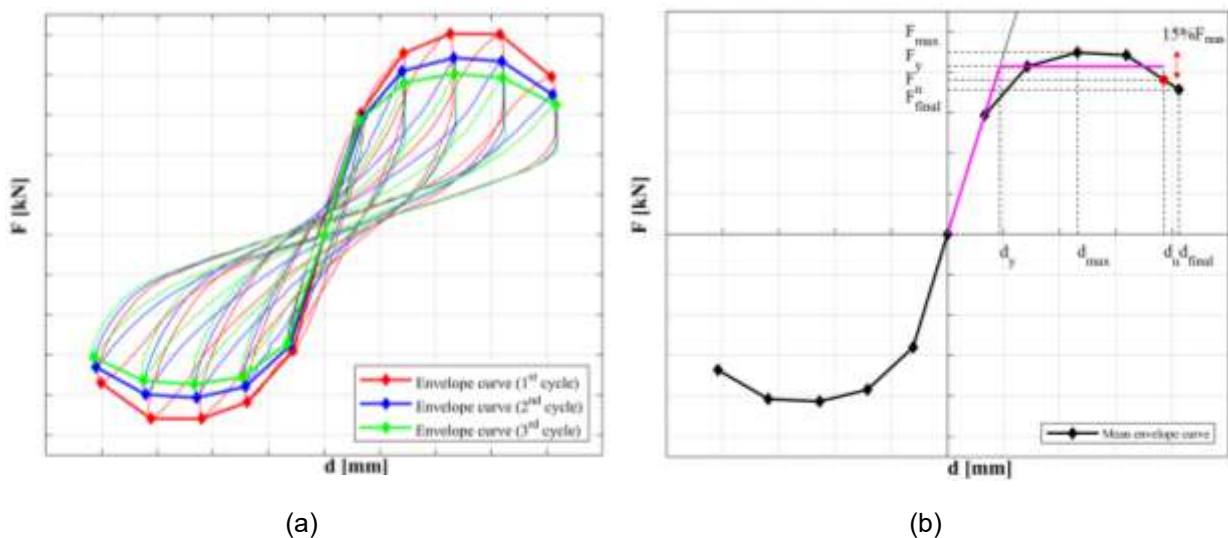


Figure C.5.1. Generic force–displacement curve: (a) cyclic response and envelope curves for each push-pull cycle; (b) mean envelope (black line) and bilinearization (magenta line)

- Skeleton curves with relevant parameters recorded during the test (Figure C.5.2):
  - $F_{crack,s}$  [kN] is the lateral force corresponding to the formation of shear cracks on the mean envelope curve;
  - $d_{crack,s}$  [mm] is the lateral displacement corresponding to  $F_{crack,s}$  on the mean envelope curve;
  - $F_{crack,f}$  [kN] is the lateral force corresponding to the formation of flexural cracks on the mean envelope curve;
  - $d_{crack,f}$  [mm] is the lateral displacement corresponding to  $F_{crack,f}$  on the mean envelope curve;
  - $F_y$  [kN] is the maximum force on the bilinear curve obtained as described above (Figure C.5.1(b));
  - $d_y$  [mm] is the displacement corresponding to  $F_y$ ;
  - $F_{max}$  [kN] is the lateral force corresponding to the capping, i.e., the maximum lateral force on the mean envelope curve;

- $d_{\max}$  [mm] is the lateral displacement corresponding to  $F_{\max}$  on the mean envelope curve;
- $F_u$  [kN] is the lateral force corresponding to a 15% reduction of the  $F_{\max}$  on the mean envelope curve;
- $d_u$  [mm] is the lateral displacement corresponding to  $F_u$  on the mean envelope curve.

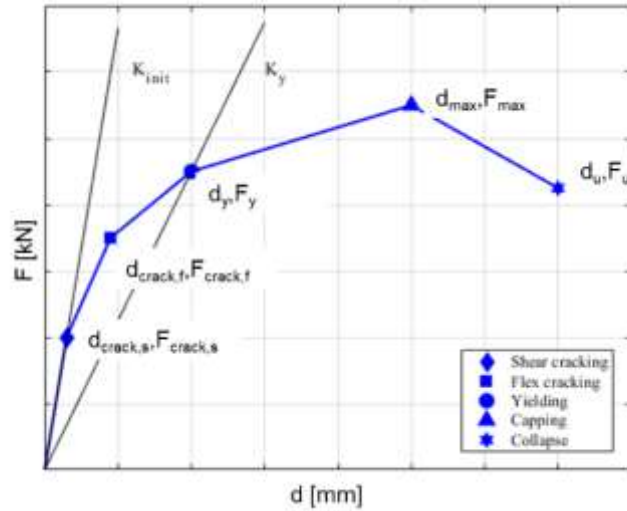


Figure C.5.2 Skeleton curve for each  $i^{\text{th}}$  specimen

## ANNEX D: COMBINED AXIAL AND LATERAL (IN PLANE) LOAD TEST ON A H-SHAPED STRUCTURE

### D.1 Summary of Test Method

The test consists in the application of combined axial and lateral loads, in quasi-static conditions, on a full-scale portion of building. The test aims to assess the global behaviour of a H-shaped structure in terms of lateral strength, lateral stiffness, elastic and post elastic displacement capacity, dissipation capacity (2.2.1.14).

### D.2 Apparatus

Actuators shall be sized to provide reserve capacity for both force and displacement beyond the maximum anticipated as necessary for the test. Actuator mounting shall be designed in order to apply the load in the desired direction only. During the loading cycle, minimize the off-axis forces and displacements created by rotations of the actuator or component under test.

For this aim, the specimen shall be completed with the connection elements to the testing system that shall guarantee the correct application of horizontal and vertical forces eliminating any slipping, off-axis displacements or end rotations. More specifically, the following additional elements shall be provided:

1. Foundation slab at the base of the structure, connecting the sub-structure to the laboratory strong floor. It shall be fixed with pretensioned bars, passing through the thickness of the laboratory strong floor (Figure D.3.1). To avoid slipping of the foundation slab, the total anchoring force shall be at least 10 times of the value of the maximum horizontal force applied to the specimen (base shear) during the test;
2. Reinforced concrete diaphragms, connecting the structural walls at each floor. They are connected to the hydraulic actuators/jacks and allow the application of the horizontal forces during the test. Each diaphragm shall guarantee a uniform distribution of the axial load. The connection between the horizontal reinforced concrete diaphragms and the specimen shall be guaranteed by means of passing reinforcement bars.

The sub-structure behaviour shall be monitored by using a data acquisition system and a network of transducers capable to capture deformations and displacements correlated to the applied forces.

Deformation and displacements shall be monitored by adopting a network of deformation/displacement transducers (linear potentiometers or Linear Variable Displacement Transducers) as shown in Figure D.2.1. All transducers included in the monitoring system shall have an accuracy class equal or lower than 1%.

The longitudinal actuators shall be equipped with a load cell to ensure an accurate measurement of the horizontal forces. Forces may also be measured by using a system of pressure transducers applied to the actuators chambers.

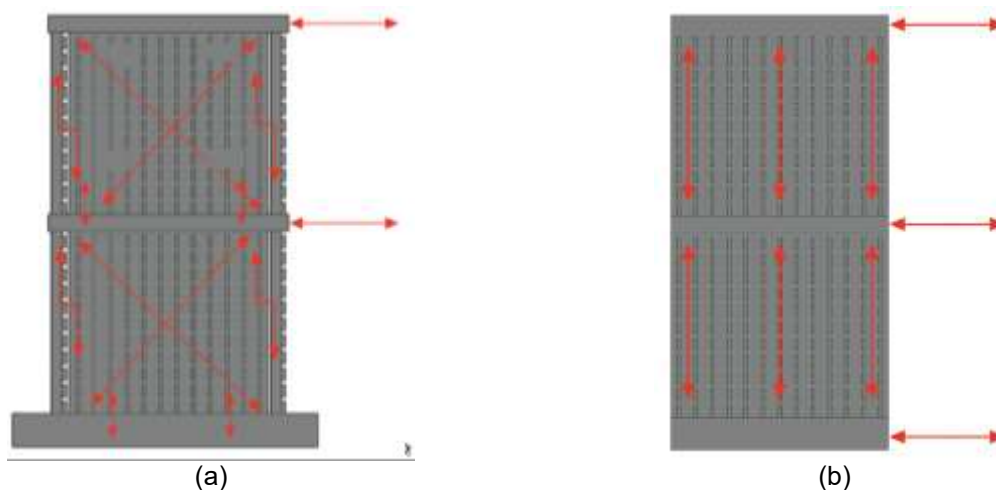


Figure D.2.1: Displacements/deformations transducers positioning scheme on sub-assembly: (a) front view and (b) lateral view

### D.3 Test Specimen

The specimen shall consist of two storeys structure, with a foundation base, two horizontal floors, two external walls and a central wall in order to perform a H-shaped plan. The specimen dimensions to be adopted in the experimental assessment shall replicate typical real applications, as indicated in the following, and shall be reported in ETA:

- 1) 3 walls ( $h=3.0 \pm 0.04$  m;  $t=t_{cm}$ ) for each storey: a wall ( $b=2.75 \pm 0.04$  m) shall be oriented in the direction of the applied horizontal force and two walls ( $b=3.0 \pm 0.04$  m) shall be oriented in orthogonal direction;
- 2) Foundation plate to fix the structure to the laboratory strong floor ( $4.60 \pm 0.04$  m x  $3.25 \pm 0.04$  m x depth  $0.525 \pm 0.01$  m)
- 3) Two horizontal rigid diaphragms ( $3.50 \pm 0.04$  m x  $2.75 \pm 0.04$  m x depth  $0.25 \pm 0.01$  m). The minimum longitudinal upper ( $\rho_{sup}$ ) and lower ( $\rho_{inf}$ ) reinforcement for each horizontal diaphragms, to be arranged in both the horizontal directions, shall be equal to:

$$\rho_{sup} = \rho_{inf} = 0,4\%$$

Assuming:

$\rho_{sup} = \rho_{inf} = A_{s,tot}/A_{cross}$  ;  $A_{s,tot}$  = the total area of the longitudinal bars, in each direction ;  $A_{cross}$  = the reference cross section, in each direction respectively.

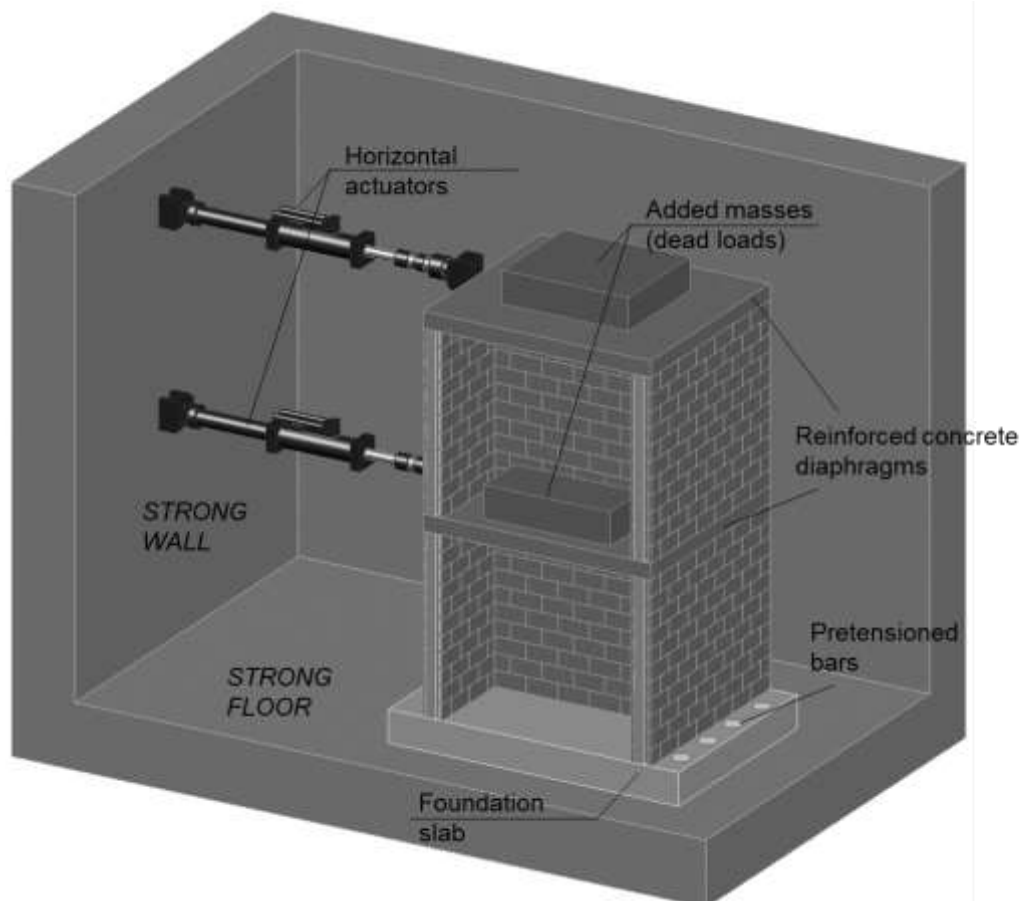


Figure D.3.1 H-shaped sub-assembly

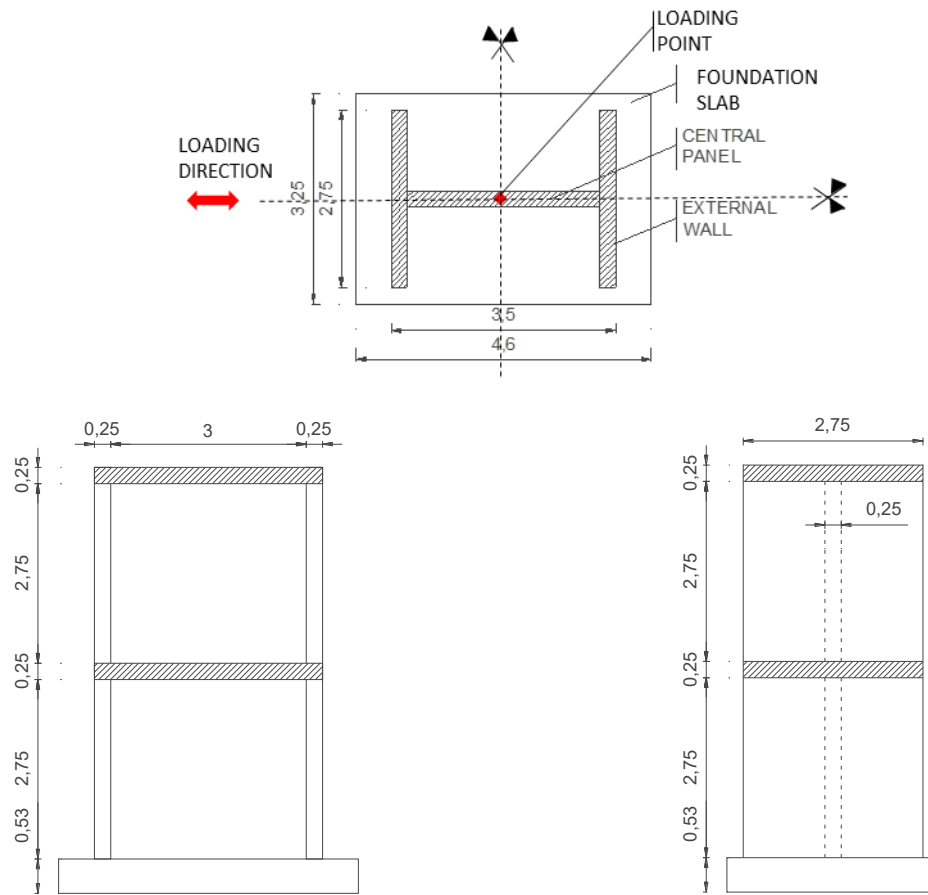


Figure D.3.2 Test setup dimensions

## D.4 Test Procedure

The protocol consists of static application of axial loads and of slow cyclic application of lateral forces or deformations with a predetermined loading pattern.

The test shall be carried according to the following steps:

1. The total vertical load shall be statically applied by adding the masses (concrete or steel blocks) on each horizontal diaphragm. At each floor, an overall vertical load of 100 kN shall be applied and it includes the horizontal slab self-weight.
2. Application of the horizontal cyclic loads through the hydraulic actuators displacement control in pseudo-static condition (i.e., load application rate lower than 0.1 mm/s).

The lateral (horizontal) load shall be applied in the central wall direction: a loading point shall be defined at each floor, corresponding to the geometric barycentre of the horizontal floors (Figure D.3.1), and the loading displacement at the second and first floor shall be defined so that a triangular lateral loading pattern shall result. Steps with increasing applied displacement shall be performed, up to the failure. Three symmetric push-pull cycles for each step are required. Pushing force/displacement values shall be assumed as positive (+). Pulling force/displacement values shall be assumed as negative (-).

The application of the horizontal cyclic loads consists of two phases:

- 2.a. Pre-damage phase up to the triggering of the yielding deformation of the steel reinforcement. In this phase, the test shall be performed with not less than 3 target displacements including:

- a target displacement which corresponds to the uncracked behaviour of the specimen ( $d_{t1}$  in Figure D.4.1);
  - a target displacement which corresponds to the theoretical value for the triggering of the permanent damage ( $d_{tn}$  in Figure D.4.1).
- 2.b. Post-damage phase. In this phase, tests shall be performed with no less than 4 target displacements until the collapse condition is reached ( $d_{tN}$  in Figure D.4.1). Collapse corresponds to a degradation of the maximum lateral force equal to 15%.

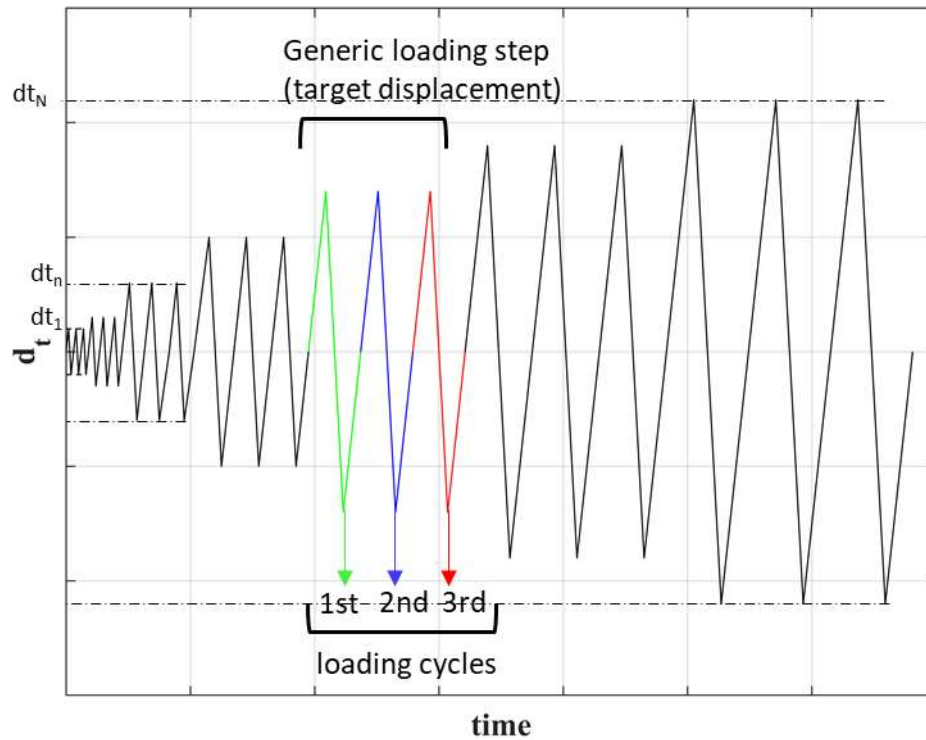


Figure D.4.1 Schematic loading protocol diagram

## D.5 Test Report

As a minimum requirement, the report shall include at least the following information:

### General

- Description of the specimens in terms of dimensions and used materials (geometry of the used shuttering blocks, arrangement and amount of reinforcement, type of concrete at the age of testing, consistence, maximum aggregate size)
- Description of the test setup (geometry)
- Description of the testing equipment: load cells, displacement transducers, software, hardware, data recording system
- Number of executed tests

### Measured values

- Parameters of load application (e.g., rate of increase of load or size of load increase steps)
- Global cyclic force-displacement curves: force values correspond to the base reaction lateral force (i.e., the sum of the applied lateral forces at the two floors, at each time), displacements correspond to the horizontal displacement recorded in the loading point at the top of the structure, in the direction of the applied horizontal loads;

- Envelope curves for each cycle of the global cyclic force-displacement curve, connecting points with maximum forces at each step, global mean envelope curve (Figure D.5.1(b));
- Bilinear curve of the mean envelope curve, in which  $F_y^* = K_{init}^* \cdot d_y^*$  and  $d_y^*$  are obtained by equating the area under the mean envelope curve and the area under the bilinear curve, calculated as in the following:

$$A_{bil}^* = \frac{F_y^* \cdot d_y^*}{2} + F_y^* \cdot (d_u^* - d_y^*) = \frac{K_{init}^* \cdot (d_y^*)^2}{2} + K_{init}^* \cdot d_y^* \cdot (d_u^* - d_y^*)$$

Assuming:

- $K_{init}^*$  as the slope of the first branch of the mean envelope curve (Figure D.5.1(b));
- $d_u^*$  as the lateral displacement corresponding to 15% reduction of  $F_{max}^*$  (Figure D.5.1(b)).

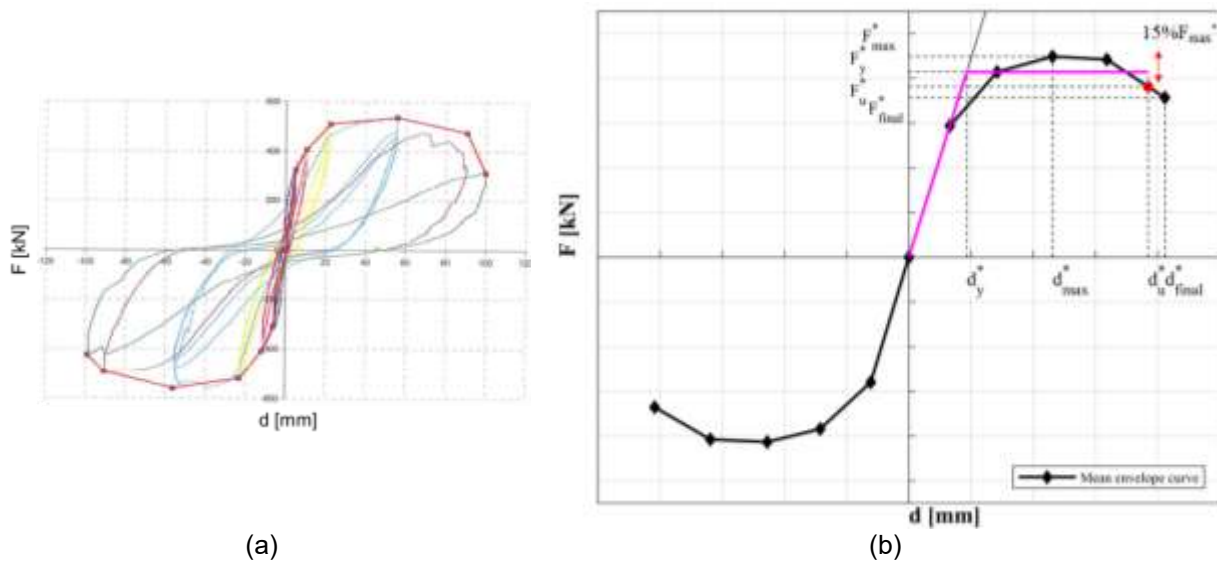


Figure D.5.1. Global force–displacement curve: (a) cyclic response and envelope curve (red line); (b) global mean envelope curve (black line) and bilinearization (magenta line)

- Skeleton curves with global relevant parameters: force values correspond to the base reaction horizontal force, i.e., the sum of the lateral forces applied by the hydraulic actuators at the two floors at each time; displacement values correspond to the horizontal displacement recorded in the loading point at the top of the H-shaped structure, in the loading direction (Figure D.3.2):
  - $F_{crack,s}^*$  [kN] is the force corresponding to the formation of shear cracks, on the global mean envelope curve;
  - $d_{crack,s}^*$  [mm] is the displacement corresponding to  $F_{crack,s}^*$ ;
  - $F_{crack,f}^*$  [kN] is the force corresponding to the formation of flexural cracks, on the global mean envelope curve;
  - $d_{crack,f}^*$  [mm] is the displacement corresponding to  $F_{crack,f}^*$ ;
  - $F_y^*$  [kN] is the force corresponding yielding, on the global mean envelope curve;
  - $d_y^*$  [mm] is the displacement corresponding to  $F_y^*$ ;
  - $F_{max}^*$  [kN] is the force corresponding to the capping, i.e., the maximum force on the global mean envelope curve;
  - $d_{max}^*$  [mm] is the displacement corresponding to  $F_{max}^*$ ;
  - $F_u^*$  [kN] is the force on the global mean envelope curve, corresponding to a 15% reduction of the  $F_{max}^*$ ;
  - $d_u^*$  [mm] is the displacement corresponding to  $F_u^*$ .

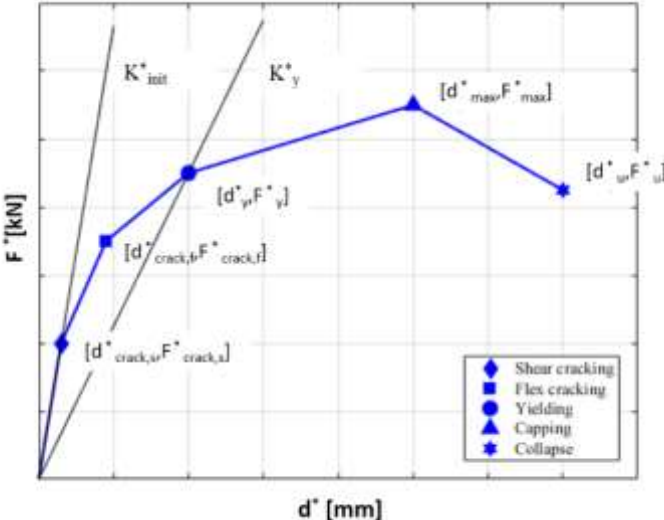


Figure D.5.2 Global skeleton curve

## ANNEX E: BENDING LOAD TEST FOR CONNECTIONS

### E.1 Summary of Test Method

The test aims to describe the structural response of wall-to-wall, wall-to-slab and wall-to-foundation connections.

### E.2 Apparatus

Actuators shall be sized to provide reserve capacity for both force and displacement beyond the maximum anticipated as necessary for the test. Actuator mounting shall be designed in order to apply in the desired direction only. During the loading cycle, the off-axis forces and displacements created by rotations of the actuator or component under test shall be minimized.

The L and T joints behaviour shall be monitored: the applied forces shall be measured by load cells; deformation and displacements shall be monitored by adopting a network of deformation/displacement transducers (linear potentiometers or Linear Variable Displacement Transducers) as shown in Figure E.2.1.

All transducers included in the monitoring system shall have an accuracy class equal or less than 1%.

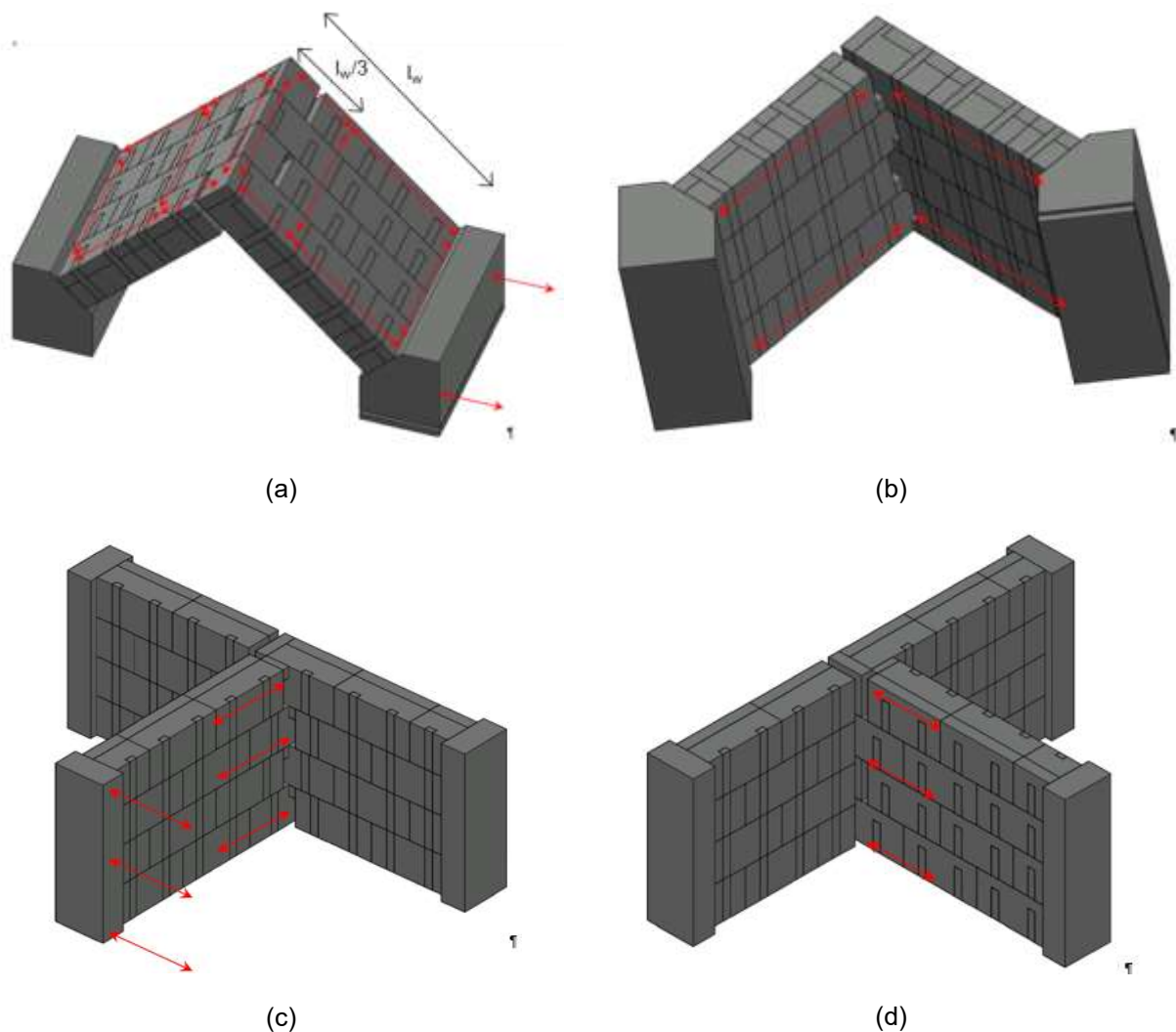
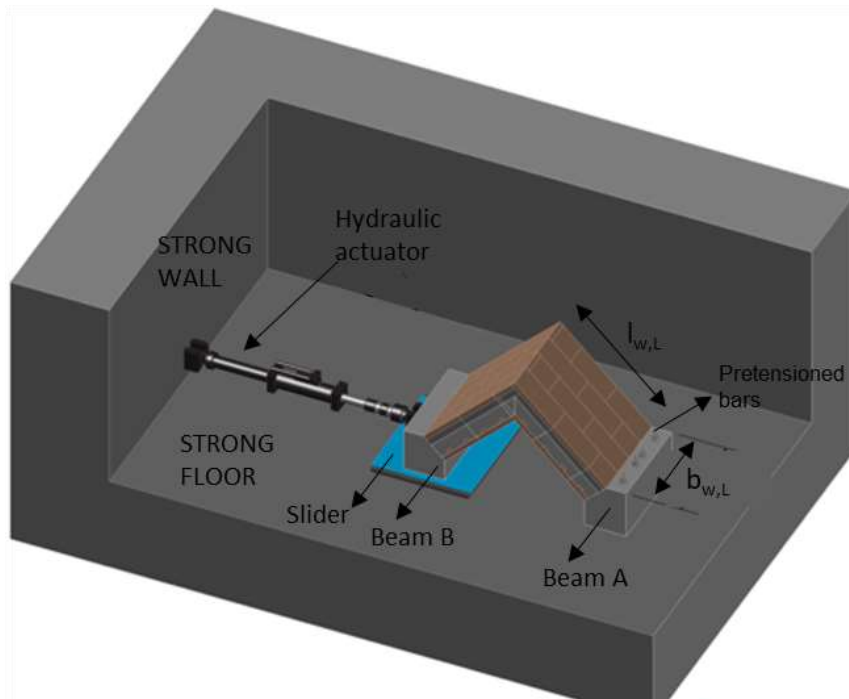


Figure E.2.1 Displacements/Deformations transducers arrangement for L connection (a,b) and T connection (c,d)

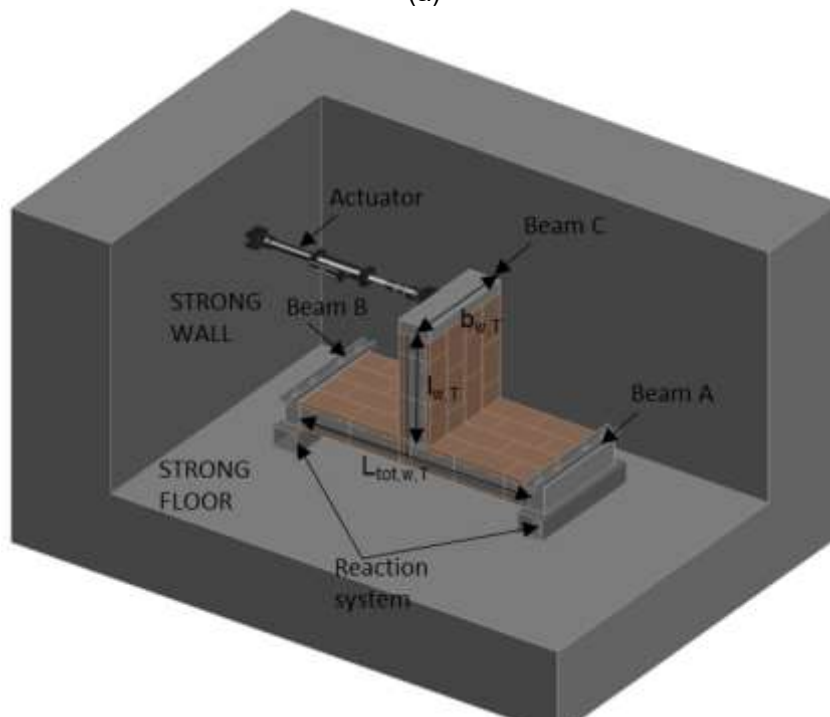
### E.3 Test Specimen

The specimens to be adopted in the experimental assessment shall replicate typical real applications, as indicated in the following:

- 1 wall-to-wall L-shaped joint, wings dimension  $l_{w,L}$  in the range  $1.1-1.2 \pm 0.01$  m, base  $b_{w,L}$   $1 \pm 0.01$  m, thickness of the concrete core equal to  $t_{cm}$ , see Figure E.3.1(a);
- 1 wall-to-wall T-shaped joint, total dimension of wings  $L_{tot,w,T} = 2.3 \text{ m} \pm 0.01$  m, dimension of the wing  $l_{w,T}$  in the range  $1.40-1.60 \pm 0.01$  m, depending on the block thickness adopted in the construction, base  $b_{w,T} = 1 \pm 0.01$  m, thickness of the concrete core equal to  $t_{cm}$ , see Figure E.3.1(b).



(a)



(b)

Figure E.3.1 Test specimens for (a) L-shaped and (b) T-shaped joints

### *L-shaped joint*

The structural joint under test, during the construction phase, shall be completed with additional elements to guarantee the correct application of the loading force. More specifically, the following additional components shall be provided:

- A reinforced concrete beam (beam A in Figure E.3.1(a)) connected to one of the joint wings and used to fix the whole element to the laboratory strong floor. It shall be fixed with pretensioned bars, preferably passing through the thickness of the strong floor. To avoid the slipping of the foundation with respect to the laboratory strong floor, the total anchoring force shall be at least 10 times the value of the maximum horizontal force applied to the specimen during the test;
- An additional reinforced concrete beam (beam B in Figure E.3.1(a)) connected to the second wing of the joint and used to apply the horizontal force by a hydraulic actuator. A low friction slider shall be placed underneath this second beam to allow relative displacements between the two joint wings, generating the bending moment in the connection. A preliminary test of the slider shall be carried out to identify the friction developed during the displacement to accurately measure the force and the bending moment applied to the joint.

### *T-shaped joint*

The structural joint under test, during the construction phase, shall be completed with additional elements to guarantee the correct application of the force. More specifically, the following additional elements shall be provided:

- two reinforced concrete beams on both wings ends (beam A and B in Figure E.3.1(b)). They shall be used to fix the joint wings ends to the reaction system. In order to avoid the slipping of the foundation with respect to the reaction system, the total anchoring force shall be at least 10 times the value of the maximum horizontal force applied to the specimen during the test.
- an additional reinforced concrete beam (beam C in Figure E.3.1(b)) shall be constructed and connected to the web of the joint to allow the application of the horizontal force by using a hydraulic actuator. Sliding elements shall be positioned under the web of the joint in order to allow horizontal sliding.

## **E.4 Test Procedure**

The test consists in the application of lateral loads, in quasi-static conditions, on wall-to-wall, wall-to-slab, wall-to-foundation connections.

The lateral load shall be applied to the connection in a cyclic way, under displacement control, with load application rate lower than 0.1 mm/s. Steps with increasing applied displacement shall be performed, up to the connection failure. Three symmetric push-pull cycles for each step are required.

1. The horizontal cyclic load shall be applied through a hydraulic actuator driven by a valve capable of performing a displacement control in pseudo-static mode. The horizontal action shall be applied by assuming increasing displacement targets and performing 3 total cycles for each selected target.

The application of the horizontal cyclic load shall be divided into two phases:

- 1.a. Pre-damage phase up to the triggering of the yielding deformation of the steel reinforcement. In this phase, the test shall be performed with not less than 3 target displacements including:
  - a target displacement which corresponds to the uncracked behaviour of the specimen ( $d_{t1}$  in Figure E.4.1);
  - a target displacement which corresponds to the theoretical value for the triggering of the permanent damage ( $d_{tn}$  in Figure E.4.1).
- 1.b. Post-damage phase. In this phase, tests shall be performed with no less than 4 target displacements until the collapse condition is reached ( $d_{IN}$  in Figure E.4.1). Collapse corresponds to a degradation of the maximum lateral force equal to 15%.

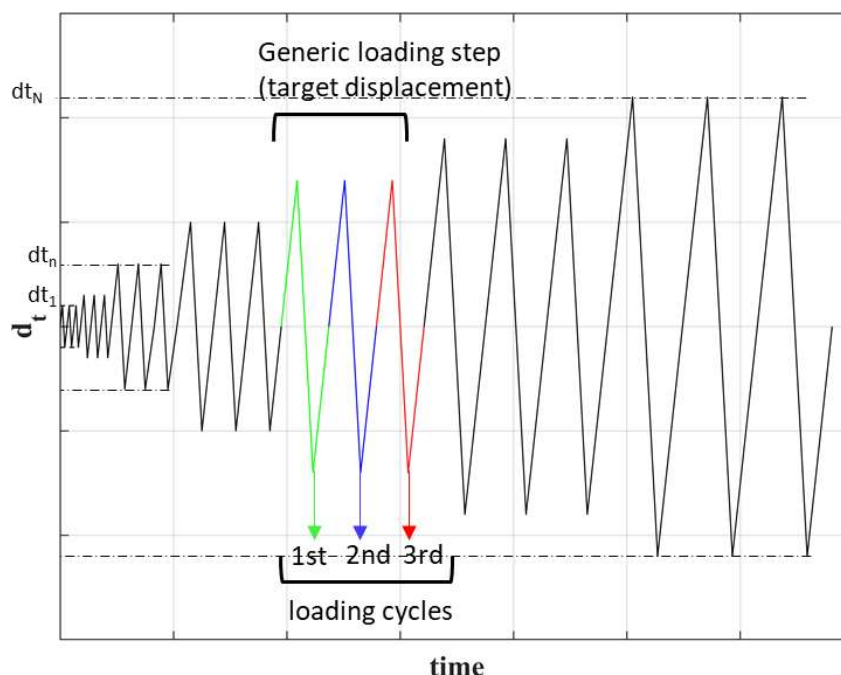


Figure E.4.1 Schematic loading protocol diagram

## E.5 Test Report

As a minimum requirement, the report shall include at least the following information:

### General

- Description of the specimens in terms of dimensions and used materials (geometry of the used shuttering blocks, arrangement and amount of reinforcement, type of concrete at the age of testing, consistence, maximum aggregate size)
- Description of the test setup (geometry)
- Description of the testing equipment: load cells, displacement transducers, software, hardware, data recording system
- Number of executed tests

### Measured values

- Parameters of load application (e.g., rate of increase of load or size of load increase steps)
- Cyclic force-displacement curves: force values correspond to the applied horizontal loads, displacements correspond to the horizontal displacements in the loading point
- Envelope curves for each cycle connecting points with maximum forces at each step, mean envelope curve obtained as the mean of the envelope curves for each cycle
- Skeleton curve, with relevant parameters:
  - $F_{y,conn}$  [kN] is the maximum lateral force on the bilinear curve obtained by equating the area under the mean envelope curve and the area under the bilinear curve (Figure E.5.1(b));
  - $d_{y,conn}$  [mm] is the lateral displacement corresponding to  $F_{y,conn}$ ;
  - $F_{max,conn}$  [kN] is the force corresponding to the capping, i.e., the maximum lateral force reached during the test;
  - $d_{max,conn}$  [mm] is the lateral displacement corresponding to  $F_{max,conn}$ ;
  - $F_{u,conn}$  [kN] is the force corresponding to a 15% reduction of the  $F_{max,conn}$ ;
  - $d_{u,conn}$  [mm] is the lateral displacement corresponding to  $F_{u,conn}$ .

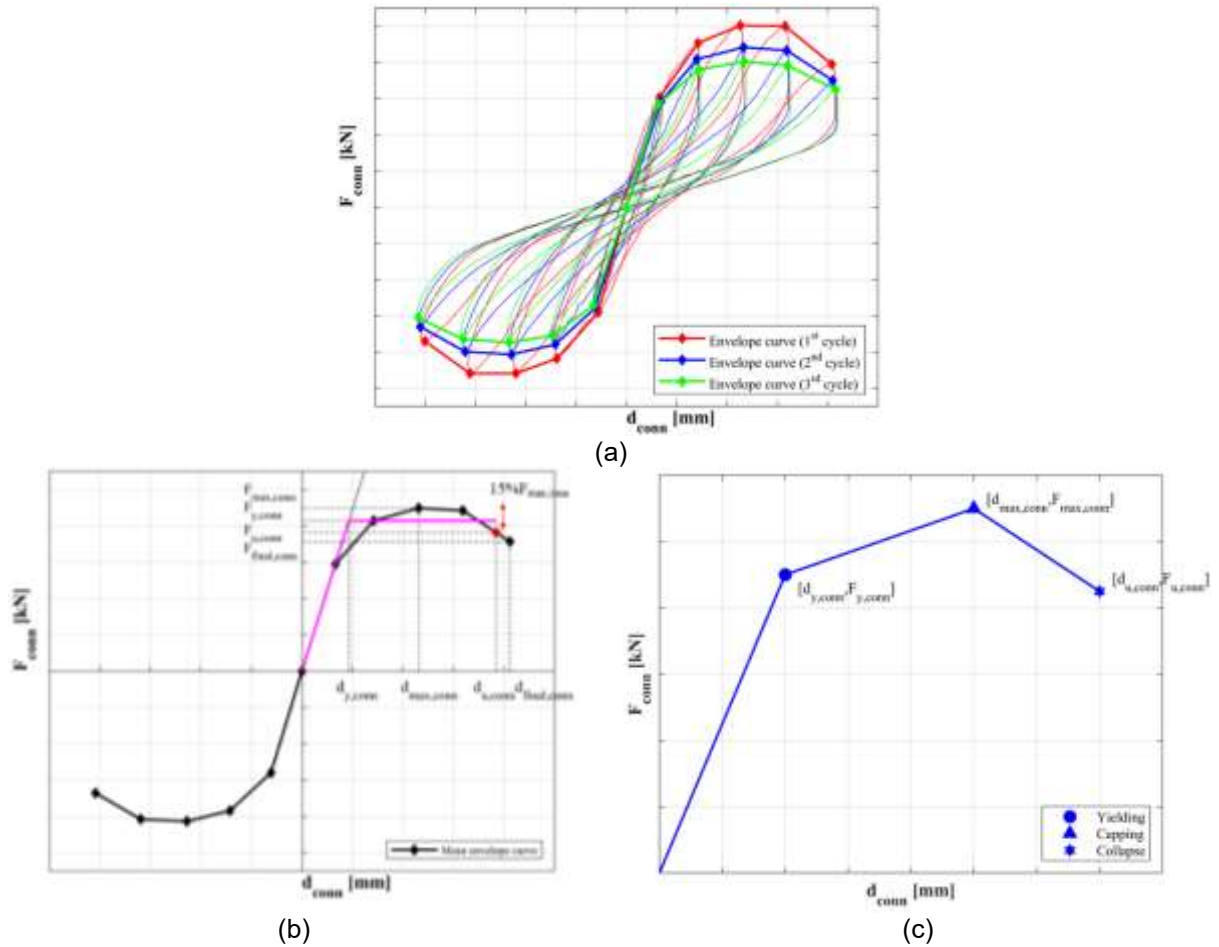


Figure E.5.1. Force–displacement curve of the connection: (a) cyclic response curves for each push-pull cycle; (b) envelope curve (black line) and bilinear curve (magenta line); (c) skeleton curve