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ANALYSIS OF DIFFERENT NUMERICAL MODELLING STRATEGIES OF MULTI-STOREY CLT SHEAR WALLS

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ABSTRACT: CLT platform-type buildings are characterized by a high level of redundancy due to the high number of connections used in the perimeter of the CLT panels. In this regard, in addition to the connections placed at the base of the walls, other structural components including the floor diaphragms and the lintels above the openings, along with their connections, influence the lateral performances of CLT shear walls. In this paper, an extensive analysis on the lateral behaviour of multi-storey CLT shear walls with openings realized with two different construction techniques is conducted. The study compares the results obtained from a simplified modelling strategy commonly used in practical design with more advanced modelling strategies that consider in detail the effects of structural interactions between floors and wall segments and between lintels and wall segments. The results of the elastic analyses conducted in this study showed significant differences in the lateral behaviour of systems analysed with the two modelling strategies, emphasizing that the simplified modelling strategies cannot always be reliable methodologies to describe the lateral behaviour of multi-storey CLT shear walls due to the significant effect of structural interactions provided by floors and lintels.

KEYWORDS: CLT structures, Multi-storey shear walls, Structural interactions, Numerical modelling, Elastic analyses

1 INTRODUCTION

CLT "box-type" buildings, and in particular those erected using the platform construction method, present a high level of structural redundancy due to the numerous connections between external walls, internal partitions and floor diaphragms, see Figure 1. Connections of this type, which are typically neglected in practical design, generate structural interactions that have a significant impact on the lateral performance of CLT shear walls and, as a result, the entire structure subjected to lateral loads.

Typically, in the practical design, the lateral stiffness of a CLT building is calculated based on the shear walls and their individual stiffness in the direction of the horizontal load. However, the high number of connections used in the perimeter of the CLT panels, provide an additional stiffening contribution due to the interaction between floor diaphragms and wall segments and between lintels and wall segments, which modifies the deformation mechanisms of a generic shear wall, see for instance [1–5].

The effects of the interactions between lintels and wall segments also depend on the method used for the construction of the openings, which include opening cut out of the panel or opening realized by assembling different CLT panel elements. In case where the openings are directly cut out of the CLT panel, the structural continuity between lintels and wall segments is ensured and the shear wall behaves as a unique structural element, see Figure 2 (a). On the other hand, in case where the openings are realized by assembling wall segments and lintels through mechanical connections, such as screws or

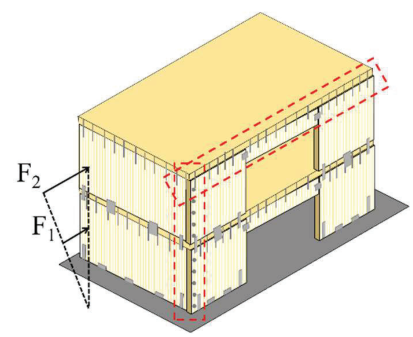

Figure 1: CLT "box-type" building erected using the platform construction method under lateral loads.

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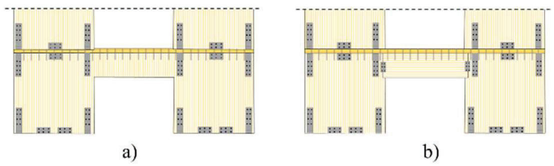

Figure 2: *a)shear wall as monolithic element, b) shear wall with assembled wall segments and lintels.*

metal brackets, a full structural continuity is difficult to achieve and, in this case, the wall segments can be assumed as independent cantilever elements [6], see Figure 2 (b). The lateral performance of CLT buildings realized with these two construction techniques has been the focus of different experimental studies, see for instance [7–9], which showed a different lateral behaviour for multi-storey CLT systems realized with the two construction techniques.

The results of various studies conducted in the literature, [7,10,11], reveal that the lateral behaviour of multi-storey CLT shear walls is influenced by the structural interactions between the wall segments and the surrounding structural elements and the different construction techniques used to realize the openings. Despite these structural interactions have an impact on the lateral behaviour of multi-storey CLT systems, they are often not considered in practical design and in simplified models.

This study investigates in detail the effects of the structural interactions provided by floors and lintels on the lateral behaviour of multi-storey CLT shear walls. The approach used in this study consisted of comparing the results obtained from the elastic analyses of simplified modelling strategies, in which the effects of the structural interactions are not taken into account, with those obtained from more advanced modelling strategies, which consider the structural interactions due to floors and lintels. Results of this numerical study show how the different modelling strategies lead to different lateral performance of the systems, highlighting the need to more carefully consider the different structural elements of CLT systems in the analysis of their lateral behaviour.

2 NUMERICAL STUDY

2.1 MODELLING STRATEGIES

Typically, multi-storey CLT shear walls are modelled by means of a simplified modelling strategy, identified as SM in this study, see Figure 3. In this case, stability for horizontal loads of multi-storey CLT shear walls is provided by wall segments, schematized as cantilever elements. Whereas, lintels are modelled as pinned elements, which connect the wall segments and have the only function of transferring horizontal and vertical loads to the wall segments, and have no ability to transfer moment at their extremities. The lateral stability of the system is ensured by the wall base connections, namely, hold-downs, which are placed at the two extremities of each wall segment, and angle brackets, which are placed along the length of the wall panels.

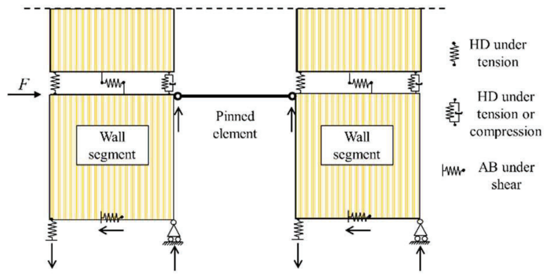

Figure 3: *Simplified modelling strategy of multi-storey CLT shear walls (SM).*

With this modelling strategy, the bending contribution of the floor diaphragms and lintels is neglected, and as a result, no bending moment is transmitted between the wall segments and the lintels, and the system failure occurs in the mechanical anchors placed at the base of the wall segments.

In order to realistically simulate the lateral behaviour of multi-storey CLT shear walls, a more advanced modelling strategy that takes into account the interactions between floor diaphragms and wall segments and between lintels and wall segments is required. In this regard, an advanced modelling strategy that considers these structural interactions (IM) is proposed and applied to the two construction techniques shown in Figure 2, for the case of monolithic (IM-MSW) and assembled (IM-ASW) multi-storey shear walls, see Figure 4 and Figure 5, respectively.

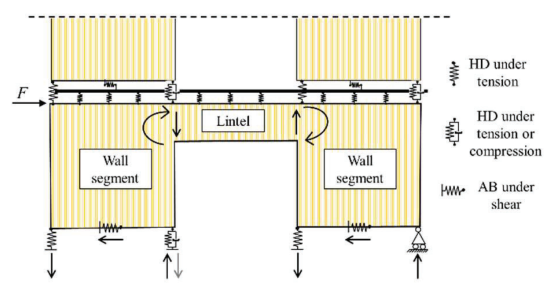

Figure 4: *Advanced modelling strategy with interactions in case of monolithic multi-storey CLT shear walls (IM-MSW).*

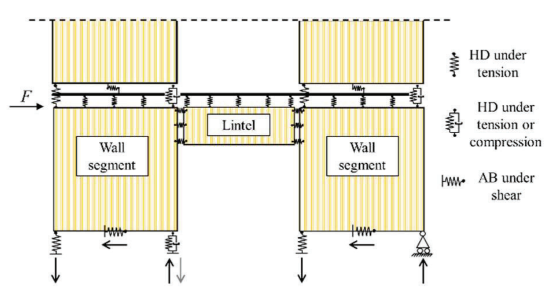

Figure 5: *Advanced modelling strategy with interactions in case of assembled multi-storey CLT shear walls (IM-ASW).*

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When structural interactions are taken into account, higher lateral performance and different lateral deformation mechanisms are expected than the SM strategy, due to the bending contribution of the floor diaphragms and, in case of monolithic walls, also due to the capability of the lintel to transfer bending actions. In case of monolithic shear walls (IM-MSW) the system failure can occur either in the connections at the base of the wall segments or in the corner of the openings in correspondence of the lintel element, depending on the stresses level in this critical zone [7,8,12]. On the other hand, in case of assembled shear walls (IM-ASW), the system failure may occur in the floor panel or in the base connections. In the following, the configurations and the mechanical parameters used for the numerical analysis are presented.

2.2 STRUCTURAL CONFIGURATIONS CONSIDERED IN THE STUDY

In order to investigate the effects of the structural interactions, a numerical analysis was performed considering different multi-storey CLT shear wall systems. An investigation was conducted to analyse the impact of different modelling strategies on two construction techniques involving shear walls. These construction techniques include the creation of shear walls as monolithic elements with openings or as assemblies of different CLT elements with openings. The numerical analysis was developed considering nine different multi-storey CLT shear walls structures consisting of one-, three- and five-storey systems and three different geometries, see Figure 6.

The first geometry, Geometry 1, has one opening of 3 m in length; the second geometry, Geometry 2, has two openings of 1 m in length; while the third geometry, Geometry 3, has three openings of 1 m in length. The height of the wall segments is equal to 3 m for all configurations analysed, while the lintels and the floors are 400 and 200 mm high, respectively. Geometrical dimensions of the three geometries are shown in Figure 7. The numerical study was conducted considering three different thicknesses of CLT wall panels along the height of the structures. The distribution of the different wall panels along the height of the structures is reported in Table 1. Wall panel 1 (WP1) consists of a three-layered

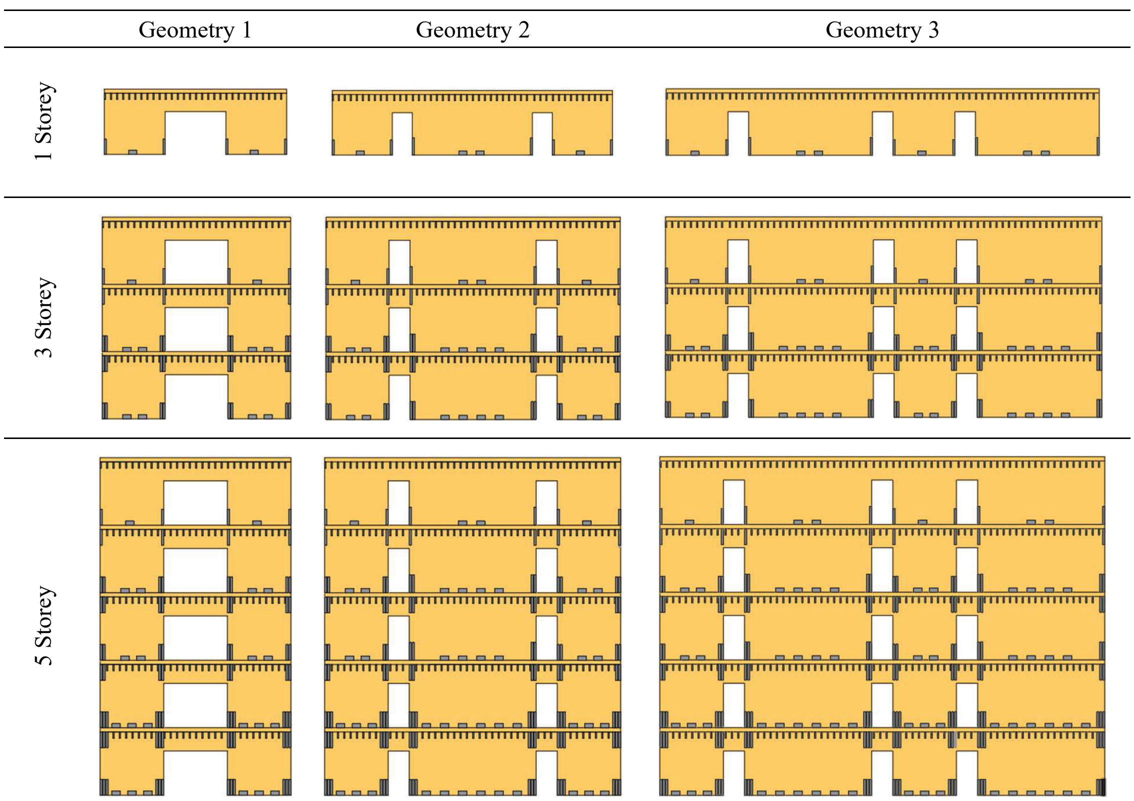

Figure 6: *Multi-storey CLT shear walls configurations and mechanical anchors distribution.*

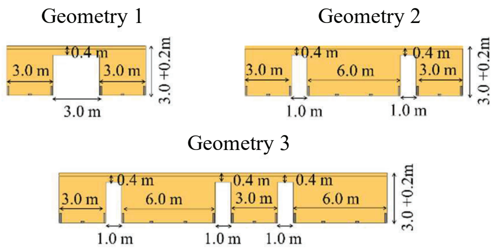

Figure 7: *CLT shear walls geometries and dimensions.*

panel with a thickness of 80 mm and layer thicknesses of **30**-20-**30** mm (in bold the layers of wooden laminated arranged in the vertical direction). Wall panel 2 (WP2) consists of a five-layered panel with a thickness of 120 mm and layer thicknesses of **30**-20-**20**-20-**30** mm. Wall panel 3 (WP3) consists of a five-layered panel with a thickness of 160 mm and layer thicknesses of **40**-20-**40**-20-**40** mm.

Table 1: *Distribution of the CLT panels thicknesses.*

	1 storey	3 storey	5 storey
Fifth storey			WP1
Fourth storey			WP2
Third storey		WP1	WP2
Second storey		WP2	WP3
First storey	WP1	WP2	WP3

A different direction of the external wooden laminates was adopted for the wall segments and the lintels: in case of monolithic shear walls, the orientation of the external wooden laminates of the CLT panels was assumed in the vertical direction for both wall segments and lintels, while in case of assembled shear wall, a vertical orientation was assumed for wall segments and a horizontal orientation for lintels (Figure 2). For all configurations, a floor panel (FP) with a total thickness of 200 mm and five layers with thicknesses of **40**-40-**40**-40-**40** mm, was adopted.
Regarding the elastic properties of CLT panels, the modulus of elasticity parallel to the grain (E_0), the modulus of elasticity perpendicular to the grain (E_{90}), and the shear modulus in the plane (G_0) of the wooden laminates were assumed equal to 11700 MPa, 390 MPa and 730 MPa, respectively.
The values of the elastic stiffness of the base connections, hold-downs and angle brackets, were defined according to the experimental results of Casagrande et al [13]. On the basis of this study, hold-downs (HDs) type WHT440 with thirty 4×60 mm annular ring nails were used and the value of vertical elastic stiffness was set equal to 6.61 kN/mm. Whereas, angle brackets (ABs) type TTF200 with thirty 4×60 mm annular ring nails were used and the value of horizontal elastic stiffness was set equal to 8.94 kN/mm. The distribution of the base connections, hold-downs and angle brackets, of the multi-storey CLT shear walls was determined based on the increase of the shear force from the upper storeys to the foundation, see Figure 6. Mechanical properties of the floor-to-wall connections (f-w) were assigned according to the experimental results of Gavric et al. [14]. Based on this study, the vertical stiffness (withdrawal, w-w_v) and the horizontal stiffness (shear, w-w_h) of one screw was set equal to 4.00 and 1.45 kN/mm, respectively. A spacing of 300 mm was chosen for these connections in all the analyses.
Table 2 summarizes the elastic stiffnesses used in the numerical analyses for one hold-down in the vertical direction, one angle bracket in the horizontal direction, and one floor-to-wall connection in both vertical (v) and horizontal (h) directions.

Table 2: *Stiffness of the connections used for the numerical analyses.*

	K_{el} [kN/mm]
HD	6.61
AB	8.94
w-w_v	4.00
w-w_h	1.45

The values of the elastic stiffness of the base connections, hold-downs and angle brackets, reported in Table 2, were modified to account for the significative influence of the connection properties on the lateral deformation of a CLT shear wall. In this context, the stiffness of each hold-down and angle bracket was multiplied by three different coefficients α equal to 0.5, 1.0, and 1.5, which lead to 3 different arrangements of connection stiffnesses in multi-storey shear walls. Table 3 provides a summary of these arrangements.

Table 3: *Stiffness of connections as function of α.*

	α=0.5	α=1.0	α=1.5
K_{HD} [kN/mm]	3.30	6.61	9.91
K_{AB} [kN/mm]	4.47	8.94	13.41

A vertical load *q* equal to 10 kN/m was applied on each storey of the system, while a triangular distribution of horizontal loads *F* was adopted. The values of the horizontal loads used in each geometry are reported in Table 4.

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__Table 4:__ Horizontal loads F adopted in the numerical analyses.

Storey configuration			N° storeys	Geometry 1	Geometry 2	Geometry 3
			Fifth storey	107.14	166.67	250.00
			Fourth storey	85.71	133.33	200.00
		5	Third storey	64.29	100.00	150.00
	3		Second storey	42.86	66.67	100.00
1			First storey	21.43	33.33	50.00

2.3 NUMERICAL MODELS

The elastic behaviour of multi-storey CLT shear walls with openings was investigated using finite element models (FEM) developed in the software package SAP2000 [15].

To accurately capture the elastic behaviour of wall segments and lintels with varying thicknesses, orthotropic shell elements were adopted in the numerical models. Specifically, the CLT panels were simulated using four-node quadrilateral shell elements with a mesh size of 100×100 mm. The mechanical properties of CLT panels were assigned considering the layered structure of the three different sections, WP1, WP2 and WP3, according to the composite theory of Blaß and Fellmoser [17]. The effective moduli of elasticity in the vertical direction, $E_{eff,v}$, and horizontal direction, $E_{eff,h}$, of the panel were defined according to Equation (1) and Equation (2), where t_v and t_h represent the total thickness of the vertical and horizontal wooden laminates, while t_{CLT} denotes the total thickness of the CLT panel.

$$E_{eff,v} = \frac{E_0 t_v + E_{90} t_h}{t_{CLT}} \tag{1}$$

$$E_{eff,h} = \frac{E_0 t_h + E_{90} t_v}{t_{CLT}} \tag{2}$$

The effective in-plane shear modulus of the wooden laminates, G_{eff}, was defined according to Bogensperger et al. [18], see Equation (3), in which w denotes the width of the wooden boards, t_{mean} represents the mean thickness of the wooden laminates and can be calculated with Equation (4), while α_T can be calculated by using Equation (5).

$$G_{eff} = \frac{G_0}{1 + 6\alpha_T \left(\frac{t_{mean}}{w}\right)^2} \tag{3}$$

$$t_{mean} = \frac{t_{CLT}}{N} \tag{4}$$

$$\alpha_T = p \left(\frac{t_{mean}}{w}\right)^{-0.79} \tag{5}$$

In Equation (4) and Equation (5), N is the number of the section's layers, while p is a parameter equal to 0.535 and 0.425 for three- and five-layered CLT panels, respectively. The elastic properties of the CLT panels adopted for wall segments and lintels are summarized in Table 5.

__Table 5:__ Elastic properties of CLT wall panels.

	$E_{eff,z}$ [MPa]	$E_{eff,x}$ [MPa]	G_{eff} [MPa]
WP1	8872	3217	573
WP2	7930	4160	598
WP3	8872	3217	570

In the following, Figure 8, Figure 9 and Figure 10 illustrate the different modelling strategies employed in this study for the case of Geometry 1 and three-storey. A representation of the simplified modelling strategy of multi-storey CLT shear walls (SM) is shown in Figure 8. The lintels were modelled as pinned beam elements with infinite axial stiffness. In case of the SM strategy, analyses were conducted by applying the horizontal forces F at the top of the wall segments to each storey, while a vertical load q was applied to the first row of shell elements as equivalent load per unit area and as uniformly distributed load on the pinned elements.

A representation of the advanced modelling strategies of multi-storey CLT shear walls in case of monolithic (IM-MSW) and assembled (IM-ASW) systems is shown in Figure 9 (a) and (b), respectively. According to Figure 9 (a), in case of monolithic shear walls analysed with the advanced modelling strategy (IM-MSW), the wall segments and the lintels were modelled as unique shell element with the same orientation of the external wooden laminates (z-direction). Whereas, in case of assembled shear walls (IM-ASW), the wall segments and lintels were modelled as separate shell elements with different orientation of the external wooden laminates (z- and x-direction, respectively). According to Figure 9 (b), wall

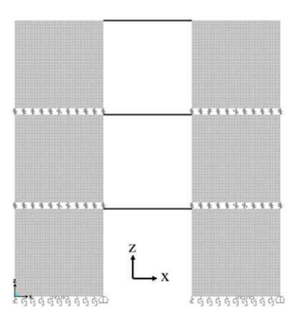

__Figure 8:__ Simplified modelling strategy of multi-storey CLT shear walls (SM).

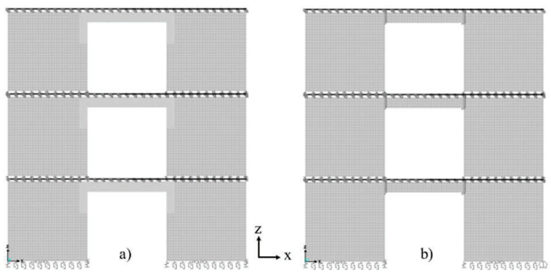

Figure 9: *Advanced modelling strategy with interactions of multi-storey CLT shear walls: a) IM-MSW, b) IM-ASW.*

segments and lintels were connected through the wall-to-lintel connections (w-l). In the modelling strategies with interactions, the floor panels were modelled as beam elements. The assigned bending stiffness, $E_0 I_{eff}$, was determined based on the FP's layered structure outlined in section 2.2, considering only the layers arranged parallelly to the bending stresses. The effective moment of inertia, I_{eff}, was calculated by using Equation (6), where t_i is the thickness of each layer considered in the calculation, a_i is the distance of each layer from the centroid of the section, while b_f represents the floor width. The floor width b_f depends on the effective collaborative section that works in case of internal bending actions, which was calculated using the methodology proposed by Masoudnia et al [19].

$$I_{eff} = \frac{\sum_{i=1}^{n} t_i^3\, b_f}{12} + \sum_{i=1}^{n} t_i b_f a_i^2 \tag{6}$$

In these modelling strategies, the horizontal loads F were applied on the top of the wall segments at each storey and a vertical load q was applied to the first row of shell elements as equivalent load per unit area.

Modelling strategies that consider structural interactions (IM-MSW and IM-ASW) were compared with the SM strategy and another additional numerical model that represents a comparison system, called CS, see Figure 10. The CS strategy takes into account the structural interactions due to floors and walls and considers the same configurations of the multi-storey CLT shear walls without openings. As the SM and CS strategies represent the cases of maximum and minimum lateral flexibility, respectively, the CS can offer valuable information on the lateral behaviour of multi-storey CLT shear walls.

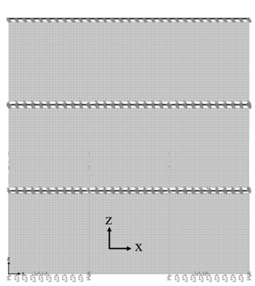

Figure 10: *Advanced modelling strategy with interactions in case of multi-storey CLT shear walls without openings (CS).*

For both modelling strategies SM and IM, multi-linear elastic links were employed to model the connections. In particular, mechanical anchors were modelled by means of one- and two-joint multi-linear elastic links from SAP2000 library. Figure 11 provides the force–displacement curves of the connections adopted in the numerical models for the elastic analyses. According to Polastri et al. [20], the hold-downs (HDs) were modelled with different behaviour for tensile and compressive forces (z-direction): for tensile forces the tensile stiffness of the hold-downs was considered, while for compressive forces the link simulated the contact between panel and foundation through high stiffness, see Figure 11 (a). Angle brackets (ABs) were modelled with symmetric elastic behaviour in the horizontal direction (x-direction), according to Yasumura et al. [8], in order to reproduce the behaviour of the angle brackets for shear loads, see Figure 11 (b). In order to reproduce the contact between the wall segments and the foundation, both the SM and IM modelling strategies utilized gap elements with rigid compression-only behaviour, see Figure 11 (c). Additionally, these gap elements were employed between the wall segments of two consecutive storeys in the SM strategy.

In case of IM strategies, the floor-to-wall connections (f-w) were modelled as a series of two-joint multilinear elastic links from SAP2000 [15] library. These connections were characterized by a symmetric elastic behaviour in the horizontal shear direction (x-direction), Figure 11 (b), while they were modelled with elastic behaviour, for tensile loads, in order to simulate the withdrawal behaviour of the connection, and with a stiff behaviour, for compressive loads, to simulate the contact between floor and wall, see Figure 11 (a). In case of assembled shear wall (IM-ASW) the wall-to-lintel connections (w-l) were modelled as a series of two-joint multi-linear elastic links with rigid compression-only behaviour in the horizontal direction (x-direction), in order to reproduce the contact between wall segments and lintels, neglecting the relative low stiffness contribution of these connections, see Figure 11 (c).

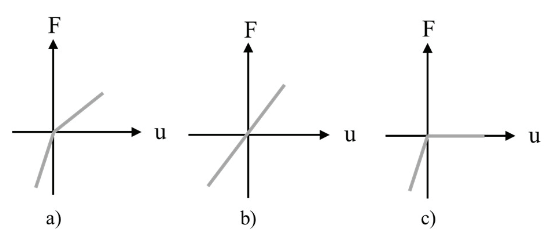

Figure 11: *Force-displacement curves of the connections used in the numerical models: a) HD and f-w in z-direction, b) AB and f-w in x direction, c) GAP in z-direction and w-l in x-direction.*

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3 RESULTS AND DISCUSSION

The results of the elastic analyses in terms of lateral storey displacements, lateral stiffness and deformation mechanisms are presented in this section. Results obtained from the advanced modelling strategy (IM) were compared with those obtained from the simplified modelling strategy (SM) and the comparison system (CS). Figure 12 shows the results in terms of lateral storey displacements of multi-storey CLT shear walls. Each graph reports four curves representing the lateral storey displacement of each structure obtained from the four modelling strategies SM, IM-ASW, IM-MSW and CS. In particular, the lateral storey displacement values are normalized with respect to the lateral storey displacement of the upper storey obtained through the SM strategy.

From Figure 12 it can be observed that the deformed shape of the monolithic (IM-MSW) and assembled shear walls (IM-ASW) modelled with interactions is very close, meaning that the floor alone strongly influences the lateral behaviour of the systems. The largest difference between the deformed shape of the IM-MSW and IM-ASW strategies is reached in case of Geometry 1 and five-storey systems, which is the case of the minimum bending stiffness of lintels and floors and the maximum lateral flexibility of the multi-storey system. In general, it can be observed that the lateral storey displacements decrease when moving from Geometry 1 to Geometry 3. This trend can be attributed to the increase in stiffness of the systems.

The graphs illustrated in Figure 12 indicate that when employing the IM-MSW and IM-ASW modelling strategies, which incorporate structural interactions, the lateral storey displacements are lower compared to those obtained using the SM strategy. In particular, the lateral storey displacements are much closer to those obtained from the CS strategy. According to Figure 12, in case of three-storey systems, the lateral storey displacements obtained from the modelling strategies with interactions of monolithic and assembled shear wall (IM-MSW and IM-ASW, respectively) reach both a maximum of 42% of those obtained from the SM strategy. Whereas, in case of five-storey systems, the lateral storey displacements obtained from the IM-MSW and IM-ASW strategies reach a maximum of 36% and 42% of those obtained from the SM strategy, respectively.

Figure 13 shows the results in terms of normalized lateral stiffness of multi-storey CLT shear walls against the coefficient α used to modify the stiffness of the wall base connections, see Table 3. Each graph shows four curves, representing the lateral stiffness of a multi-storey CLT shear wall modelled with the four modelling strategies (SM, IM-ASW, IM-MSW and CS) and normalized respect to the lateral stiffness obtained from the CS strategy. The lateral stiffness of each system was calculated as the ratio between the base shear and the lateral displacement at the top of the shear wall obtained from the numerical analyses.

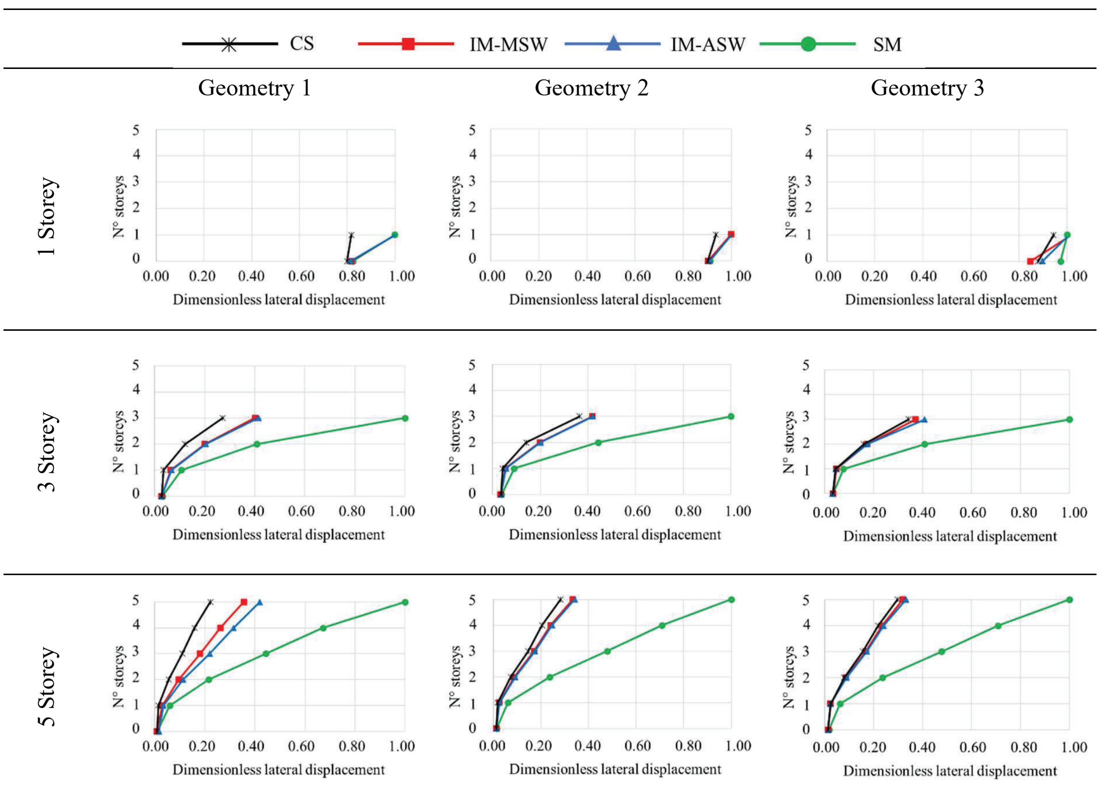

__Figure 12:__ Results in terms of lateral storey displacement.

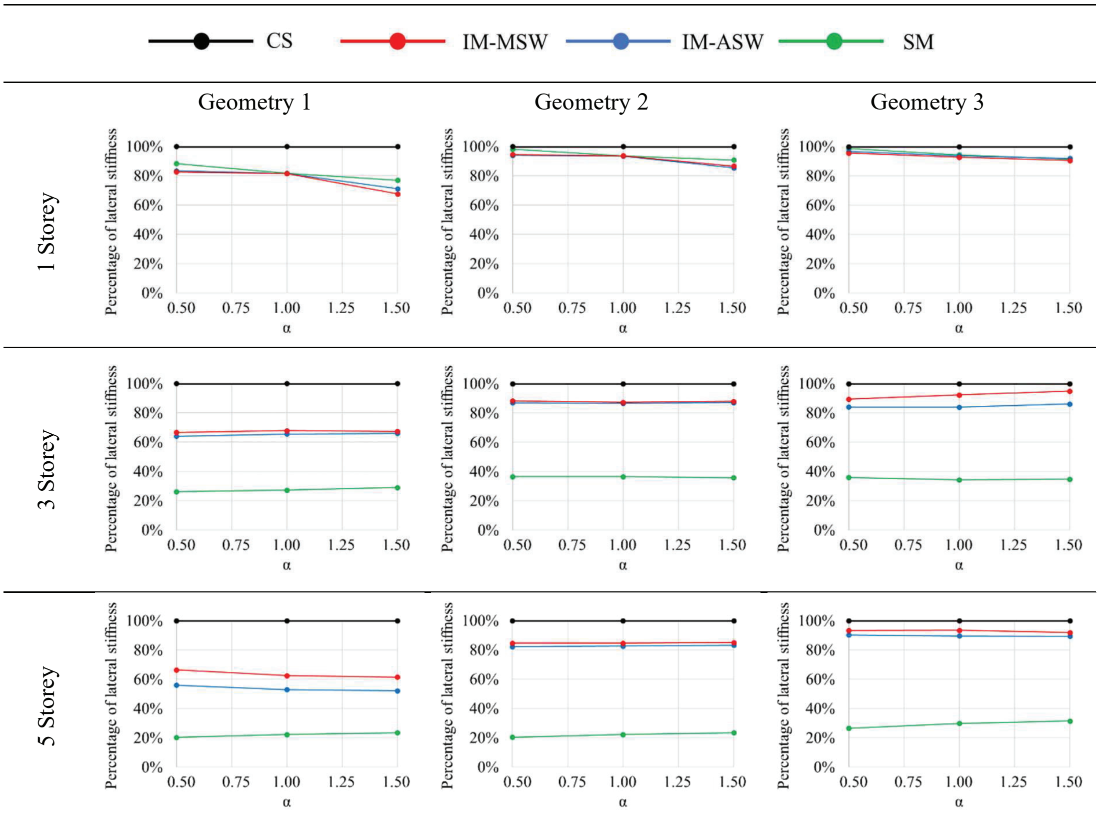

Figure 13: *Results in terms of lateral stiffness.*

The results about the lateral stiffness, depicted in Figure 13, align with those obtained for lateral storey displacements. The findings of Figure 13 demonstrate that IM-MSW and IM-ASW, which incorporate the structural interactions, have lateral stiffness between that of the SM and CS strategies. Specifically, the curves obtained from the monolithic and assembled shear walls (IM-MSW and IM-ASW, respectively) are much closer to those obtained from the comparison system (CS).

According to Figure 13, in case of one-storey systems, the curves representing the lateral stiffnesses lie approximately on the same level of the CS strategy. This is due to the fact that the systems deform with a predominant sliding mechanism and low rocking, generating negligible structural interactions.

Figure 13 shows that the overall lateral stiffness of multi-storey CLT shear walls is similar for both construction techniques depicted in Figure 2 (IM-MSW and IM-ASW). In this regard, the maximum differences between the IM-MSW and IM-ASW strategies are equal to 9%, for Geometry 3 and three-storey, and 11%, for Geometry 1 and five-storey.

Moreover, Figure 13 shows that, in case of Geometry 1, the monolithic and assembled shear walls modelled with interactions (IM-MSW and IM-ASW, respectively) have normalized lateral stiffness values all greater than 60% and 50% for three- and five-storey systems, respectively. However, in case of Geometry 2, these values are greater than 80% for both three- and five-storey systems. Whereas, in case of Geometry 3, the normalized lateral stiffness values are greater than 80% and 90% for three- and five-storey systems, respectively.

Figure 14 shows the structures in the deformed configuration obtained from the four modelling strategies, SM, IM-ASW, IM-MSW and CS, in case of Geometry 1. It can be observed that moving from SM to CS (from left to right of Figure 14), the rocking contribution decreases and the sliding contribution increases, due to the effects of the structural interactions. From Figure 14 it can be observed the significant effect of the interactions due to floors and lintels; in fact, the multi-storey systems with interactions deform similarly to multi-storey systems without openings (CS).

In particular, in case of SM strategy and CS strategy, the predominant deformation mechanisms were rocking and sliding, respectively, while in case of IM-MSW and IM-ASW a combination of sliding and rocking mechanism, with predominant sliding, were performed.

Results obtained from the elastic analyses, show that the interactions between lintels and wall segments and between floors and wall segments strongly influence the deformation mechanism of multi-storey CLT shear wall systems, which is closer to that of multi-storey shear wall systems without openings (CS) rather than that of multi-storey shear wall systems modelled with the SM strategy, in which these interactions are not taken into account.

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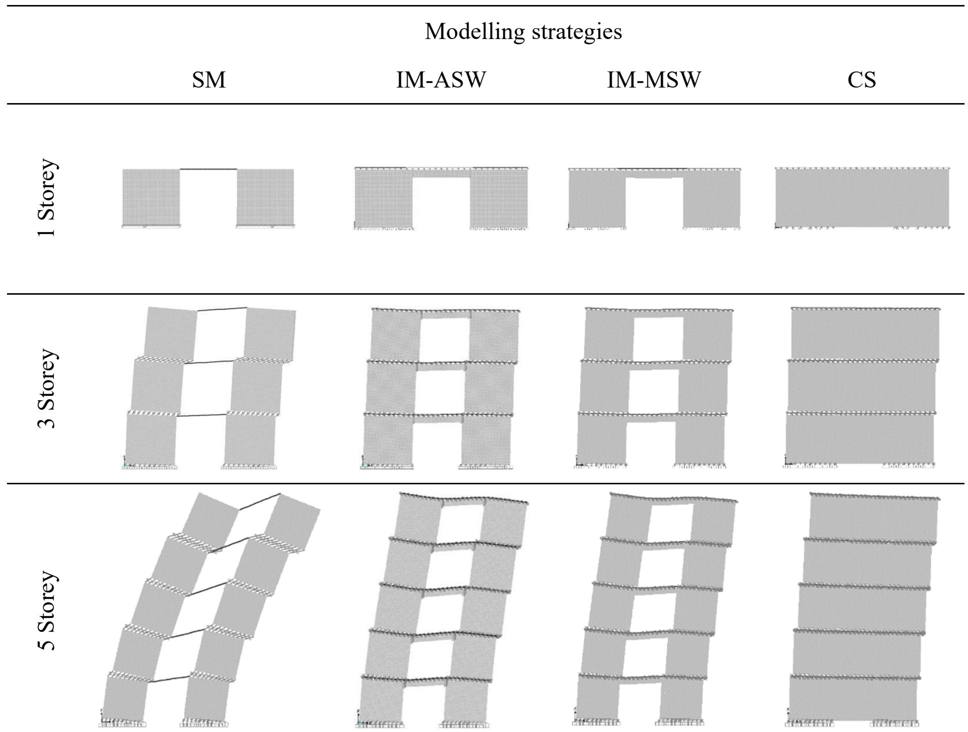

Figure 14: *Deformation mechanisms of the systems in case of Geometry 1.*

4 CONCLUSIONS

This paper presented a numerical study that aims to examine how the lateral behaviour of multi-storey CLT shear wall systems, constructed using monolithic and assembled shear walls, is affected by structural interactions provided by floor diaphragms and lintels. In particular, the effects of the structural interactions were studied by considering both simplified modelling strategy (SM) and more advanced modelling strategies (IM), which consider these structural interactions. The numerical study was conducted considering nine structural configurations, consisting of one-, three- and five-storey systems, and including three multi-storey shear wall geometries and different mechanical properties of the connections placed at the base of the wall segments. The study was conducted by comparing the results, in terms of lateral storey displacements, lateral stiffness and deformation mechanisms, obtained from the advanced modelling strategies with interactions, in case of monolithic and assembled shear walls (IM-MSW and IM-ASW), with those obtained from the SM strategy. Moreover, an additional numerical model representing a comparison system (CS), which considers the same configurations of multi-storey CLT shear walls without openings, was developed only for purpose of comparisons.

Results of the elastic analyses show that the structural interactions due to floors and lintels modify the deformation mechanism of multi-storey CLT systems compared to the cases in which these structural interactions are neglected. In particular, these structural interactions reduce the rocking component of the lateral displacement and increase the overall lateral stiffness of the multi-storey systems, which becomes closer to that that of an equivalent system without openings.

Results of this study show that the simplified modelling strategies, often adopted in the design practice, may not always properly describe the behaviour of the multi-storey CLT shear walls subjected to lateral loads.

As result, this study suggests to take into account the contribution given by lintels and floors in the numerical modelling of multi-storey CLT shear walls, since they significantly modify the lateral performance of the system, which is typically modelled by means of simplified modelling strategy.

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