Journal of Architectural and Planning Research
37:3 (Summer, 2023) 3

INTERACTION-INDUCED LOAD REDISTRIBUTION AND HIERARCHY INVERSION IN ONE-STORY SEGMENTED CLT SHEAR WALLS WITH OPENINGS

Zora Goodwin Jr.

The lateral response of segmented cross-laminated timber (CLT) shear walls with openings is commonly interpreted through global strength and displacement capacity, whereas the more consequential design question is often local: how floor, lintel, and parapet continuity reroutes forces across coupled walls, alters the intended sequence of connector yielding, and shifts the wall mechanism from rocking toward sliding. This study addresses that question through a mechanism-oriented reanalysis of a previously validated numerical database for one-story multi-panel segmented CLT shear walls. The analyzed wall family comprises three wall geometries, two panel aspect ratios, four structural-interaction idealizations, three floor-panel thicknesses, and three wall-to-floor self-tapping screw (STS) spacings. All derived indices were recomputed directly from the reported wall-level capacities, and the summary PNG figures were regenerated from the verified numerical arrays to ensure consistency among text, tables, and graphics. Using the coupled-wall force–displacement responses and panelwise displacement decompositions, three diagnostic indices are applied: a strength amplification ratio, a deformation-retention ratio, and an interaction severity index. The reanalysis shows that floor interaction alone increases strength while largely preserving deformation capacity, but continuity through lintels and parapets produces a markedly different regime characterized by larger strength gains, reduced deformation capacity, earlier STS and bracket participation, stronger right-side force concentration, and local hierarchy inversion in moderate-aspect-ratio wall lines. High-aspect-ratio panels remain more deformation-tolerant and preserve the spline-before-hold-down hierarchy more reliably, although they can still exhibit localized reverse sliding in the first coupled wall when parapet gaps open. Floor-panel bending stiffness has a negligible global effect within the analyzed range, whereas the vertical stiffness of wall-to-floor STS connections is a dominant moderator of both strength gain and deformation penalty. The contribution is therefore a reproducible interaction-focused synthesis, bounded to monotonic envelope response, that clarifies when whole-wall strength gains are accompanied by non-uniform connector demand, hierarchy inversion, and opening-adjacent floor demand concentrations.

© The author(s) 2023. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY 4.0) license (http://creativecommons.org/licenses/by/4.0/).

https://doi.org/10.66033/japr2022-301

INTRODUCTION

Segmented CLT shear walls are attractive lateral-force-resisting systems because they combine robust panel action with ductility concentrated in mechanical connectors. Their global behavior, however, is strongly influenced by interactions with surrounding structural components, particularly floor diaphragms, lintels, parapets, and the associated non-dissipative connections. Prior work has established that floor-to-wall interaction can increase rocking stiffness and alter post-elastic behavior in segmented CLT walls, while lintels and parapets can substantially modify the strength and stiffness of wall lines with openings (D'Arenzo et al., 2021; Khajehpour et al., 2022; Liu et al., 2018; Ruggeri et al., 2023; Tamagnone et al., 2020). Analytical work has also clarified that floor-to-wall interaction and cumulative rotational effects are fundamental to the deformation of platform-type CLT systems (Chen et al., 2012; Lukacs et al., 2019). Yet practical design procedures still idealize many segmented wall lines using kinematic models that distribute force according to the stiffness of the coupled walls while neglecting the redistribution caused by secondary structural continuity (Baldus, 2006; Ding et al., 2022).

The consequence of that simplification is not merely a bias in wall-level strength prediction. Once floors, lintels, and parapets participate, the wall mechanism itself changes. Rocking can be partly suppressed, sliding can intensify, local connector demands can shift between coupled walls, and the intended yielding order may no longer hold uniformly along the wall line. These issues are especially important in segmented walls with openings, where force transfer through lintels and floor strips can produce asymmetric demand patterns not visible in a single global pushover curve.

Recent numerical work on one-story segmented CLT shear walls quantified the global effect of floors, lintels, and parapets on lateral strength, deformation capacity, yielding hierarchy, and failure mode across a family of validated OpenSees models (Baldus, 2006). That study demonstrated large strength increases and corresponding reductions in deformation capacity. It also reported several observations with major design significance: right-side coupled walls attracted a larger share of demand after lintels and parapets were introduced; moderate-aspect-ratio panels became vulnerable to local hierarchy inversion in leftmost coupled walls; floor demand peaks occurred above panel interfaces and around openings; and reverse sliding could occur in the first coupled wall when parapet gaps opened (Baldus, 2006). Those observations are important, but they remain distributed across wall-level, coupled-wall, and panelwise outputs and therefore are not yet organized into a compact framework for mechanism-oriented interpretation.

The present study fills that gap by reframing the same validated wall archetypes around a different research question: *when and why do secondary structural elements induce load redistribution, hierarchy inversion, and mechanism concentration in segmented CLT wall lines with openings?* The contribution is intentionally bounded. It does not claim a new experimental campaign or a new finite-element formulation. Instead, it (i) formalizes three transparent diagnostic indices for comparing strength gain against deformation retention, (ii) numerically cross-checks the reported database for internal consistency, and (iii) converts coupled-wall and panelwise responses into an interaction-aware interpretation of redistribution, hierarchy vulnerability, and local mechanism concentration. Framed this way, the paper strengthens motivation and practical interpretability while keeping all conclusions within the validation envelope of the underlying source models.

Four research questions guide the paper:

RQ1: How strongly do floors, lintels, and parapets amplify lateral strength relative to the accompanying loss or retention of deformation capacity?

RQ2: Under which wall configurations does structural continuity lead to asymmetric coupled-wall participation and hierarchy inversion?

RQ3: How do panel aspect ratio and wall-to-floor connection stiffness moderate the transition from rocking-dominated to sliding-dominated response?

RQ4: Which design checks should be prioritized when the wall line includes floor, lintel, and parapet continuity?

Answering these questions is valuable for both research and practice. For research, it clarifies the mechanism by which secondary elements re-route forces inside segmented wall lines. For practice, it highlights when a global wall-level design model is inadequate and which local checks should be introduced for reliable detailing.

WALL ARCHETYPES AND REANALYSIS FRAMEWORK

Underlying validated wall family

The analyzed database is based on a previously validated family of one-story segmented CLT shear wall archetypes developed in OpenSees (Baldus, 2006). The wall family includes three geometries with increasing numbers of coupled walls and openings, two panel aspect ratios, and four numerical idealizations of structural interaction. The underlying numerical models were calibrated using connection tests and wall tests on customized self-tapping-screw (STS) systems, with SAWS constitutive laws used for the nonlinear connectors (Cao et al., 2020; Folz & Filiatrault, 2001; Gavrić et al., 2015). The source study validated the baseline wall model against cyclic wall tests and then used the resulting wall family for monotonic pushover analyses (Baldus, 2006). That validated model family provides the basis for the present mechanism-oriented reanalysis. Because the strongest direct experimental support in the source work concerns the connector constitutive laws and the baseline wall response, the present manuscript treats Models II–IV as calibrated interaction cases within that validated framework rather than as independently tested specimens.

Table 1 summarizes the wall family considered here. Geometry 1 contains two coupled walls and one opening; Geometry 2 contains three coupled walls and two openings; Geometry 3 contains four coupled walls and three openings. In all cases, wall height is 3.2 m, panel thickness is 175 mm, and the wall panels are arranged with either a moderate aspect ratio (2:1) or a high aspect ratio (4:1). Floors were considered with thicknesses of 175 mm, 245 mm and 315 mm, and the vertical stiffness of wall-to-floor connections above was varied through STS spacing values of 50 mm, 100 mm and 200 mm. The four structural-interaction models are as follows (Baldus, 2006):

- *Model I*: wall panels and base connections only, with a rigid-diaphragm constraint;
- *Model II*: explicit floor diaphragm and wall-to-floor connections, but no lintels or parapets;
- *Model III*: Model II plus CLT lintels;
- *Model IV*: Model III plus CLT parapets.

Table 1: Analyzed wall family and principal variables.

Item	*Description*
Wall geometries	Geometry 1: two coupled walls and one opening; Geometry 2: three coupled walls and two openings; Geometry 3: four coupled walls and three openings
Wall height	3.2 m
Panel aspect ratios	Moderate (2:1) and high (4:1)
Wall panel thickness	175 mm five-layer CLT
Floor thicknesses	175 mm, 245 mm and 315 mm CLT
Wall-to-floor STS spacing	50 mm, 100 mm and 200 mm
Model I	Wall panels and base connections only; rigid floor diaphragm idealization
Model II	Model I plus explicit floor diaphragm and wall-to-floor connections
Model III	Model II plus CLT lintels
Model IV	Model III plus CLT parapets
Primary response data used here	Wall-level peak strength and deformation capacity; coupled-wall pushover responses; yielding/failure sequence; panelwise displacement contributions at peak strength

Mechanism-oriented response quantities

The original wall dataset reports global lateral strength F_u, deformation capacity δ_u, coupled-wall force–displacement curves, and the decomposition of wall displacement into sliding and rocking components. Following the source study, wall displacement is interpreted as

$$\delta_f = \delta_{s,f-w} + \delta_{r,w} + \delta_{s,w-b}, \tag{1}$$

where $\delta_{s,f-w}$ is horizontal sliding between the floor and wall, $\delta_{r,w}$ is the displacement due to rocking of the wall panel, and $\delta_{s,w-b}$ is horizontal sliding between the wall and the base (Baldus, 2006).

To reorganize the wall-level results around mechanism distortion rather than global capacity alone, three derived indices are introduced:

$$\Lambda_F^{(m)} = \frac{F_u^{(m)}}{F_u^{(\mathrm{I})}}, \tag{2}$$

$$\Lambda_\delta^{(m)} = \frac{\delta_u^{(m)}}{\delta_u^{(\mathrm{I})}}, \tag{3}$$

$$\Psi^{(m)} = \frac{\Lambda_F^{(m)}}{\Lambda_\delta^{(m)}}, \tag{4}$$

where superscript (m) denotes Models II–IV and Model I is the baseline for the same geometry and aspect ratio. Λ_F measures strength amplification, Λ_δ measures deformation retention, and Ψ is an *interaction severity index*. A value of $\Psi > 1$ indicates that the strength gain outpaces deformation retention; larger values identify stronger interaction-induced mechanism distortion. The indices are used here as diagnostic comparison tools rather than as stand-alone acceptance limits.

In addition to these continuous metrics, a qualitative *hierarchy vulnerability* classification is used for each model/aspect-ratio family:

- *Low*: spline-before-hold-down yielding maintained in all coupled walls;
- *Moderate*: local deviation from the intended sequence in at least one coupled wall;
- *High*: local deviation plus evidence of marked force redistribution and/or reverse sliding.

Scope and reproducibility

The present paper does not alter the validated constitutive assumptions of the underlying numerical wall family. Instead, it reinterprets the published wall responses through the indices in Eqs. (2)–(4), together with the coupled-wall and panelwise response information reported for the same archetypes. In the revised manuscript, all tabulated capacities, ratios, averages, and normalized quantities were recomputed directly from the reported numerical values before finalizing the text, and the PNG figures were regenerated from those verified arrays rather than redrawn from previously exported graphics. This check confirmed consistency between Tables 2, 3, and 5 and removed rounding drift between prose, tables, and figures. Reproducibility therefore rests on the already documented archetype set, connection properties, and parametric ranges reported in the source work (Baldus, 2006), while the interpretive conclusions in the present paper remain explicitly bounded to that monotonic, previously calibrated database.

RESULTS

Global interaction trade-off: strength gain versus deformation loss

Table 2 lists the reported wall-level peak strengths and deformation capacities for the 175 mm floor-thickness cases across the three geometries and two aspect-ratio families. The derived indices in Eqs. (2)–(4) reveal a clear progression from benign floor interaction to severe mechanism distortion once lintels and parapets are introduced. All plotted coordinates in Figure 1 were regenerated from the same verified values to ensure exact consistency, up to displayed rounding, with the tabulated ratios.

Table 2: Wall-level peak strength F_u and deformation capacity δ_u for the principal wall set (175 mm floor thickness).

Model	*Response*	*Moderate aspect ratio*			*High aspect ratio*		
		G1	G2	G3	G1	G2	G3
I	F_u (kN)	292	434	600	292	451	569
I	δ_u (mm)	112	113	114	144	143	143
II	F_u (kN)	481	693	924	397	592	745
II	δ_u (mm)	119	120	123	149	149	149
III	F_u (kN)	640	991	1378	533	822	1149
III	δ_u (mm)	120	92	88	150	120	126
IV	F_u (kN)	633	1005	1485	597	968	1361
IV	δ_u (mm)	72	80	80	139	116	115

Figure 1 shows the global interaction trade-off for all wall archetypes. Two distinct regimes emerge. In the first regime, represented by Model II, floor interaction increases strength while largely preserving deformation capacity. Averaged across the three geometries, Model II increases strength by about 59.5% for moderate panels and 32.7% for high-aspect-ratio panels, while deformation retention remains above unity in both cases (Table 3). In the second regime, represented by Models III and IV, continuity through lintels and parapets produces much larger strength amplification together with a clear loss of deformation capacity. For moderate panels, the mean interaction severity index rises from 1.49 in Model II to 2.61 in Model III and 3.39 in Model IV. For high-aspect-ratio panels, the increase is more moderate but still substantial, from 1.28 to 2.07 and 2.58, respectively.

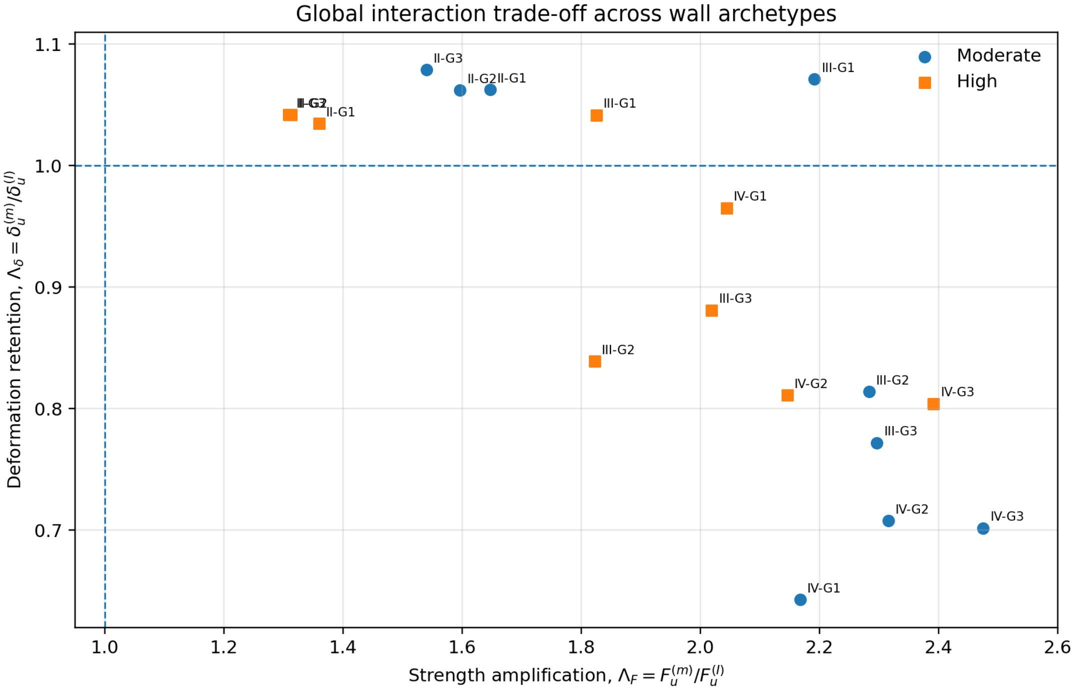

Figure 1: Strength amplification versus deformation retention for the analyzed wall archetypes. Points farther to the right and lower on the plot represent stronger interaction-induced mechanism distortion.

The most severe case in the database is Geometry 3 with moderate panels and Model IV, where the wall strength rises from 600 kN to 1485 kN ($\Lambda_F = 2.48$) while deformation capacity drops from 114 mm to 80 mm ($\Lambda_\delta = 0.70$), giving $\Psi = 3.53$. By contrast, Geometry 3 with high panels and Model II displays a much milder shift: strength rises from 569 kN to 745 kN ($\Lambda_F = 1.31$) and deformation capacity increases slightly from 143 mm to 149 mm ($\Lambda_\delta = 1.04$), yielding $\Psi = 1.26$. This contrast indicates that the inclusion of floors alone does not necessarily distort the mechanism severely; the strongest mechanism distortion occurs when floor interaction is coupled with lintel and parapet continuity.

Table 3: Average derived metrics by model family and aspect ratio.

Model	*Aspect ratio*	$\overline{\Lambda_F}$	$\overline{\Lambda_\delta}$	$\overline{\Psi}$
II	Moderate	1.595	1.068	1.494
II	High	1.327	1.040	1.277
III	Moderate	2.257	0.886	2.609
III	High	1.889	0.921	2.072
IV	Moderate	2.319	0.684	3.390
IV	High	2.194	0.860	2.579

Figure 2 makes the escalation especially clear. The transition from Model II to Model III is already large, but Model IV systematically pushes the wall family into the highest-severity regime. For design purposes, this means that the global strength benefit of parapet and lintel continuity should not be interpreted as an unqualified improvement: it is coupled to a more abrupt mechanism transition and a more demanding local force path.

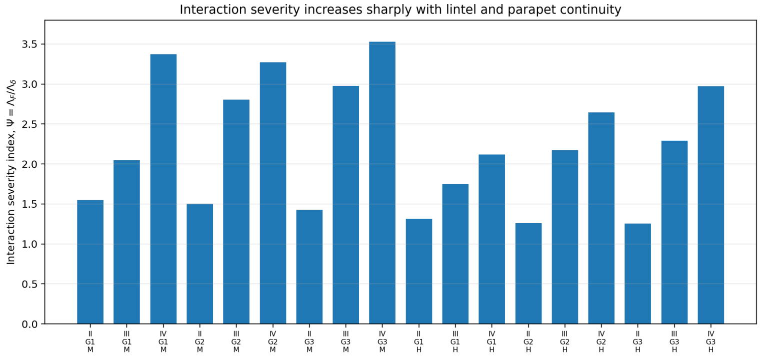

Figure 2: Interaction severity index Ψ for all non-baseline wall archetypes. The highest values occur when lintels and parapets are included, especially for moderate-aspect-ratio panels.

Coupled-wall redistribution and hierarchy inversion

The global indices above do not explain *where* the extra force goes. The coupled-wall force–displacement responses reported for the wall family provide that missing information. The baseline model behaves as intended by the simplified kinematic design concept: coupled-wall contributions are broadly proportional to the stiffness of the constituent walls, and the yielding hierarchy is largely uniform along the wall line. Once secondary elements are included, however, the distribution shifts.

Three mechanism changes are particularly important.

Right-side amplification. The reported coupled-wall curves indicate that the progressive inclusion of floors, lintels, and parapets increases the contribution of the coupled walls located on the right side of the wall line. This effect intensifies from Model II to Model IV and becomes especially visible in Geometries 2 and 3, where more openings and longer wall lines allow stronger continuity effects to develop. The practical implication is that a wall line designed by stiffness-proportional force distribution can still experience markedly uneven local demand after continuity is mobilized.

Local hierarchy inversion in moderate-aspect-ratio walls. For moderate-aspect-ratio panels, the intended spline-before-hold-down sequence is maintained in Model I, but it is no longer uniform in Models II–IV. In the far-left coupled wall, hold-downs can yield before splines because that wall behaves more like a single panel than a coupled rocking system. The source study indicates that this inversion is localized rather than system-wide, but it is structurally significant because it changes the ductility mechanism in precisely the coupled wall that first receives the imposed displacement path from the loading direction.

Reverse sliding in Model IV. The clearest non-classical response in the database occurs in Model IV, where gap opening between parapets and wall panels can push the first coupled wall in the opposite direction of the applied loading. This causes early force degradation or even negative force values in the first coupled wall, particularly in the higher-aspect-ratio cases for Geometries 2 and 3. Reverse sliding of that kind is a strong indicator that the wall line is no longer responding as a set of nominally similar rocking segments; instead, continuity is imposing kinematic constraints that locally override the expected force path.

Table 4 summarizes the redistribution and hierarchy outcomes in an engineering screening format. Moderate-aspect-ratio walls become progressively more vulnerable as continuity is added, whereas high-aspect-ratio walls preserve the intended spline-before-hold-down sequence more reliably.

Table 4: Qualitative redistribution and hierarchy outcomes derived from coupled-wall responses.

Model	*Aspect ratio*	*Coupled-wall redistribution*	*Yielding hierarchy outcome*	*Vulnerability level*
I	Moderate	Near stiffness-proportional sharing	Spline-before-hold-down sequence achieved in coupled walls	Low
I	High	Near stiffness-proportional sharing	Spline-before-hold-down sequence achieved in coupled walls	Low
II	Moderate	Mild right-side amplification	Local hold-down-first yielding in far-left coupled wall	Moderate
II	High	Mild redistribution	Intended sequence maintained	Low
III	Moderate	Stronger right-side amplification	Local hierarchy inversion persists; STS and brackets enter yielding sequence earlier	High
III	High	Moderate redistribution	Intended sequence maintained, but sliding demand increases	Moderate
IV	Moderate	Strong redistribution with concentrated right-side demand	Local hierarchy inversion plus concentrated bracket/STS demand in redistributed zones	High
IV	High	Strong redistribution; reverse sliding can occur in first coupled wall of longer geometries	Intended sequence mostly maintained, but kinematics become non-classical	High

Taken together, these observations show that the main effect of lintel and parapet continuity is not merely to make the wall stronger. It redistributes the load path within the wall line and changes the local mechanism by which individual coupled walls accommodate displacement.

Panelwise mechanism concentration: from rocking to sliding

The wall-level displacement decomposition makes it possible to observe where the global force–deformation trade-off comes from. In the baseline model, rocking is overwhelmingly dominant. The panelwise displacement decomposition reported for the wall family shows rocking contributions of roughly 95.7–96.6% in the moderate-aspect-ratio baseline and about 97.0–98.3% in the high-aspect-ratio baseline, leaving only a small residual share for sliding. In other words, the baseline wall family behaves as a genuinely rocking-dominated segmented system.

That picture changes once continuity is introduced. In Models III and IV, rocking decreases and sliding rises, but the sliding increase is not spatially uniform. Instead, sliding concentrates differently depending on location along the wall line:

- In moderate-aspect-ratio walls, leading panels can develop large *floor-level* sliding contributions, while trailing panels develop large *base-level* sliding contributions.
- In high-aspect-ratio walls, rocking remains comparatively stronger than in the moderate walls, but sliding still becomes localized and can change sign in the first coupled wall when lintel or parapet gaps open.

The strongest mechanism concentration occurs in Model IV. In Geometry 2 with moderate-aspect-ratio panels, the rightmost panels of the wall line exhibit rocking shares of only about 55.7–56.1%, while base sliding rises to approximately 41.8–41.9%. In Geometry 3, the trailing panels show a similar pattern, with rocking around 55.2–55.7% and base sliding around 41.2–41.6%. By contrast, the leftmost panels of those same walls exhibit much larger floor-level sliding, with values on the order of 24.6–31.3%. This spatial asymmetry is a direct signature of continuity-induced force rerouting.

High-aspect-ratio walls remain more rocking-dominated overall, which helps explain their better deformation retention. Even so, Models III and IV still show panelwise concentration of sliding. In the longer wall lines, the first coupled wall can exhibit reverse base sliding once parapet gaps open, which is consistent with the negative force values reported in the coupled-wall response curves.

This mechanism shift has two design implications. First, a wall line can remain globally strong while being locally much less rocking-dominated than the designer intends. Second, the location of the critical deformation mode is not fixed; it moves with the interaction topology of the wall line. Opening-adjacent and end-wall regions therefore require more explicit detailing checks than a wall-level pushover curve alone would suggest.

Moderators of redistribution: aspect ratio, floor stiffness, and wall-to-floor connection stiffness

Aspect ratio. Panel aspect ratio is the strongest geometric moderator in the analyzed database. Moderate-aspect-ratio walls are stronger once floor, lintel, and parapet interaction is engaged because their larger vertical displacement under rocking mobilizes more floor participation. However, that same interaction makes them more vulnerable to hierarchy inversion and to abrupt reductions in deformation capacity. High-aspect-ratio walls, by contrast, consistently preserve larger deformation capacity and maintain the intended yielding sequence more reliably. This indicates that panel slenderness is not only a capacity variable; it is also a mechanism-stability variable.

Floor-panel bending stiffness. The reported sensitivity study on floor thickness shows that floor-panel bending stiffness has almost no effect on the global wall response for the analyzed range. Changes in thickness from 175 mm to 315 mm produce nearly identical pushover curves, with only minor differences in yielding onset and floor-demand exceedance (Baldus, 2006). Within this database, those small differences are not large enough to alter the mechanism-based interpretation developed here. This result is important because it isolates the dominant source of interaction: it is not primarily the flexural stiffness of the floor panel itself, but the *kinematic restraint transmitted through the wall-to-floor connection system.* For design simplification, this suggests that effort is better spent characterizing connection stiffness and continuity conditions than refining floor flexural stiffness within ordinary practical bounds.

Wall-to-floor connection stiffness. By contrast, the vertical stiffness of wall-to-floor STS connections above has a pronounced effect. Table 5 lists the reported strength and deformation capacities for Geometry 2 at STS spacings of 50 mm, 100 mm and 200 mm. Decreasing spacing (i.e., increasing vertical stiffness) systematically raises strength and generally reduces deformation capacity. The effect is especially strong in Model II. For moderate-aspect-ratio panels in Model II, reducing spacing from 200 mm to 50 mm increases peak strength from 592 kN to 838 kN, a gain of 41.6%, while deformation capacity declines from 117 mm to 105 mm. The corresponding increase for the high-aspect-ratio Model II wall is 30.6%.

Table 5: Effect of wall-to-floor STS spacing on Geometry 2.

Aspect ratio	*Spacing*	*Model II*		*Model III*		*Model IV*	
		F_u (kN)	δ_u (mm)	F_u (kN)	δ_u (mm)	F_u (kN)	δ_u (mm)
Moderate	50 mm	838	105	1075	87	1083	76
	100 mm	693	120	991	92	1005	80
	200 mm	592	117	912	96	961	84
High	50 mm	700	150	896	114	1026	110
	100 mm	592	149	822	120	968	116
	200 mm	536	148	783	125	940	122

Figures 3 and 4 summarize the same trend in normalized form. The normalized ordinates shown in both figures were recalculated directly from Table 5. The strength penalty for using more flexible wall-to-floor connections is clear, but so is the mechanism benefit: more flexible STS spacing helps preserve deformation capacity and delays non-spline yielding. That finding aligns with the broader interpretation advanced in this paper—the decisive variable is not simply how much continuity exists, but *how strongly* that continuity restrains the wall's rocking mechanism.

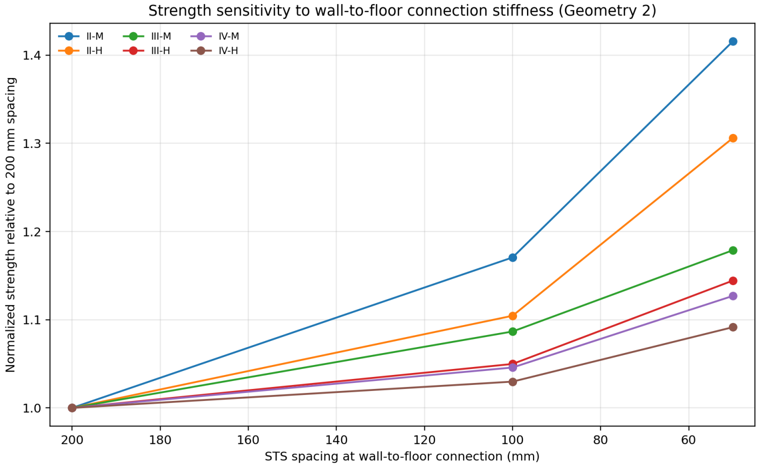

Figure 3: Normalized strength relative to the 200 mm spacing case for Geometry 2. Increasing wall-to-floor connection stiffness amplifies strength most strongly in Model II.

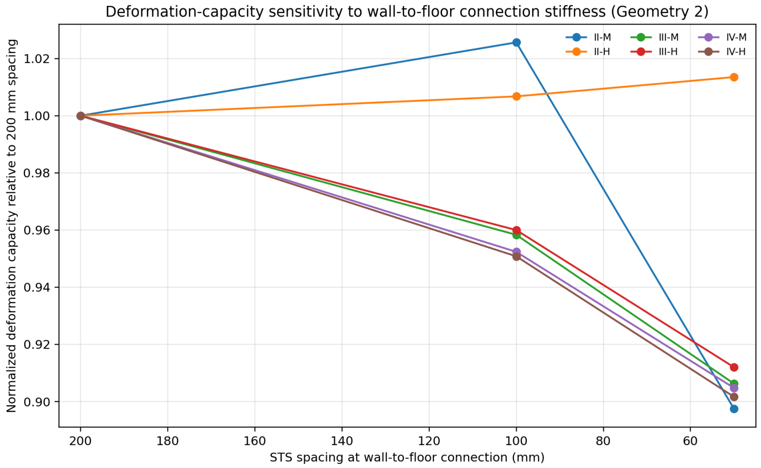

Figure 4: Normalized deformation capacity relative to the 200 mm spacing case for Geometry 2. Increased wall-to-floor connection stiffness generally reduces deformation capacity, especially when lintel and parapet continuity is present.

DISCUSSION

Mechanism interpretation

The combined evidence supports a coherent mechanism interpretation. Model I behaves as a segmented rocking wall system. Model II still behaves predominantly as a rocking wall system, but with moderate kinematic restraint provided by the floor and wall-to-floor connections. That restraint increases strength without radically changing the mechanism. Models III and IV, however, enter a different behavioral class. In those walls, continuity through lintels and parapets does not just add stiffness; it changes the kinematic compatibility of the wall line. The result is a wall system in which some coupled walls are partially forced toward single-wall behavior, some connections yield earlier than intended, and sliding becomes concentrated rather than uniformly distributed. Because these interpretations are derived from monotonic envelope responses, they are strongest when read as relative mechanism trends rather than as full-cycle damage predictions.

This interpretation helps explain why moderate-aspect-ratio walls perform differently from high-aspect-ratio walls. The wider panels mobilize stronger floor participation and therefore higher strength, but they are also more vulnerable to mechanism distortion when rocking is partially suppressed. The narrower panels remain more deformable and preserve hierarchy more reliably because their coupled-wall behavior is harder to disrupt, even though they are not immune to local sliding anomalies.

Implications for design and detailing

Three practical implications follow from the verified trends in the database.

First, wall lines with CLT lintels or parapets should not be checked only at the whole-wall level. At minimum, the designer should identify the most highly loaded coupled wall on the stiff side of the system and the first coupled wall on the loaded edge, because these locations experience fundamentally different kinematic demands.

Second, connector hierarchy should be verified locally rather than assumed globally. In moderate-aspect-ratio wall lines with floor, lintel, and parapet continuity, the source data show that the leftmost coupled wall can lose the intended spline-before-hold-down sequence even when the overall wall still appears to behave satisfactorily.

Third, floor strips above panel interfaces and near openings deserve explicit demand checks. The analyzed database shows that floor bending-demand exceedance occurs at repeatable locations, especially above interfaces adjacent to opening zones. This means that the floor element is not merely a passive distributor of force; it can become a local demand hotspot when wall continuity is engaged.

These implications suggest a practical screening rule. If a segmented CLT wall line includes continuous CLT lintels or parapets *and* uses moderate-aspect-ratio panels, interaction-aware checks should be treated as a high-priority design requirement. If the same wall line also uses closely spaced wall-to-floor STS connections, the need for such checks becomes even more pronounced.

Limitations

The conclusions of this paper are bounded by the validated wall family from which the analyzed response data were drawn. The present revision strengthens numerical verification and consistency checking, but it does not expand the underlying experimental database. The numerical models were validated directly for the baseline wall representation, whereas configurations with floors, lintels, and parapets were not validated against an equally comprehensive experimental program (Baldus, 2006). The analyzed responses are also monotonic rather than cyclic. Accordingly, the present findings should be interpreted as mechanism-based design guidance for monotonic envelope behavior, not as a substitute for cyclic deterioration assessment or seismic collapse evaluation.

A second limitation is that the present study focuses on one-story wall lines. Multi-story systems introduce additional axial-load accumulation, cumulative rotation, inter-story compatibility, and floor-system interactions that can intensify or attenuate the phenomena discussed here (Chen et al., 2012; Ruggeri et al., 2023). Nevertheless, the one-story wall family is still a valuable basis for identifying the onset of redistribution and hierarchy inversion because these mechanisms appear already at the story level.

CONCLUSIONS

This paper reorganized a previously validated numerical database of one-story segmented CLT shear walls with openings to answer a different question from the usual wall-level strength study: how floor, lintel, and parapet continuity alters coupled-wall force routing, local yielding order, and the rocking–sliding balance within the wall line. On that basis, and within the bounds of monotonic response interpretation, the following conclusions are drawn:

1. Floor interaction alone increases strength while largely preserving deformation capacity. Across the analyzed wall family, Model II produces a relatively mild interaction-severity regime.
2. Lintel continuity, and especially the combined lintel–parapet configuration, moves the wall family into a high-severity regime characterized by larger strength amplification, reduced

deformation retention, earlier STS and bracket participation, and stronger coupled-wall redistribution.

3. Moderate-aspect-ratio panels are more vulnerable to local hierarchy inversion. In the analyzed wall family, far-left coupled walls can exhibit hold-down yielding before spline yielding once secondary structural continuity is introduced.

4. High-aspect-ratio panels retain larger deformation capacity and preserve the intended yielding sequence more reliably, even though they can still develop localized reverse sliding in the first coupled wall when parapet gaps open.

5. The transition from rocking to sliding is spatially nonuniform. Sliding concentrates differently in leading and trailing regions of the wall line, which means that local connector and floor-strip checks cannot be inferred safely from a single wall-level pushover curve.

6. Floor-panel bending stiffness has little influence on the global response within the analyzed range, whereas wall-to-floor connection stiffness is a dominant moderator of both strength gain and deformation penalty.

The central design message is therefore straightforward: in segmented CLT wall lines with openings, the main consequence of floor, lintel, and parapet continuity is not simply higher strength. It is a redistribution of force and deformation that can distort the intended rocking mechanism and relocate the critical demand to specific coupled walls, connectors, and floor regions. Interaction-aware detailing should therefore accompany any design strategy that relies on structural continuity to enhance global wall performance.

ACKNOWLEDGMENT

The figure set included in this manuscript was regenerated by the present authors from the verified wall-response database as summary visualizations used consistently throughout the revised text, tables, and graphics.

REFERENCES

Baldus, M. (2006). Molecular interactions investigated by multi-dimensional solid-state nmr. *Current opinion in structural biology*, *16*(5), 618–623.

Cao, J., Xiong, H., Wang, Z., & Chen, J. (2020). Experimental investigation and numerical analysis for concrete-clt connections. *Construction and Building Materials*, *236*, 117533.

Chen, S., He, J., & Shahrour, I. (2012). Estimation of elastic compliance matrix for fractured rock masses by composite element method. *International Journal of Rock Mechanics and Mining Sciences*, *49*, 156–164.

D'Arenzo, G., Schwendner, S., & Seim, W. (2021). The effect of the floor-to-wall interaction on the rocking stiffness of segmented clt shear-walls. *Engineering Structures*, *249*, 113219.

Ding, Y., Pang, Z., Lan, K., Yao, Y., Panzarasa, G., Xu, L., Lo Ricco, M., Rammer, D. R., Zhu, J., Hu, M., et al. (2022). *Emerging engineered wood for building applications* (Vol. 123). ACS Publications.

Folz, B., & Filiatrault, A. (2001). Cyclic analysis of wood shear walls. *Journal of Structural Engineering*, *127*(4), 433–441.

Gavrić, I., Fragiacomo, M., & Ceccotti, A. (2015). Cyclic behaviour of typical metal connectors for cross-laminated (clt) structures. *Materials and Structures*, *48*, 1841–1857.

Khajehpour, M., Casagrande, D., & Doudak, G. (2022). The role of lintels and parapets on the mechanical performance of multi-storey cross laminated timber shearwalls with openings. *Engineering Structures*, *255*, 113912.

Liu, Q., French, C. W., & Sritharan, S. (2018). Study of interaction between a prewec system and surrounding structure. *ACI Structural Journal*.

Lukacs, I., Björnfot, A., & Tomasi, R. (2019). Strength and stiffness of cross-laminated timber (clt) shear walls: State-of-the-art of analytical approaches. *Engineering Structures*, *178*, 136–147.

Ruggeri, E. M., D'Arenzo, G., & Fossetti, M. (2023). Investigating the effect of the structural interactions due to floors and lintels on the lateral response of multi-storey cross-laminated timber shear walls. *Engineering Structures*, *290*, 116327.

Tamagnone, G., Rinaldin, G., & Fragiacomo, M. (2020). Influence of the floor diaphragm on the rocking behavior of clt walls. *Journal of Structural Engineering*, *146*(3), 04020010.

AUTOBIOGRAPHICAL SKETCHES

Dr. Zora Goodwin, University of Alaska; dgoodwin4@alaska.edu

Manuscript revisions completed 18 December 2022.