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Original Article

Effect of opening layout and sheathing on lateral load bearing capacity in wooden shear walls

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ABSTRACT

Wood is preferred as building material in earthquake zones thanks to its light-weight. In countries with high seismic activity, wooden construction systems are required to be resistant to lateral and vertical loads. In traditional architecture, lateral load resistance is ensured with filled and unfilled walls which are strengthened with braces. In present day lateral load resistance is ensured with wooden shear walls formed by sheathings covered on the wall frame. Wooden shear walls may contain openings such as windows, doors and service channels. These types of openings reduce rigidity in wooden shear walls. The opening ratio, opening location, sheathing thickness and connection types have an impact on the lateral load bearing capacity of shear walls. This study investigates the use of two types of wooden shear walls with different-layout openings which were modelled with plywood sheathing material. For the purposes of this study, lateral load bearing capacities were calculated for both types of sheathing material of different thicknesses. The results are presented in tables by comparing the calculated capacity increase to the increase in weight.

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INTRODUCTION

The lightness of wooden structures is regarded as a natural advantage as it creates lower earthquake loads compared to structural systems. Wooden construction systems, widely preferred in countries located in high seismic zones, are required to have the necessary resistance to both lateral and vertical loads. In traditional architecture, lateral load resistance is ensured by filled and unfilled walls supported by braces. In present day, lateral load resistance is ensured with wooden shear walls formed by sheathings covered on the wall frame.

Wooden shear walls, which resist lateral loads such as wind and earthquakes, ensure significant rigidity and resistance for the structure. This behaviour limits the displacement of structures under lateral loads and reduces potential damages. Moreover, the size and placement of wooden shear walls hold utmost significance for the structure's reaction to

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lateral loads. The symmetrical placement of shear walls to reduce structure's torsional effect, appropriate design and detailing are regarded as positive elements for earthquake performance. Structures with adequately-designed and detailed wooden shear walls performed well in past earthquakes [1].

Wooden shear walls in buildings may accommodate openings, such as windows on exterior walls, and doors or service channels on interior walls. Depending on their geometry and position, such openings reduce rigidity in wooden shear walls.

Earthquake loads acting on the structure are distributed proportionally to lateral load-bearing wooden walls. Openings that cause losses in stiffness adversely affect the seismic behaviour of the structure. In order to configure the openings on the wooden shear wall properly, it is necessary to know the size and position of the opening in the shear wall as well as the effects of the openings on the seismic response and behaviour of the structural system [2].

The Rules of Calculation and Construction of Wooden Structures TS 647, published in November 1979 still holds valid. However, in terms of content, it does not meet present-day wooden construction requirements. The TS 647 specification does not include any calculation method for wooden shear walls.

The specification titled "EN 1995-1-1 (2004): Eurocode 5: Design of timber structures - Part 1-1: General - Common rules and rules for buildings" is currently in force in Europe, was translated by the Turkish Standards Institute and published with the full name of the standard with TS (Turkish Standard) and EN (European Norms) labels. TS EN 1995-1-1 includes two calculation methods for wooden shear walls with two types of opening (A and B).

Turkish Building Earthquake Code (TBDY-2018) refers to the design principles of wooden shear walls under the earthquake loads in chapter 12.4. According to TBDY-2018, walls with door and window openings are not considered as lateral load-bearing shear walls, and the shear capacity of the wooden shear wall should be greater than the shear force acting on the wall. However, TBDY-2018 does not specify a method for calculating wooden shear walls with openings. Turkish standard TS EN 1995 has sections for the design of shear wall studs and connections.

The American specifications for 2015 Special Design Provisions for Wind and Seismic (SDPWS) and Eurocode 5 Design of Timber Structures (EC5) offer practical methods for calculating wooden shear walls. This study aims at investigating the lateral load-bearing capacities of wooden shear walls with openings in the context of opening ratio, opening layout and sheathing thickness parameters. Thus, three methods from SDPWS and EC5 specifications were selected for numerical analysis and calculations via the Tekla Tedds software [3].

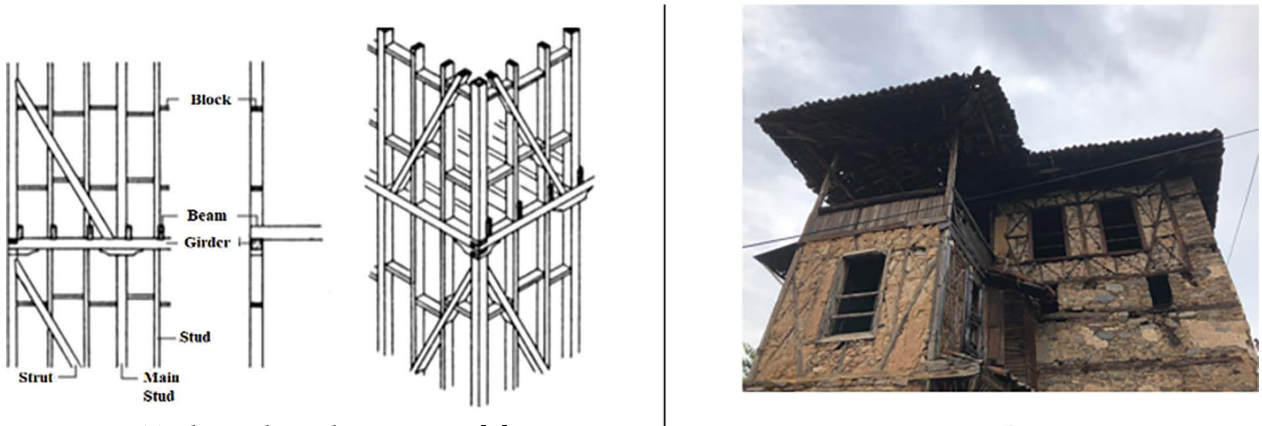
- Segmented Shear Wall-SDPWS
- Perforated Shear Wall-SDPWS
- EC5 Wooden Shear Wall Design.

EARTHQUAKE RESISTANCE OF WOODEN SHEAR WALLS

In Turkey, traditional wooden structures consist of horizontal, vertical and diagonal elements. Whereas horizontal members consist of top and bottom chords, beams, girders and blocks, vertical members are comprised of studs and end studs. In the same vein, diagonals accommodate buttresses [4] and "X" shaped braces (Fig. 1).

Walls with diagonal elements are filled or unfilled walls that provide high resistance to lateral loads. Materials such as adobe, brick, stone and cones are used as filling in filled walls. Wall surfaces are preferably covered with or left without plaster. In structures with unfilled walls, lathed and plastered systems are utilized as the coating material.

Aktaş et al. [5], (2014) tested 8 one-to-one scale frames built with different materials and geometrical configurations under lateral-load to examine the seismic strengths



Traditional wooden structure [5].

Birgi, İzmir

Figure 1. Structural members of wood construction.

Figure 2. Soft story damage in a traditional wooden structure, 1999 Düzce earthquake [7].

of traditional Ottoman "Hımış" dwelling houses, which constitute the majority of the wooden dwelling structures in Turkey. The frames were constructed with or without brick infilling. Frames without filling were plastered, prepared with Şamdolma and Bagdadi techniques and covered with wide and thin laths. The results demonstrated that the weight of infilled wooden frames increased considerably compared to lateral load bearing capacities.

Gölcük and Düzce earthquakes in 1999 damaged some wooden houses. These damages were caused by a loss in the quality of wooden members which was engendered by previous earthquakes in 1943 and 1967 [6]. Furthermore, weakening wooden structural systems could not resist the large earthquake loads caused by heavy infilled walls (Fig. 2).

In the same vein, many wooden structures were damaged and destroyed in the Great Hanshin Earthquake in Japan in 1995. It was indicated that the roof systems of the seriously damaged structures were covered with heavy tiles. Heavy roof systems, widely preferred in traditional wooden Japanese houses due to architectural and cultural reasons, were also utilized to prevent the roof from flying in strong winds such as typhoons. These heavy roof systems also led to an increase in earthquake loads that affected the structure [7]. Due to this effect and traditional design features, wooden structures with soft floor problems collapsed [8] (Fig. 3).

Figure 3. Wooden structure damaged in the Great Hanshin earthquake [9].

One of the most significant advantages of wooden structures exposed to earthquake loads is their light-weight. Turkey is located in an earthquake zone with active fault lines. Therefore, wooden structures built in areas with high seismic activity need to be designed to resist earthquake loads. The intensity of earthquake loads acting on a wooden structure are contingent upon the following factors:

- Ground movement (the distance of the building to the epicentre, the magnitude of the earthquake, depth of focus etc.)
- Soil characteristics (type of soil, acceleration records, response spectrum of ground motion, etc.)
- Building characteristics (column and shear wall layout, stiffness, weight, natural vibration period, height of the structure etc.)

In TBDY 2018, the total earthquake load acting on the structure is defined by Equation 1 [10].

$$V_{tE}=m_t\times S_{aR}\ (Tp)>0.04\times m_t\times I\times S_{DS}\times g \tag{1}$$

m_t: Total mass

$S_{aR}(T_p)$: Reduced design spectral acceleration

T_p: Fundamental natural vibration period of structure

S_{DS}: The design spectral response acceleration parameter in the short period

I: Importance factor

g: Gravitational acceleration $g=9{,}81\ m/s^2$

As seen in Equation 1, the weight of the structure is directly proportional to the earthquake load acting on it. Wood is preferred as building material in earthquake zones thanks to its light-weight.

Sheathings provide high lateral load resistance capacity and ductile behaviour in contemporary wooden structures. In TBDY 2018 [10], it is recommended to use nails, screws, and proper connections determined in chapter 12.2.1.1-(a) to design high ductile structural systems with OSB and plywood sheathings. Li et al. [11] (2009), conducted a seismic reliability analysis on eight types of diagonal-braced and structural-panel-sheathed shear walls, commonly used in modern post-and-beam wooden buildings. They concluded that the seismic reliability of the structural-panel-sheathed walls was higher than that of the diagonal-braced walls.

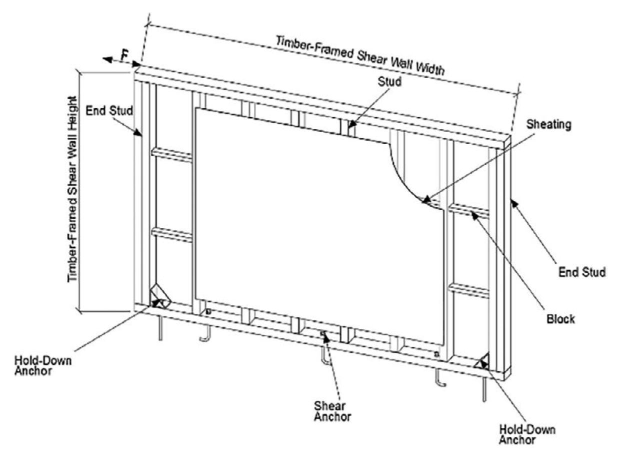


Figure 4. Typical components of a wooden shear wall.

In this study, two types of wooden shear wall that accommodate openings with different placements are modelled with plywood sheathing. Tekla Tedds [3], a general-purpose structural analysis software, is used in numerical analyses. Lateral load bearing capacities were calculated for both types of sheathing material of different thicknesses. The results are presented in tables by comparing the calculated capacity increase to the increase in weight.

CALCULATION METHODOLOGY FOR WOODEN SHEAR WALLS WITH OPENINGS

A typical wooden shear wall consists of a wooden frame, sheathings attached to this frame with fasteners, the connection anchor formed on the chords of the shear wall, the fixing bolt or nails that provide the connection with the floor (Fig. 4).

The following is the calculation methodology for the three methods used to determine the lateral load-bearing capacity of wooden shear walls with openings:

Segmented shear wall

In this calculation method, each shear wall is assumed to be a cantilever wall that is fixed at the base and displaced at the top. Full-height wall sections between the doors and windows are defined as shear wall sections. Each part is modelled as a single cantilever and designed according to the moment value at the base. Tensile and compression reactions of shear wall's chord elements are calculated in each segment [12].

Openings are allowed to be created on shear wall edges. However, the lengths of these openings are not included in the shear wall calculation length. Aspect ratios to be used in the calculations are provided in Table 1. [13] (Fig. 5).

h= The height of the shear wall or shear wall section

b_s= Minimum curtain wall width to be used in aspect ratio calculation

Only the full-height sheathing segments are assumed to provide resistance to lateral loads (Fig. 6 hatched parts).

Table 1. Max. aspect ratios (AWC's Wind & Seismic Task Committee, 2015)

Max. aspect ratios for the shear walls	
Shear wall sheathing type	**Max. aspect ratio (h/b_s)**
Wood structural panels, unblocked	2: 1
Wood structural panels, blocked	3.5: 1
Particleboard	2: 1
Diagonal sheathing, conventional	2: 1
Gypsum wallboard	2: 1
Portland cement plaster	2: 1
Fiberboard	3.5: 1

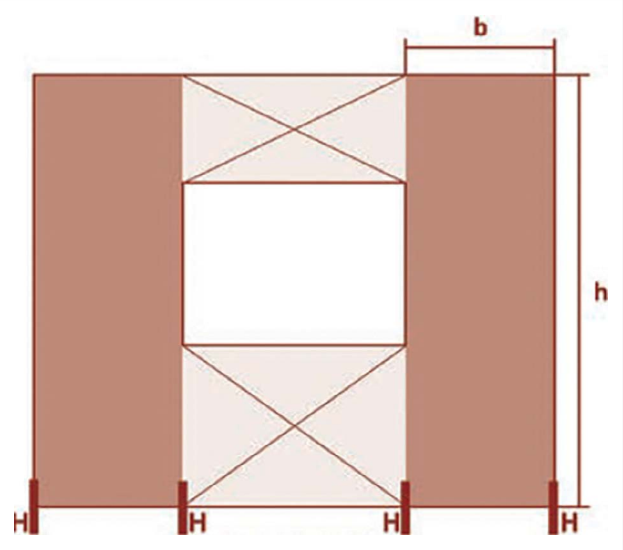


Figure 5. Segmented shear wall [14].

The sheathing grade and thickness and the nail size and spacing determine the shear capacity per meter of length of the full-height segments. SDPWS 2015 explains these variables in related tables [16]. The design shear capacity;

$$V=v\times\Sigma b_i \quad (2)$$

V: Total allowable shear capacity of wall (kN)

v: Allowable shear capacity per unit length (kN/m)

Σb_i: Sum of lengths of full-height sheathing segments

SDPWS places limits on the dimensions of wood frame shear walls. These restrictions are based on the poor performance of tall, narrow wood-frame shear wall segments. The limits are in the form of maximum height-to-width ratios ($h:b_s$) in the Table 1.

Overturning moments are;

$$M_1=v\times b_1\times h \quad (3)$$

$$M_2=v\times b_2\times h \quad (4)$$

$$M_3=v\times b_3\times h \quad (5)$$

Chords forces are;

$$C_1=T_1=M_1/b_1 \quad (6)$$

$$C_2=T_2=M_2/b_2 \quad (7)$$

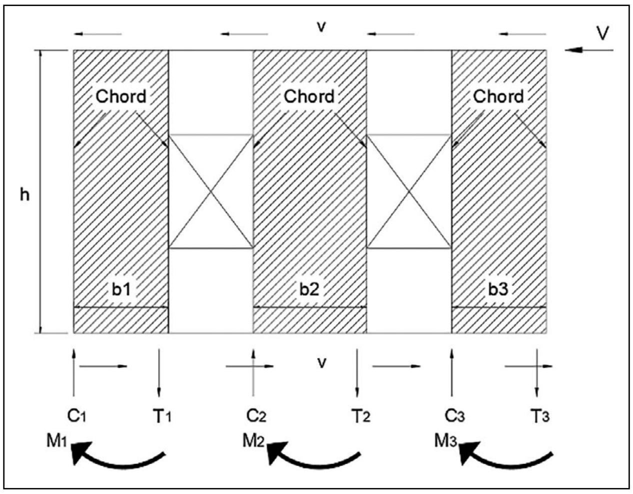


Figure 6. Free body diagram of segmented shear wall.

$C_3=T_3=M_3/b_3$ (8)

The elastic deflection of a shear wall can be calculated by summing the effects of four sources of deflection: bending, shear, nail slip and anchorage. Total wall deflection is the sum of the deflections obtained from each of these components.

$\Delta_s=\Delta_b+\Delta_v+\Delta_n+\Delta_a$ (9)

$\Delta_a=(8\times v\times h^3)/(E\times A\times b)$ (10)

$\Delta_v=(v\times h)/(G_v\times t_v)$ (11)

$\Delta_n=0.75\times h\times e_n$ (12)

$\Delta_a=(h/b)\times\Delta_h$ (13)

b: Length of shear wall
A: Cross-sectional area of chord
E: Modulus of elasticity of chord
h: Shear wall height
v: Unit shear
t_v: Effective thickness of structural sheathing panel
G_v: Modulus of rigidity of structural sheathing panel
e_n: Nail deformation under load
Δ_h: Hold-down deflection

Perforated shear wall

This method is a semi-experimental method developed with shear wall tests. The entire wall and the openings are used in this method. In contrast to other calculation methods, a lower level of detail is required. Due to less detailing, the wall capacity and stiffness are lower. The method calculates an adjustment factor to identify lower capacity and stiffness [12].

It is necessary to form a wall segment at both ends of the shear wall. Openings at the shear wall edges are permitted provided that the length of these openings is not included in shear wall calculation length. In the specification, lateral load bearing capacities are provided according to the sheathing thickness of wooden shear walls and the distance of nails used at the end stud of the shear wall. The wall shear capacity values are classified according to the same parameters.

Perforated shear wall height (h) is required to be at a maximum of 6 m. Aspect ratios to be used in the calculations are laid out in Table 1. [13] (Fig. 7).

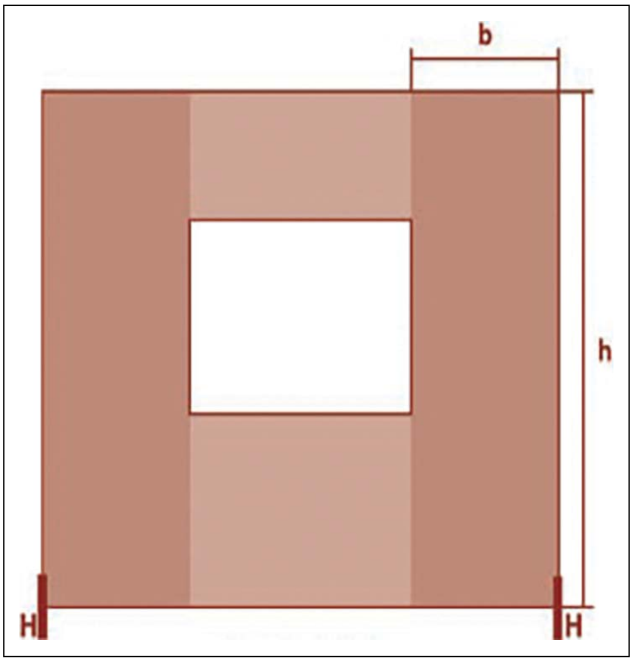


Figure 7. Perforated shear wall [14].

The first step in the design is to determine the unit shear capacity (v) of the wall by means of the SDPWS 2015 table as demonstrated previously for segmented shear walls. The next step is calculation of shear capacity adjustment factor (Co).

Percent full-height sheathing=$\Sigma b_i/L$ (14)

L: Total length of the wall
b_i: Length of full-height sheathing segment
h: Height of shear wall

Once the shear capacity adjustment factor (Co) is determined, it is used to calculate the allowable shear capacity of the perforated shear wall as follows:

$V=(v\times Co)\times\Sigma bi$ (15)

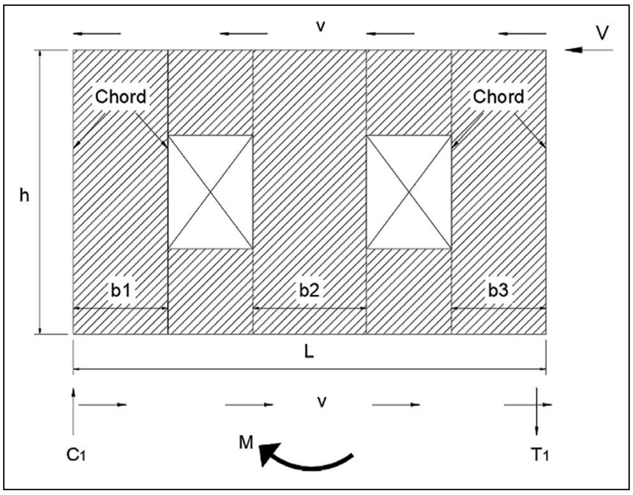


Figure 8. Free body diagram of perforated shear wall.

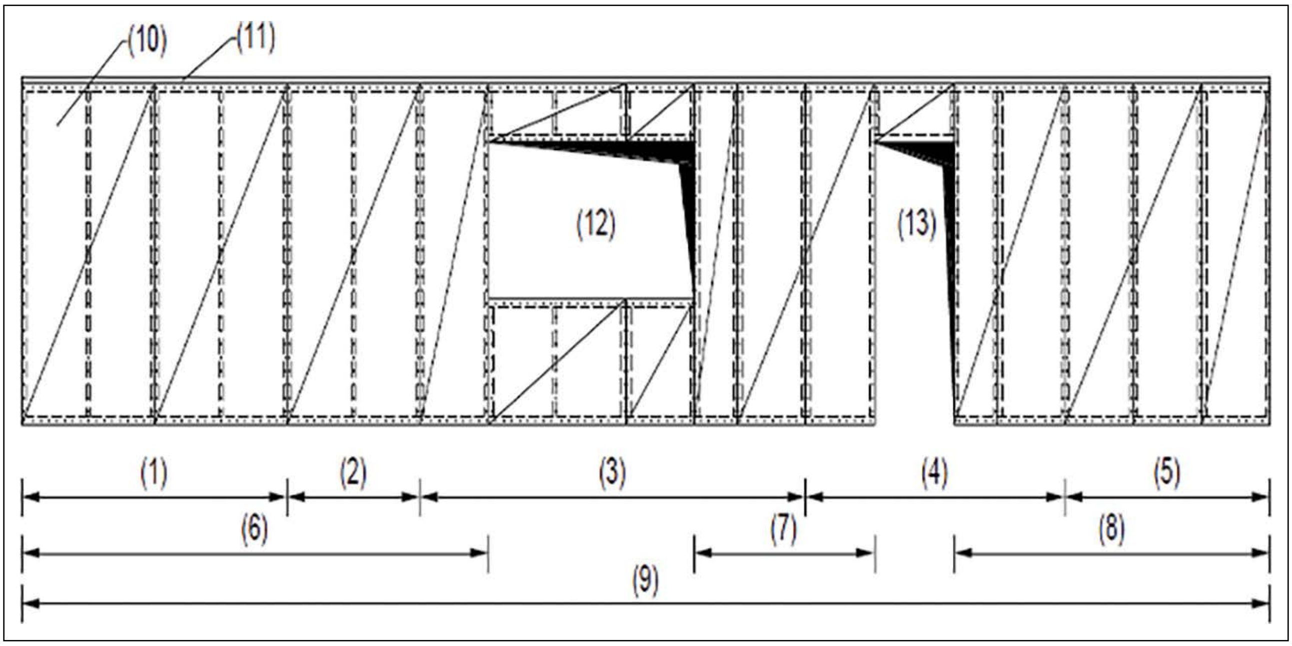


Figure 9. Wooden shear-wall 1-5: Wall panel, 6-8: Wall, 9: Wall assembly, 10: Sheet, 11: Head binder, 12: Window, 13: Door.

Overturning moment, chord force and displacement calculations are the same as the segmented shear wall method (Fig. 8).

Timber shear wall design-EC5 method B

The concepts and formulas provided in this EC5 method are based on a semi-experimental theory that assumes that the shear wall functions as a solid body. This simplified method defines a shear wall in which each wall consists of one or more panels. Figure 9 shows the form of the shear wall [16].

The main concept in the design is to determine the shear resistance of a single wall segment and capture the shear resistance of the entire wall based on this data. Furthermore, it is recommended in Eurocode 5 that supporting elements are designed to ensure the structure's lateral stability, regardless of the shear strength of wooden shear walls [17].

The racking strength Fi,v,Rd of wall is the lateral resistance capacity of the wall and can be considered to be equivalent to the maximum resistance force the wall will be capable of sustaining at its top (Fig. 10).

$$F_{v,Rd}=\Sigma\ F_{i,v,Rd} \qquad (16)$$

$$F_{i,v,Rd}=(F_{f,Rd}\times b_i/s_0)\times k_d\times k_{i,q}\times k_s\times k_n \qquad (17)$$

$F_{f,\,Rd}$: Design capacity of an individual fastener in lateral shear

b_i: Length of the wall (m)

s_0: Fastener spacing

k_d: Dimension factor of the wall

$k_{i,q}$: Uniformly distributed load factor

k_s: Fastener spacing factor

k_n: Sheathing material factor

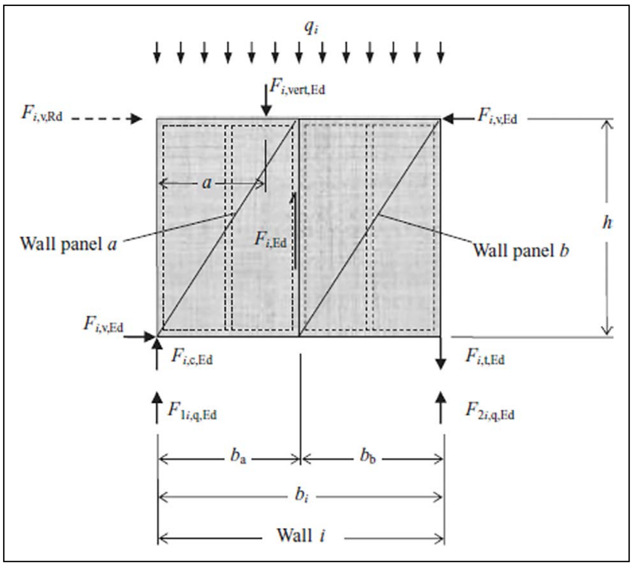


Figure 10. Layout of a typical wall and its associated actions and reactions [18].

In EC5 method B, there is no formulation and limitation related to lateral deflections of wooden shear walls. In order to find the deflection values on the wooden shear walls, a finite element model was created. In the finite element model, end posts and studs are defined as frame, and sheathings are defined as shell elements. Calculations were made by means of Sap2000 software.[19]

SAMPLE DESIGN

The assumptions made in the sample calculation to be designed for horizontal earthquake loads are given below.

Location: Istanbul

Peak ground acceleration PGA: 0.4 g

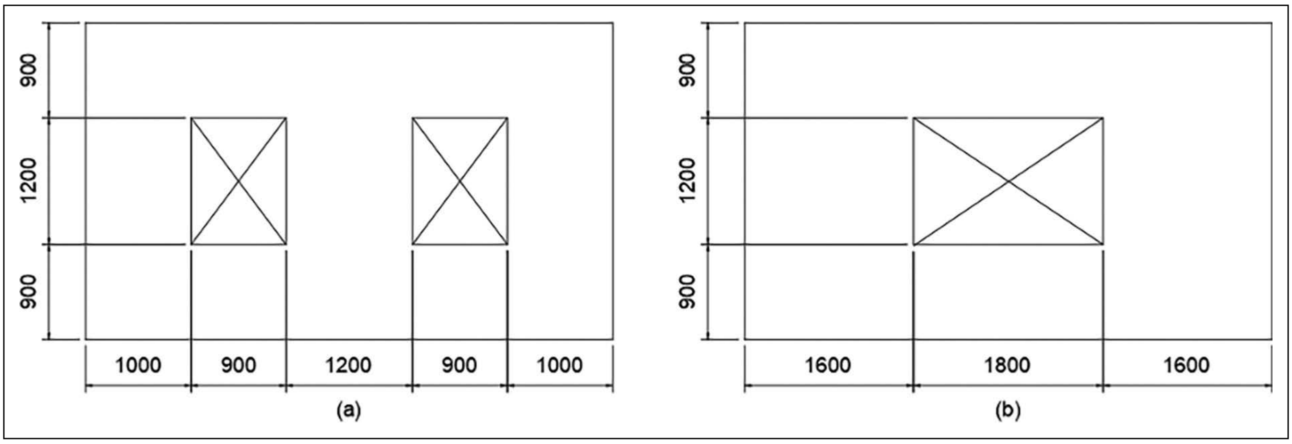


Figure 11. (a) Wooden shear wall type 1; (b) wooden shear wall type 2.

Spectral response acceleration parameter at short periods S_{ds}: 1

Importance factor I: 1

Risk category: II

Deflection amplification factor for sheathed panes systems C_d: 4

Deflection limit: 0.025×h

The shear walls are 3000 mm×5000 mm in dimension and accommodate two different types of openings (Fig. 11). The walls were calculated by means of three various methods based on existing assumptions.

Due to its similar mechanical properties, Southern Pine Select Structural was opted for the calculation of segmented and perforated shear walls. On the other hand, the C16-quality structural wood, as specified by Eurocode 5, was selected for the design. A double stud was utilized on the end posts of shear wall. All the studs accommodate 50 mm×100 mm sections and were placed with a spacing of 400 mm. The sheathings are made from a 9 and 12 mm thick plywood. The sheathings are fixed to shear wall posts at a 100 mm spacing. According to the specification regarding perforated wall design, the nominal unit shear capacity of the wall is limited to 2.36 kN/m in the seismic effect and 3.30 kN/m in the wind effect [13].

Standard nails, 3 mm in diameter and 50.8 mm in length, were employed in the calculation of segmented and perforated shear walls. In line with Eurocode 5, the design benefited from 65 mm long smooth-round nails (SRN) which are 2.87 mm, 3.10 mm and 3.33 mm in diameter, and 75 mm long spiral-threaded nails (STN) with a diameter of 3.10 mm and 3.35.

Sheathings were formed on one side of the shear wall in order to prevent lateral load bearing capacity of the wooden shear wall from the adverse effect of potential user interventions.

The lateral-load bearing capacities of two shear walls with different opening layouts were also identified following the calculations. Table 2 and Table 3 show the results from the segmented and perforated wall methods.

Table 2. Calculation summary of Type 1 wooden shear wall

Wall type	Design method	t_{SHEATING}	Lateral load bearing capacity	Anchor force	Lateral displacement
Type 1	Segmented Wall	9 mm	17.66 kN	12.05 kN	18.00 mm
Type 1	Segmented Wall	12 mm	19.35 kN	13.29 kN	18.50 mm
Type 1	Perforated Wall	9 mm	16.56 kN	13.75 kN	13.60 mm
Type 1	Perforated Wall	12 mm	19.66 kN	16.37 kN	17.50 mm

Table 3. Calculation summary of Type 2 wooden shear wall

Wall type	Design method	t_{SHEATING}	Lateral load bearing capacity	Anchor force	Lateral displacement
Type 2	Segmented Wall	9 mm	20.00 kN	12.88 kN	17.00 mm
Type 2	Segmented Wall	12 mm	23.86 kN	15.41 kN	19.00 mm
Type 2	Perforated Wall	9 mm	19.90 kN	16.38 kN	11.60 mm
Type 2	Perforated Wall	12 mm	23.64 kN	16.37 kN	15.20 mm

Table 4 shows the results of the calculations in which the same type of connection nail was used with sheathings of different thickness. In addition, Table 5 demonstrates the calculation results which include sheathings with the same thickness but different types of fastening nails.

The shear capacities of shear walls, chord capacity under axial tensile and compression forces, and lateral displacement of shear walls were checked in the calculation of segmented and perforated shear walls.

The seismic deflection calculations of wooden shear walls were made according to ASCE 7 [20]. The seismic deflections are obtained by multiplying the elastic deflections via the deflection amplification factor. Tables 6 and 7 show a comparison of seismic deflections with limit deflections.

Δ_{sws}: Amplification seismic deflection
Δ_{lim}: Limit deflection

$$\Delta_{sws}=Cd\times\Delta s/I \qquad (18)$$

$$\Delta_{lim}=0.025\times h \qquad (19)$$

ASSESSMENT

The shear capacities of shear walls, chord capacity under axial tensile and compression forces, and lateral displacement of shear walls were checked in the calculation of segmented and perforated shear walls.

Stabilizing moment at top and base, sliding stability, racking strength and serviceability validation were calculated according to Eurocode 5.

Table 4. Lateral load bearing capacities of wooden shear walls, which were designed with 3.35 mm×65 mm STN

Wall type	Design method	$t_{SHEATING}$	Lateral load bearing capacity	Lateral displacement
Type 1	Eurocode 5	9 mm	22.56 kN	16.00 mm
Type 1	Eurocode 5	12 mm	22.94 kN	11.00 mm
Type 2	Eurocode 5	9 mm	22.56 kN	12.10 mm
Type 2	Eurocode 5	12 mm	22.56 kN	9.95 mm

STN: Spiral-threaded nails.

Table 5. Lateral load bearing capacities of the wooden shear wall according to the selected fastening nail type

Wall type	Design method	Nail type	Lateral load bearing capacity
Type 1-Type 2	Eurocode 5	2.87 mm×65 mm (SRN)	14.97 kN
Type 1-Type 2	Eurocode 5	3.1 mm×65 mm (SRN)	16.74 kN
Type 1-Type 2	Eurocode 5	3.35 mm×65 mm (SRN)	18.59 kN
Type 1-Type 2	Eurocode 5	3.10 mm×75 mm (STN)	20.04 kN
Type 1-Type 2	Eurocode 5	3.35 mm×75 mm (STN)	22.56 kN

SRN: Smooth-round nails; STN: Spiral-threaded nails.

Table 6. Comparison of seismic displacements with limit displacements in Type 1 wooden shear walls

Wall type	Lateral deflection (mm)	Cd/I	Seismic deflection (mm)	Limit deflection (mm)	Result
Type 1 Segmented 9 mm	18	4	72	75	Ok
Type 1 Segmented 12 mm	18.5	4	74	75	Ok
Type 1 Perforated 9 mm	13.6	4	54.4	75	Ok
Type 1 Perforated 12 mm	17.5	4	70	75	Ok

Table 7. Comparison of seismic displacements with limit displacements in Type 2 wooden shear walls

Wall type	Lateral deflection (mm)	Cd/I	Seismic deflection (mm)	Limit deflection (mm)	Result
Type 2 Segmented 9 mm	17	4	68	75	Ok
Type 2 Segmented 12 mm	18.62	4	74.48	75	Ok
Type 2 Perforated 9 mm	11.6	4	46.4	75	Ok
Type 2 Perforated 12 mm	15.2	4	60.8	75	Ok

In Type 1 segmented shear-wall calculations, the lateral load bearing capacity and anchorage strength increased by 9.57% and 10.29% respectively due to the increase in sheathing thickness. This ratio was found to be 18.72% and 19.05% respectively in perforated shear-wall design (Fig. 12).

In Type 2 wall calculations, the lateral load bearing capacity increased by 19.3% in segmented shear walls due to the increase in sheathing thickness while there was an 18.79% increase in perforated shear walls (Fig. 13).

Fasteners are one of the most significant factors affecting the lateral load carrying capacity of shear walls in EC5 calculations. Figure 14 shows the effects of diameter and embedding depths of the connection pins on the shear wall lateral-load bearing capacity. Thanks to an increase of 0.23 mm (from 2.87 mm to 3.1 mm) in 65 mm-long nails, the lateral-load bearing capacity increased by 11.82%. Whereas an increase of 0.25 mm (from 3.1 mm to 3.35 mm) led to an 11.05% rise in capacity, there occurred a 12.57% increase in the capacity of 75 mm nails. A 10 mm increase in 3.1 mm diameter nails enhanced the lateral load capacity by 19.71%. The increase of the 3.1 mm diameter nail from 65 mm length to 75 mm length increased the lateral load carrying capacity by 19.71%. On the other hand, there was a capacity increase of 21.36% in nails with a 3.35 mm diameter.

RESULTS

This article examined the lateral load bearing capacities of wooden shear walls with openings in the context of opening ratio, opening layout, sheathing thickness, and connection type parameters.

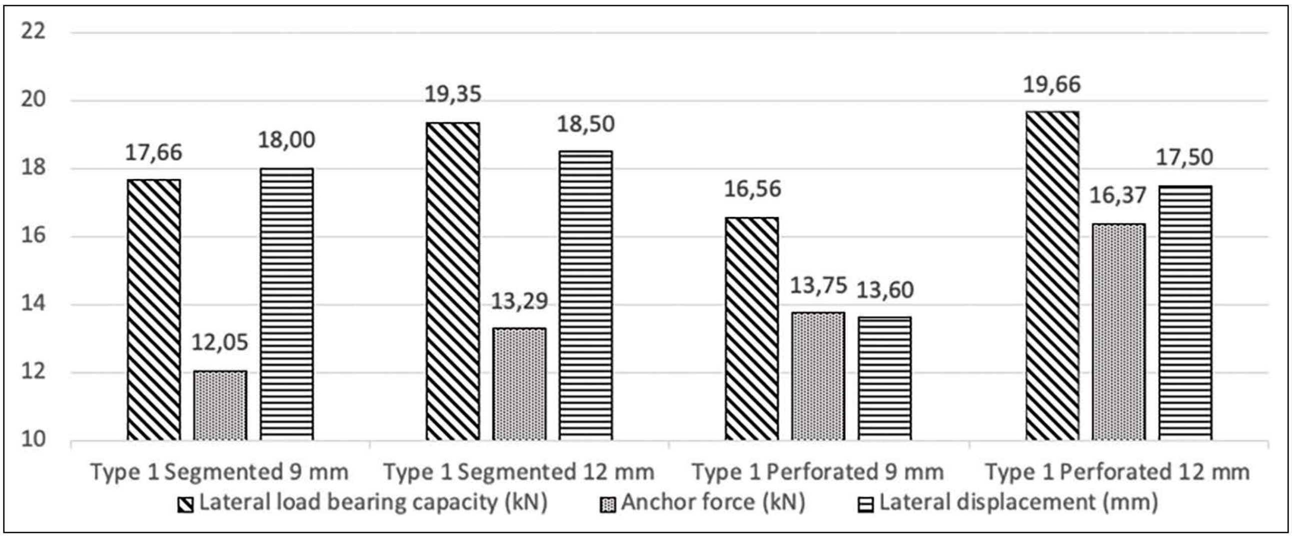


Figure 12. Comparison of lateral load bearing capacity, anchorage forces and lateral displacement of Type 1 wooden shear walls.

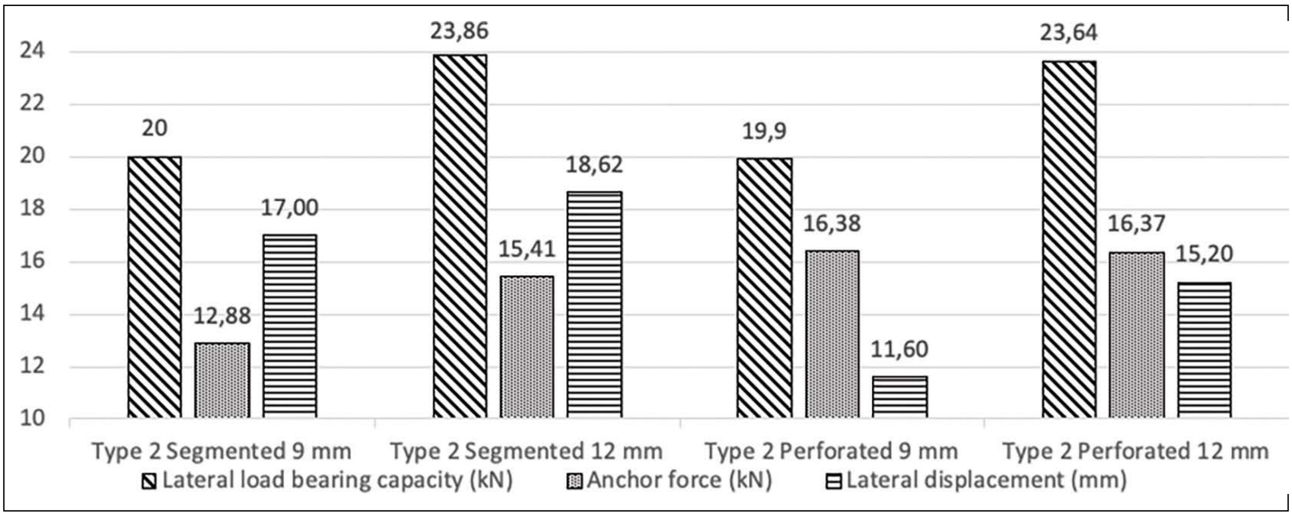


Figure 13. Comparison of lateral load bearing capacity, anchorage forces and lateral displacement of Type 2 wooden shear walls.

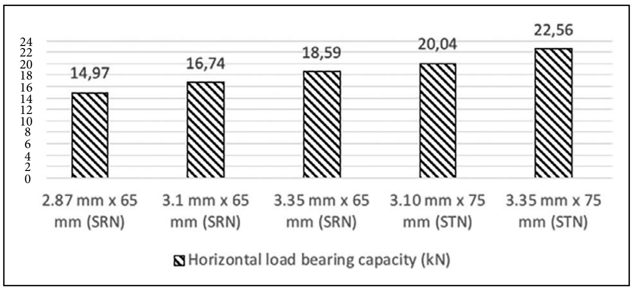


Figure 14. The effect of fasteners on the lateral load bearing capacity of Type1 and Type2 wooden shear walls.

The analysis demonstrated that the same sheathing thicknesses yield close results in segmented and perforated shear wall calculations. In both methods, the determining factor is the shear capacity of the wooden shear wall. The shear capacity of the wooden shear wall is directly proportional to the thickness of the sheathing. Furthermore, in segmented and perforated shear wall method, the percentage increase in lateral load bearing capacity due to sheathing thickness change was found to be less than the percentage increase in weight.

The opening layout within the shear wall is important in segmented and perforated shear wall calculations. As a result of the calculations, it was observed that the wall with a single opening could resist lateral load better compared to the wall with two openings in the same area. The comparison of two wooden shear walls using the same criteria (sheathing and design method) demonstrated that type 2, which has a single opening, resist more lateral load.

In the segmented shear wall calculation method, full-height wall segments between doors and windows are defined as shear wall segments. For this reason, more anchors are used in comparison to the perforated shear wall method. Increasing the number of anchors causes more connection detail solution and cost increase in the project.

In Eurocode 5 calculations; it has been observed that the selected sheathing thickness and the layout of the openings within the shear wall do not have a determining effect. The determining factor is the shear strength of the wooden shear wall. The most important factors affecting shear strength are diameter, the type and length of the nails. Eurocode 5 calculates 6 different collapse mechanisms in nailed connection calculations (Table 4-Fig. 10).

It is considered that the wooden shear wall examined within the scope of the study is a significant alternative for strengthening needs in the restoration of historical wooden buildings besides their use in new buildings. With sheathings to be covered on one or both sides according to the suitability of the existing wall system of historical buildings, the wooden frame turns into a wooden shear wall without increasing the weight of the system. In this way, the lateral load resistance increases and the performance levels against earthquakes is improved.

The study results are expected to create a scientific background for researchers and facilitate the re-evaluation of a globally-applied system for the restoration of existing structures and the production of new wooden building systems which are becoming increasingly widespread in Turkey.

Declaration of Competing Interest:

The authors declare that they have no known competing inancial interests or personal relationships that could have appeared to influence the work reported in this paper.

Authorship Contributions:

All of the authors have contributed equally to the article. Further, all of the authors have validated and approved the final manuscript.

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