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Research Article

THE EFFECT OF SOME TECHNOLOGICAL PROPERTIES OF PLYWOOD PANELS ON SEISMIC RESISTANT PERFORMANCE OF WOODEN SHEAR WALL

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ABSTRACT

Wooden buildings with many advantages such as being lightness, durability, earthquake resistant, healthy, insulating, and aesthetic are suitable for all kinds places especially in earthquake zones. The aim of this study is to investigate the effect of some technological properties of the plywood panels manufactured from some wood species grown in Turkey on seismic resistant performance of shear walls. Two different wood species (scots pine, spruce) and two different number of layers (5 and 7) were used in this study. Phenol formaldehyde resin was used as adhesive for plywood panels manufacturing. Bending strength and modulus of elasticity and density of plywood panels manufactured in an industrial plant were determined according to TS EN 310 and TS EN 323, respectively. Plywood panels were tested on full scale shear wall to determine the actual structural performance, maximum load and maximum displacement under the monotonic load according to ASTM E72. As a result of the study, the bending strength and modulus of elasticity values increased with number of layers for scots pine while the values decreased with number of layers for spruce. It was determined that maximum load values were increased for shear wall of each group with increasing bending strength and modulus of elasticity values of the plywood panels, while maximum displacement values of them were decreased.
Keywords: Shear wall, plywood, scots pine, spruce, seismic resistant performance.

1. INTRODUCTION

Light-frame wood construction is the primary building method for residential and light commercial structures and represents the largest portion of buildings in the United States. In recent years, light-wood framing has become a growing trend in midrise commercial and residential structures in part because of its economical construction technique, its wide availability of materials, and more recently because of its sustainability [1-2]. Wood diaphragms (walls, floors, and ceilings), which provide lateral stability, are important components of these

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structures. They consist of framing (studs, joists, and blocking), sheathing (wood structural panels), and fasteners (nails, screws, and staples), which connect the sheathing to the framing [3].

Structural systems with massive wooden shear walls are becoming widespread in construction practice, particularly for p re-cast buildings. These structural systems have excellent thermal and acoustic insulation performance [4]. The shear walls are used as lateral resistant system in platform frame construction in North America whereas in Japan and other eastern Asian countries, it is preferred as consisting of post and beam structures with wood to wood connections in traditional construction [5]. However, wood construction has not been widely used in Turkey. In Turkey, concrete buildings are preferred over wooden structures. Although Turkey is an earthquake country, there is few research on wood construction. Turkey does not have enough knowledge concerning the earthquake performance of wood based materials [3]. In light-frame wood structures, shear walls are popular structural systems to resist lateral forces acting on buildings such as wind and earthquake loading [6]. A typical light-frame shear wall is composed of sawn lumber framing members to which sheathing panels are attached with dowel-type fasteners such as nails or staples [7]. Plywood and OSB are the best sheathing materials for resisting earthquake loads, because they are able to tolerate the greatest amount of displacement before failing. Moreover, when a wood-frame house is properly designed and constructed, plywood sheathing will not decay, and hence, will retain sufficient strength in the long term [3,8].

A shear wall has two structural functions: lateral strength and stiffness. A shear wall must provide the necessary lateral strength to resist horizontal forces, such as those from wind or from an earthquake. When shear walls are strong enough, they transfer these horizontal forces to the next element in the load path below them, such as other shear walls, floors, foundation walls, slabs, or footings, primarily through the lateral resistance of the fasteners, which are usually nails [9]. In general, the strength, stability, and life of a structure largely depend on the strength, rigidity, and durability of the joints [10]. In the case of shear walls sheathed with wooden structural panels, the strength primarily comes from the strength of the sheathing fasteners [11]. The stiffness of a shear wall depends on the combined stiffness of its three components: lumber, sheathing, and fasteners. The connections, such as sheathing nails, in the shear walls provide ductility, damping, and energy dissipation through mechanisms such as internal friction, unrecoverable damage, connection failure, and yielding of the metal fasteners [12-13]. Altering the initial stiffness, resistance, or energy dissipation capacity of a lateral load resisting system can affect the performance of a structure [14]. However, their structural behaviour, especially under seismic action, is still required to be demonstrated, since their resistance, stiffness, ductility and dissipative properties must be fully assessed [3].

The evaluation of seismic performance of shear walls is essential for the seismic design of timber structures especially if the mechanical properties of the structures are governed by those of shear wall elements. The seismic performance of shear walls can be determined by the following criteria from the reversed cyclic and monotonic lateral loading tests, the initial stiffness, the yield strength, the ultimate strength, the ductility and the hysteresis damping [15].

Even though Turkey is an earthquake country, new developments and studies about the wooden buildings have not been followed in the country, causing there is few research on wood construction. The aim of this study is to investigate the effect of some technological properties of the plywood panels manufactured from some wood species grown in Turkey on seismic resistant performance of shear walls.

2. MATERIALS AND METHOD

2.1. Wood Material, Manufacturing of Plywood

Scots pine (*Pinus slyvestris*) and spruce (*Picea orientalis L.*) were used in this study. The logs were obtained from Trabzon region. The logs were steamed for 12-16 hours before veneer production. A rotary type peeler (Valette& Garreau - Vichy, France) with a maximum horizontal holding capacity of 800 mm was used for veneer manufacturing and rotary cut veneer sheets with dimensions of 1.2x2.4 m by 2 mm were clipped. Vertical opening was 0.5 mm and horizontal opening was 85% of the veneer thickness in veneer manufacturing process. After rotary peeling, the veneer sheets were oven-dried at 110°C, for 5-7% moisture content in a laboratory scale jet veneer dryer (manufactured by Hildebrand Holztechnik GmbH).

Five and seven-ply plywood panels, 10 and 14 mm thick, were manufactured by using phenol formaldehyde (PF) glue resin with 47% solid content. Veneer sheets were conditioned to approximately 6–7% moisture content in a conditioning chamber before gluing. The glue was applied at a rate of 160 g/m^2 to the single surface of veneer by using a four-roller spreader. The assembled samples were pressed in a hot press at a pressure of 8 kg/cm^2 and at 140°C for 10 and 14 min. Two replicate plywood panels were manufactured from each group.

2.2. Bending Strength, Modulus of Elasticity and Density

Bending strength and modulus of elasticity tests was carried out for plywood panels manufactured according to EN 310 [18] standard. Twenty samples were used for the evaluation of plywood bending strength and modulus of elasticity. Density of plywood panels manufactured in industrial plant were determined according to EN 323 [17]. Twenty samples were used for the evaluation of plywood density.

2.3. Manufacturing of Shear Wall Sheathed Plywood and Determination of Its Seismic Resistant Performance

The test specimen, 2.4 by 2.4 m, was assembled to frame as shown in Figure 1. The frame elements are made of spruce timber in 5x10 cm sizes, and the upper and the edges are made of two pieces of timber beam. 12 pieces of 0.05x0.1x2.4m = 0.012 m^3 timber was used for each group test frame. Two repetitive systems were installed for each test group. The connection to the concrete floor of the frame system was made with appropriate fasteners (Figure 2). The plywood panels were fastened frame with 8d (76mm) common nails. The distance between the fasteners was 76 mm at the edge of the panel and 152 mm at the center of the panel.

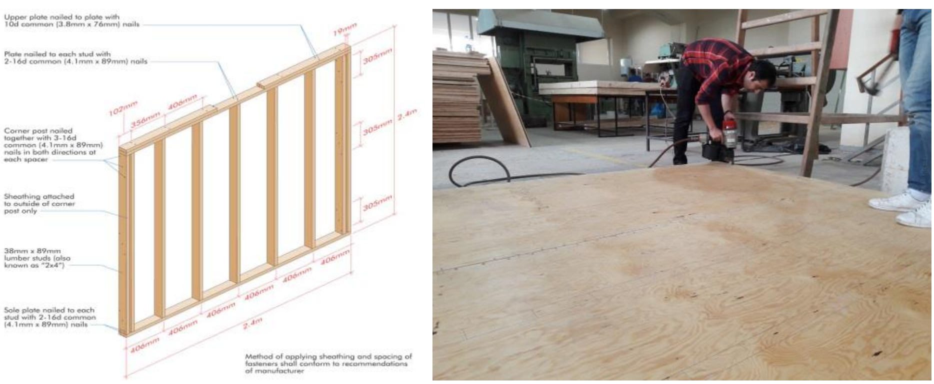

Figure 1. Standard wood frame and plywood sheathing

Figure 2. Mounting of shear wall to floor

Shear wall analysis test was carried out under linear load according to ASTM E72 [18] standard. The schematic representation and visual representation of the test setup is given in Figure 3.

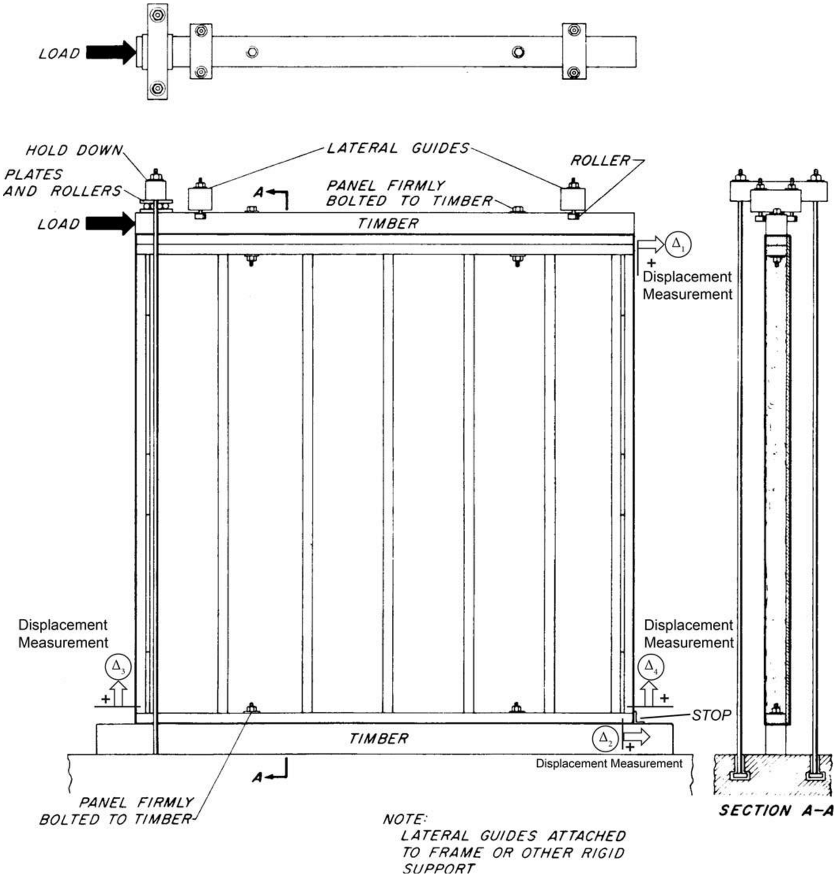

Figure 3. Racking load assembly

Shear wall analyses were carried out according to the ASTM E72 [18] standard for displacements under loads of 354 kg, 712 kg and 1071 kg. The load was then loaded up to the maximum load that the shear wall could carry and displacements at the maximum load were determined. Initial stiffness, by selecting the points closest to 10 and 40% of the maximum load and fitting a straight line to the intervening points, were also calculated from this test.

3. RESULTS AND DISCUSSION

The density, bending strength and modulus of elasticity values of the plywood panels are given in Table 1 according to wood species and number of layers. Besides, stiffness, maximum load and maximum displacement at maximum load values of the shear wall sheathed Scots pine and spruce plywood are given in Table 1. Deformations at the end of the test of the shear walls using two plywood panels in the frame are shown in Figure 4-7.

Table 1. Test results of some technological properties of plywood and shear wall

Wood Species	Number of Layers	Density (g/cm^3)	Bending Strength (N/mm^2)	Modulus of Elasticity (N/mm^2)	Maximum Load (kg)	Maximum displacement (mm)	Stiffness (kN/mm)
Scots pine	5	0.585	64.27	7432.92	3876	61.64	1.28
	7	0.663	76.39	9878.15	4685	44.22	1.81
Spruce	5	0.510	53.24	6279.11	4329	69.34	0.99
	7	0.487	44.84	5527.11	3071	79.65	1.01

Figure 4. Deformations at the end of the experiment in the shear wall sheathed 5-ply Scots pine plywood

Figure 5. Deformations at the end of the experiment in the shear wall sheathed 7-ply Scots pine plywood

Figure 6. Deformations at the end of the experiment in the shear wall sheathed 5-ply spruce plywood

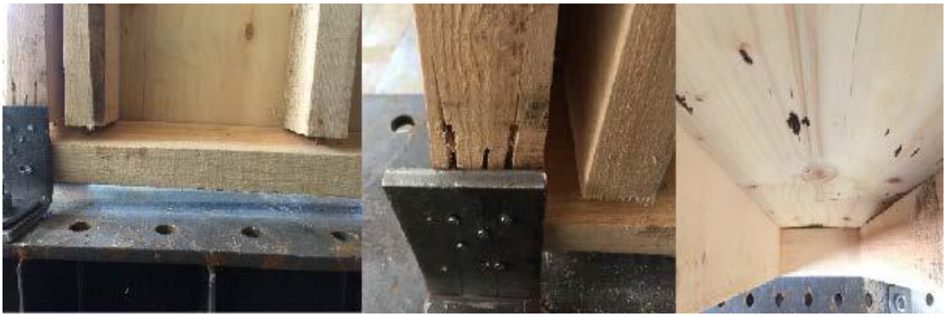

Figure 7. Deformations at the end of the experiment in the shear wall sheathed 7-ply spruce plywood

According to the obtained results, the bending strength values of the plywood panels with 7 layers were found higher than those of the panels with 5 layers in the Scots pine plywood. In spruce plywood, the panels with 5 layers gave slightly higher values. It might be explained the effect of density of the panels on mechanical properties. Because density values of 7-ply spruce plywood panels were lower than 5-ply spruce plywood panels. It is known that panels density has positive effect on the bending strength [19]. It is stated that the mechanical properties of the plywood produced from the veneers of density woods are higher [20]. When examined in terms of wood species, the highest density values were found in Scots pine plywood and the lowest values in spruce plywood. The primary impact on the density of the plywood is wood specie [21]. Demirkır et al. [19] also stated that the difference in density values of plywood panels might be resulted from the raw material density. In the literature, the density of the Scots pine wood is determined as 0.49 g/cm^3, and the density of spruce wood is determined as 0.43 g/cm^3 [22]. As similar with the results in present study, Peker and Tan [23] found that the bending strength and modulus of elasticity values decreased with the increase in the number of layers in spruce plywood. The bending strength values of all plywood panels met the requirements (40 N/mm^2) given in DIN 68705-3 [24].

As can be seen from Table 1, the maximum load values of the shear wall sheathed plywood panels increased with increasing the bending strength and modulus of elasticity values of the panels. However, maximum displacements at maximum load are reduced by increasing these values. It is stated that the lateral load resistance of a timber frame system depends on the rigidity of the timber, the coating material and the connecting elements used on the shear wall [25]. The lateral resistance of shear walls is generally influenced by 4 factors which are stiffness, bending strength, resistance at break and ductility [21]. Stiffness defined as the rigidity of an object is one of the most important factors affecting stability of buildings. The highest rigidity value was obtained from Scots pine 7-ply plywood panels as seen in Table 1.

4. CONCLUSIONS

Recently, it is focused on awareness of earthquake and development of earthquake-resistant structures in Turkey. Prime Ministry Disaster and Emergency Management Presidency has announced that studies about designing of the earthquake resistant building, materials and standards are supported under the earthquake strategy and action plan 2012-2023 Strategy B.1.3. Wooden buildings with many advantages such as being lightness, durability, earthquake resistant, healthy, insulating, and aesthetic are suitable for all kinds places especially earthquake zones. However, Turkey does not have enough knowledge concerning the earthquake performance of wood based materials. If studies regarding wooden structures and materials are increased, more natural and safe buildings can be built. The aim of this study is to investigate the effect of some technological properties of the plywood panels manufactured from some wood species grown in Turkey on seismic resistant performance of shear walls. As a result of the study, the bending strength and modulus of elasticity values increased with number of layers for scots pine while the values decreased with number of layers for spruce. It was determined to increase maximum load and decrease maximum displacement for shear wall of each group with increasing bending strength and modulus of elasticity values of the plywood panels.

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