Sigma J Eng & Nat Sci 11 (2), 2020, 127-134

Publications Prepared for the Sigma Journal of Engineering and Natural Sciences
Publications Prepared for the ORENKO 2020 - International Forest Products Congress Special Issue was published by reviewing extended papers

Research Article

DETERMINATION OF DAMAGE AND DEFECTS IN HISTORICAL WOODEN STRUCTURES USING NONDESTRUCTIVE TEST DEVICES

Engin Derya GEZER*[1], Büşra AYDOĞAN SELÇUK[2]

[1]*Karadeniz Technical University, Dept. of Forest Industry Eng., TRABZON;* ORCID:0000-0001-9657-7290
[2]*Karadeniz Technical University, Dept. of Forest Industry Eng., TRABZON;* ORCID:0000-0002-1893-7884

Received: 28.11.2020 Accepted: 03.12.2020

ABSTRACT

The rich accumulation of historical and cultural mosaic of Anatolian geography can be found in Rize. The examples of civil architecture in the region have survived to the present day, largely without deteriorating their original qualities. The preservation of the historical urban texture in the region where the historical wooden structures that defy the centuries are intense are of great importance in terms of transferring to future generations and maintaining the cultural memory. There are not many studies in the forest industry engineering literature to determine the damage and defects in historical wooden structures and to protect the original texture of these defects. Within the scope of the study, a research was conducted in Cinan mansion, a 200-year-old wooden mansion in Rize Pazar district. In this study, the damage and defects in the historical wooden structure were determined by non-destructive test methods. In addition, screw holding, shear and elasticity modulus of the wooden carrier beams in the structure were determined. With this study, it is aimed to determine the defects and damages in historical wooden structures and to develop appropriate protection techniques that can contribute to the solution of the problems encountered. In addition, it is aimed to be able to intervene without damaging the texture of the wooden structure and to ensure the sustainable use of historical wooden structures for many years.
Keywords: Historical wooden structures, Non-destructive tests, deterioration and decay.

1. INTRODUCTION

The rich accumulation of historical and cultural mosaic of Anatolian geography can be found in Rize. The examples of civil architecture in the region have survived to the present day, largely without deteriorating their original qualities. The preservation of the historical urban texture in the region where the historical wooden structures that defy the centuries are intense are of great importance in terms of transferring to future generations and maintaining the cultural memory. There are not many studies in the forest industry engineering literature to determine the damage and defects in historical wooden structures and to protect the original texture of these defects.

Today, restoration works of wooden structures are generally perceived to be carried out under the monopoly of architects or civil engineers. It is obvious that the knowledge of forestry industrial engineering having technical knowledge about wood material is not benefited and, it is identified with architects and is addressed only from an architectural perspective. Despite all

* Corresponding Author: e-mail: gezer@ktu.edu.tr, tel: (462) 377 15 32

technological developments, wood has continued its existence in many different areas, especially in the fields of architecture and design, and forest industry. Wooden material has been preferred in all periods because of its advantages (Sayar et al, 2009). However, wood material is very weak when it cannot be protected against negative external factors. Sustainable use of wood materials is also of great importance in terms of its role in carbon storage and the carbon cycle (Erdin, 2003; Lippke et al, 2010). Wooden structures also play an active role in reducing global warming, as they continue to store carbon as long as they live.

In expanding the service life of wooden materials in historical structures it is essential to assess drilling resistance, screw holding, shear and elasticity modulus of the wooden carrier beams in the structure. Historical wooden materials must be preserved in order to maintain their original structural purpose as much as possible, and to protect our values and ensure that this heritage can survive for generations. This is partly caused by the concept of globalization, which is under the control of strong economies and aims at the unification of all life expressions at a single level that lead to the disappearance of cultural heritage over time. In order to restore and keep the historical and wooden structures alive without damaging their original texture, the damaged or defective areas of the wooden material should be removed with appropriate intervention methods. Therefore, an accurate condition assessment is needed to evaluate the serviceability of the materials. One of the most convenient way of determining the mechanical properties, deterioration and decay is non-destructive methods.

On the other hand, there are several non-destructive methods that can be used in the assessment and determination of the quality and properties of wooden structures (Niemz, 2009):

- mechanical (drilling resistance, hardness, intrusion behavior);
- electrical (correlation between electrical resistance and moisture, correlation between electrical resistance and fungal decay);
- acoustic (sound velocity, sound reflection, sound attenuation);
- thermal (heat radiation);
- electromagnetic waves (visible light, IR/NIR radiation, X-ray, neutron radiation, Synchrotron radiation).

In the light of the information given above, the aim of this study is to determine the defects and damages in historical wooden structures in Rize Region through non-destructive methods such as drilling resistance, screw holding, shear and elasticity modulus and to develop appropriate protection techniques that can contribute to the solution of the problems encountered.

2. MATERIAL AND METHODS

In this study, a mansion situated in Rize Pazar district called Cinan mansion (Figure 1), which is about 200 years old and made from chestnut wood, was studied. Wooden materials were taken from different exterior sides of the mansion.

The damage and defects in the historical wooden structure were determined by non-destructive test devices including Resistograph, FAKOPP Screw withdrawal resistance meter and FAKOPP Microsecond Timer. In addition, screw holding, shear and elasticity modulus of the wooden beams in the structure were determined.

2.1. Resistograph

The IML-RESI F-300 instrument is used to inspect structures such as poles and beams. Often, possible defects are located in the interior of the wooden structures and can’t be identified from the outside. The IML-RESI System is based on a drilling resistance measuring method. The variation in resistance results in increases and decreases in the amount of torque applied to the drill shaft. A drilling needle with a diameter of 1.5 mm to 3.0 mm penetrates into the wooden structure with a regular advance speed, and the drilling resistance is measured. The data is recorded on a wax paper strip at a scale of 1:1 and also transferred to computer for further evaluation. The wood is only insignificantly injured, and the drilling hole closes itself due to a special drilling angle that was customized for the drill bit. (Gezer et al., 2015)

Figure 1. Cinan Mansion, Pazar-Rize

2.2. Screw withdrawal resistance meter

Screw withdrawal force is an indicator of the wood material strength, density and shear modulus. Fakopp Enterprise developed a portable screw withdrawal force meter. The applied screw diameter is 4mm, the length of the thread is 18 mm. The screw withdrawal force is a local parameter but selecting a representative location on a beam it is a useful information in wooden structure evaluation. (Fakopp Enterprise, 2010).

2.3. Microsecond Timer

Microsecond Timer equipment developed by FAKOPP designed for evaluation of living trees. The equipment is able to detect holes, decay, cracks in trees by non-destructive technique. FAKOPP measures the transit time of stress wave between two transducers. Another important application of the equipment is the determination of residual strength of old timbers and log evaluation. (Fakopp Enterprise, n.d.).

3. RESULTS AND DISCUSSION

3.1. Resistograph:

The wooden beams in basement and north, south, east facing exterior of the Cinan Mansion were evaluated by Resistograph in order to determine the internal defects and deteriorations. Some of the Resistograph outputs obtained are given in Figure 2. As shown in the outputs, the higher peaks represent the solid zone whereas the lower peaks represent the decay, cracks, splits or deteriorated zones.

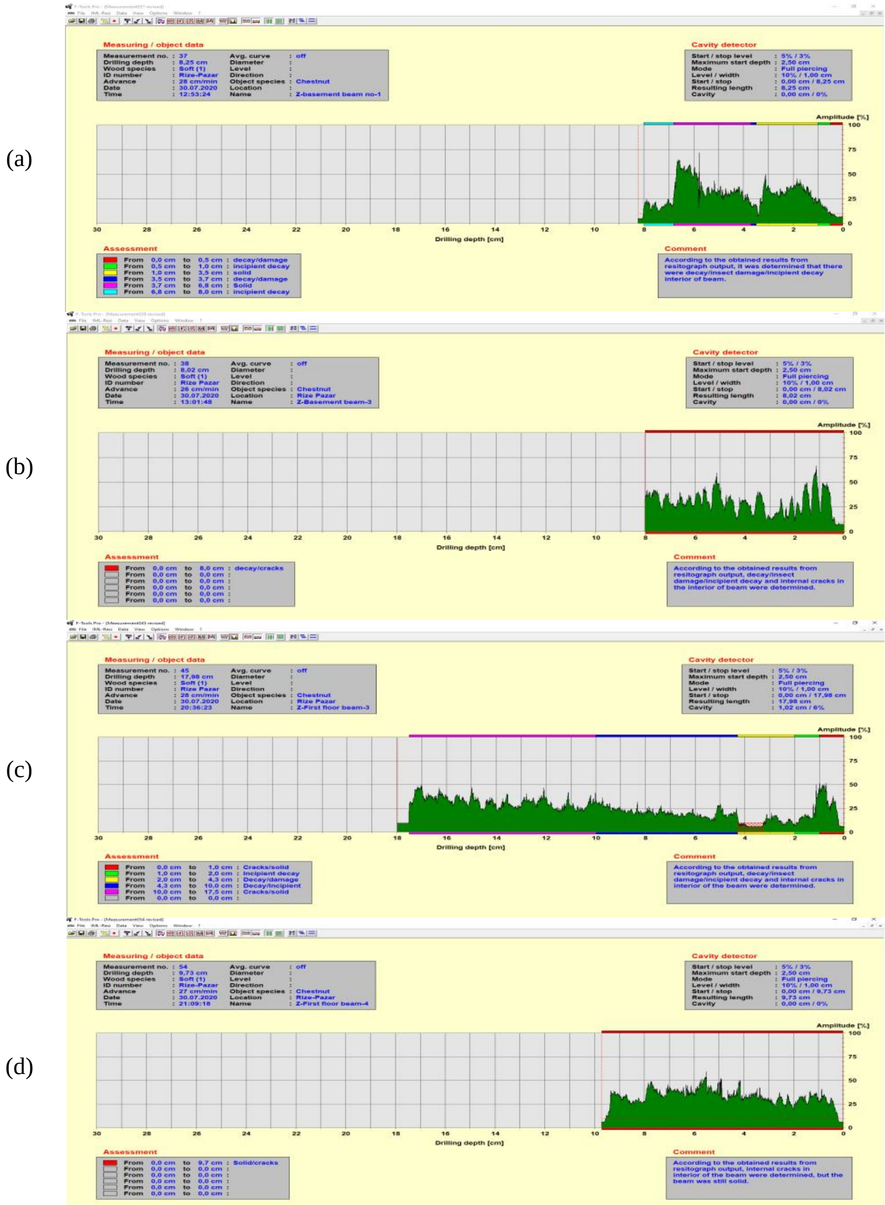

Figure 2. Some Resistograph output of the beam

The results indicate that beams in (a) and (c) had damage, rot, cracks/voids in the interior. Rot/insect damage and the onset of rot were detected in the inner parts of the beam examined. As shown in the shaded area in (b), internal cracks with rot insect damage were detected in the inner parts of the beam. (d) output internal cracks in interior of the beam were determined but the beam was still solid.

3.2. Screw withdrawal resistance results:

Six measurements were made on the basement floor, seven on the north and south sides, and one on the west side of the historical wooden building. Screw withdrawal values and shear resistance of the wood material were showed in Table 1.

Table 1. Screw withdrawal resistance meter results

Basement	Screw withdrawal (kN)	Shear resistance (MPa)
1B	0,94	420,11
2B	1,84	622,16
3B	1,64	576,91
4B	1,73	598,42
5B	1,89	633,36
6A	1,00	433,10
Entrance floor (North)		
1	1,40	523,15
2	1,27	493,58
3	1,49	543,76
4	1,47	539,73
5	1,49	542,86
6	1,20	479,25
7	1,21	481,49
South		
8	1,05	444,75
9	0,95	422,35
10	0,96	425,04
11	0,98	429,52
12	1,04	442,06
13	0,60	344,40
14	0,92	416,08
East		
15	1,07	450,13

Screw withdrawal resistance values of the beams in the wooden structures examined during the study were determined between 0.60 and 1.89 kN. Measurement results were assessed according to EN 338 standard (2003). According to the results, second and fifth beam have shown the highest shear resistance and same beams also have the highest screw withdrawal resistance. The lowest results were obtained from the beam in the Southern side.

3.3. Fakopp Microsecond timer results:

The sample graph for determining the time correction coefficient of a measurement made on the wooden beams determined in the study area is given in Figure 6. The speed of sound in wood material is regulated according to the correction coefficient.

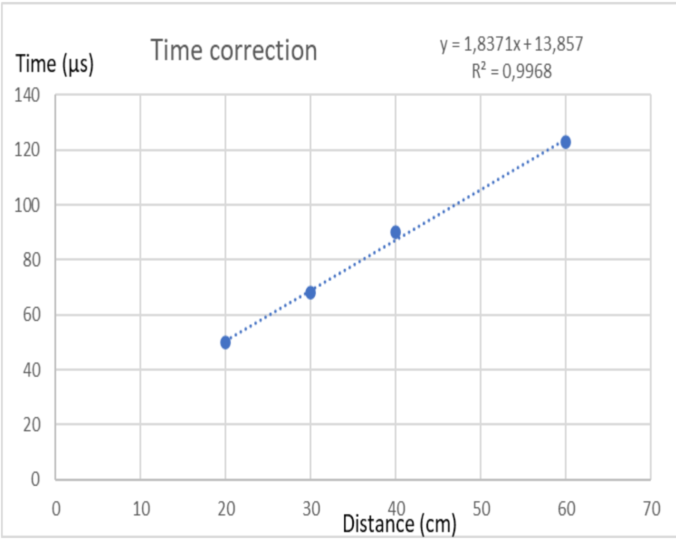

Figure 6. Microsecond Timer (V = distance / (transit time - correction))

Six measurements were made on the basement floor, seven on the north and south sides, and one on the west side of the historical wooden building for Fakopp Micro Second Timer results. As seen in Table 2, while the speed of sound is higher in the solid parts, the speed of the sound decreases in the rotten and destructive parts.

Table 2. Microsecond Timer results

Basement	Velocity [m/s]	Entrance floor North	Velocity [m/s]
1B	45,09	1	44,42
2B	39,71	2	44,09
3B	41,07	3	44,42
4B	44,75	4	44,09
5B	39,20	5	44,42
6A	46,48	6	44,09
		7	45,77
South	Velocity [m/s]	East	Velocity [m/s]
8	41,94	15	41,94
9	43,77		
10	44,75		
11	44,42		
12	29,18		
13	65,88		
14	50,81		

Generally, the highest velocity was detected in the northern side; the lowest velocity was measured in the basement and the southern side. In general, the mechanical strength properties of the beams tested fall into classes D35 and D70 in accordance with the EN 338 standard and may still be used.

As a result of the investigations carried out with the Resistograph device, it was determined that some of the beams had partial damage, while some of them had severe damage/cracks/decay However, some of the beams recommended to be changed as a result of the findings obtained from both visual inspections and examinations made with non-destructive test devices. The screw withdrawal resistance, bending and shear strengths of the beams were calculated thanks to the data obtained with the non-destructive test device and it was determined that the strength properties of the beams had the lowest resistance properties in this structure in the resistance classes specified in the EN 338 standard. Although these beams still had enough strength properties, it might be recommended to replace them considering the fatigue resistance due to the service life.

4. CONCLUSION

1. As a result of the investigations carried out with the Resistograph device, it was determined that some of the beams had partial damage, while some of them had severe damage/cracks/decay.
2. Generally, the mechanical strength properties of the beams examined fell into D35 and D70 classes according to EN 338 standard and it may be still possible to use them. However, some of the beams recommended to be changed as a result of the findings obtained from both visual inspections and examinations made with nondestructive test devices.
3. The screw withdrawal resistance, bending and shear strengths of the beams were calculated thanks to the data obtained with the nondestructive test device and it was determined that the strength properties of the beams had the lowest resistance properties in this structure in the resistance classes specified in the EN 338 standard. Although these beams still had enough strength properties, it might be recommended to replace them considering the fatigue resistance due to the service life.

Acknowledgments

This work has been funded by the Scientific Research Project Coordination Office of Karadeniz Technical University (Project No: FBA-2019-8102).

REFERENCES

[1] EN, B. (2003). 338: 2003. *Structural timber–Strength classes*. Erdin, N. ‘’Ağaç Malzeme Kullanımı ve Çevreye Etkisi’’. Türkiye Mühendislik Haberleri Sayı 427, 2003/5. 96-100. http://www.imo.org.tr/resimler/dosya_ekler/5ab2602e73575e4_ek.pdf?dergi=168 Son erişim tarihi: 24 Ocak 2019.

[2] Fakopp Enterprise (2010). *User's guide: Screw withdrawal resistance meter*. https://www.fakopp.com/docs/products/withdrawal/withdrawal_guide.pdf

[3] Fakopp Enterprise (n.d.). *Fakopp Microsecond Timer User’s Guide*. https://www.fakopp.com/docs/products/mstimer/Fakopp_MT_Guide.pdf

[4] Gezer, E.D.; Ali Temiz, A.; Yüksek, T. Inspection of wooden poles in electrical power distribution networks in Artvin, Turkey. Adv. Mater. Sci. Eng. 2015, 2015, 1–11.

[5] Lippke, B., Wilson, J., Meil, J., Taylor, A. 2010. ‘’Characterizing the importance of carbon stored in wood products’’. Wood and Fiber Science: Journal of the Society of Wood Science and Technology. 42(CORRIM Special Issue). 5-14.

[6] Niemz, P. (2009) Methods of non-destructive wood testing. Zurich: Institute for Building Materials.
[7] Sayar, Z., Gültekin N, A., Dikmen, B., Bilgin, Ç. 2009. "Sürdürülebilir Mimarlık Kapsamında Ahşap ve PVC Doğramaların Değerlendirilmesi", 5. Uluslararası İleri Teknolojiler Sempozyumu (İATS'09), 2067-2072.