Evaluation of historical wooden structures using nondestructive methods

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Abstract Paper demonstrates a technique for residual bending strength prediction of old wooden beams, based on stress wave velocity, screw withdrawal resistance determination and drill sampling. Wood NDT techniques are supporting the restoration of historical wooden structure and parallel saves old wood material.

Keywords Strength prediction, stress wave, screw withdrawal resistance

1. INTRODUCTION

Jozsef Bodig Nondestructice Evaluation of Wood Laboratory of the University of West Hungary has developed a strength prediction procedure for in-service wooden beams. The strength predictor parameters are the stress wave velocity and screw withdrawal resistance

2. NONDESTRUCTIVE WOOD-STRUCTURE EVALUATION

2.1. The basic concept

Structural engineer selects the wooden beams for the evaluation, based on the importance in a structure. Typically the main load bearing members are selected and those where degradation is expected based on the location and visual inspection. In a previous study (Divos 1997) we developed a strength predictor formula for in-situ applications. The best strength predictor parameter is modulus of elasticity (MOE), this is the concept of Euro Norm 338. The dynamic $MOE = \rho V^2$ where ρ is density, V is the p-wave velocity in fiber direction. In-situ velocity determination is rather easy, but density determination is difficult. For predicting the density we selected screw withdrawal resistance. These parameters - velocity and screw withdrawal resistance - are statistically independent parameters. This two-parameter formula provides good MOR estimation, whereby the standard error of estimation is less than 9 MPa. The MOR estimation formula is constructed according to the dynamic MOE formula:

$$MOR_{est} = aF_{screw} \cdot V^2 + b$$

where: F_{screw} is the screw withdrawal resistance, V is the velocity, a and b are empirical parameters. Empirical parameters are calculated from rupture test of hundreds of full size beams. European Norm

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for Strength classes of structural lumber (EN338) dealing with two species groups: conifer and deciduous species. Using this principle we have determined the empirical parameters *a* and *b* for conifer and deciduous species. The correlation coefficients between the bending strength and MOR_{est} is 0,74. Figure 1. shows the correlation between MOR and the above predictor parameters.

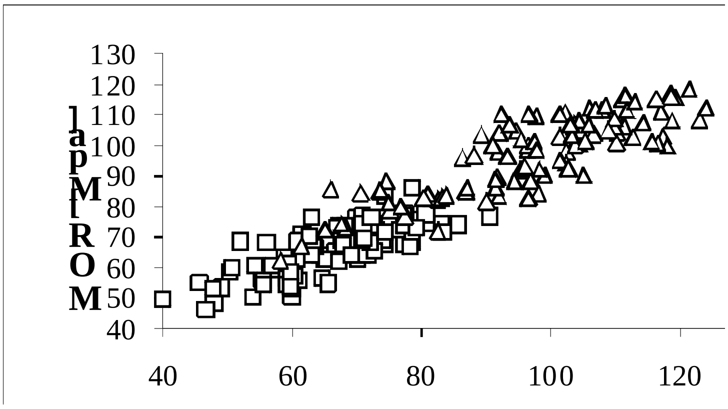

Figure 1 – Correlation between MOR and predictor. □ represents coniferous, ∇ represents hardwood specimens.

2.2. Screw withdrawal resistance measurement

For screw withdrawal resistance determination we are using a Hungarian made tool. The screw diameter is 4 mm, and the length of the thread is 18mm. Rest of the thread is removed. If it is driven deeper into the wood material its effective length remains 18mm. We need to select a location for the test that is represents the beam, because screw withdrawal resistance is a local parameter. Proximity of crack and knots would provide wrong data. The screw is slowly (0.2 - 0.4 mm/s) pulled out, and the maximum force value is recorded by the electronics. This is the screw withdrawal resistance. The screw withdrawal resistance is well correlated with density. That is why we use screw withdrawal resistance as density predictor.

2.3. Determination of the stress wave velocity in the longitudinal direction

A portable microsecond timer called FAKOPP Microsecond Timer is used to measure the stress wave time in longitudinal direction. The timer is connected with two piezoelectic type sensors, which are equipped with 60mm long spikes. The spikes can be driven into the wood by hitting the sensor on the end with a hammer, because the high sensitivity transducers are shock resistant. The stress wave is generated by a simple hammer knock. The weight of the hammer is 200g. The velocity is calculated from the measured transit time and the distance between the sensors. Stress wave technique is accepted for timber bridge inspection. Using a long cable 11 m long beams can be measured without difficulty, but most of the time we test shorter (1-3 m) sections. The test is quick, two experienced person can carry out the test within 30 seconds.

2.4. Drill sampling

To obtain exact information about the inner layers of the beam, we are using drill samples. The applied screw diameter is 5mm. We used the particles falling out of the hole to verify the strength measurement described above. The consistency and odour of the particles were used to judge about the quality of the wood, according to the particle conditions. Conglomerating particles indicates good, loose particle medium and crumbling particle indicates poor beam quality.

3. CONCLUSION

Nondestructive evaluation of wooden structures are becoming a regular practice, especially when the function of the building is changing. Reliable prediction of modulus of rapture and modulus of elasticity of individual beams is possibel by stress wave technique and screw withdrawal resistance determination.