WOOD RESEARCH
60 (3): 2015
409-416

COMPRESSIVE STRENGTH OF WOOD *PINUS SYLVESTRIS* DECAYED BY *CONIOPHORA PUTEANA* FUNGI AND REINFORCED WITH PARALOID B-72

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(Received March 2014)

ABSTRACT

Compressive strength along the grain tests were performer for sound wood and wood decayed in laboratory conditions. Tests were made on Instron 3382 testing machine. For impregnation, most common in Poland Paraloid B-72 toluen solution was used. Paraloid B-72 was introduced into the wood by vacuum metod. Testing showed effectiveness of fungi decayed wood reinforcement by Paraloid B-72.

KEYWORDS: Wood consolidation, structural reinforcement of wood, Paraloid B-72, *Coniophora puteana*, compressive strength.

INTRODUCTION

Wood as a natural material is susceptible to aging and destructive processes, caused by fungi and insects. Such processes are common to wooden antiques. Decayed wood in antique objects requires conservator's intervention. Usual conservational procedures contain drying, clearing, sterilizing filling and structural reinforcement.

Synthetic polymers solutions in organic solvents are commonly used for structural reinforcement of degraded wood. Polymers, injected into wood, after evaporation of solvents, reinforce structure of the material (Unger et al. 2001).

Research of application of synthetic resins for wood protection is being conducted since nineteen seventies. Epoxy resins in such applications were tested by Soldenhoff (1987) and Schaffer (1974). Buksalewicz et al. (1987), Schniewind and Eastman (1994) tested acrylic resin.

Research of penetration of consolidating liquid for wood were performed also by Kučerová et al. 2009, Tudace et al. 2011, Kučerová 2012.

Testing of wood acrylate treated and subsequently attacked by *Coniophora puteana* and

Gloeophyllum trabeum were made by Reinprecht et al. (2001), Reinprecht (2009) and Tiralová and Reinprecht (2004).

Compressive strength tests of wood decayed by fungi in natural conditions, and comparative testing of wood reinforced by Paraloid B72 were made by Buksalewicz et al. (1987) (*Pinus sylvestris* degraded by *Anobium* spp.), Jankowska et al. (2010) (*Pinus sylvestris* decayed by *Phellinus pini*), Mańkowski et al. (2012) (*Pinus sylvestris* decayed by brown rot fungi).

Fungi decay of wood in natural conditions is often non-homogenous. Effectively, when degree of decay caused by fungi varies, loss of wood mass and strength becomes variable, which again causes significant spread of wood density values, as well as variable polymer retention and mechanical properties.

In aim to unify properties of wood used for testing (infected by *Coniophora puteana* fungus) presented work bases on wood decayed by fungi in controlled way, in laboratory conditions.

Aim of the work was to determine major axis compression strength of pine wood (*Pinus sylvestris*) decayed by *Coniophora puteana* fungus, and consolidated with Paraloid B-72.

MATERIAL AND METHODS

Tests were made on *Pinus sylvestris* L. sapwood samples, degraded by brown rot fungus *Coniophora puteana* Karst. in laboratory conditions.

It was assumed that pine wood (sapwood) will be most suitable for testing, because of wide application and vast amount of literature for mycologic research.

Wood coming from demolition is the easiest one to obtain for research purposes, it is usually naturally fungi infected. However, proper selection of similar samples with similar degree of decay is problematic. Tests on naturally decayed samples have undeterminate measurement error, caused by mentioned problematic selection of similar samples. It was decided then, to grow the fungus in laboratory conditions.

Samples 20×20×30 mm were used for tests (last dimension in axial direction). Samples were defectles, with growth rings paralel to axis. Tested was 200 wood samples.

Samples were dried down to the constant weight in vacuum kiln at 40°C, after that measured. Thewood density in oven dry state was calculated according formula.

$$g = m_0 \times V^{-3} \qquad (g.cm^{-3}) \qquad (1)$$

where: g – density,
m_0 – mass of dry sample,
V – sample volume.

Preparation of samples was performed in accordance to PN-D/79-04102 (1979) standard. Samples were divided into four groups:

* Control samples (K),
* Control samples saturated with 15 % Paraloid B-72 solution (K B-72),
* Decayed by fungus (G),
* Primary decayed by fungus, and subsequently saturated with 15 % Paraloid B-72 solution G B-72).

Testing method applied was conforming to PN-EN 113: 2000 standard. Mycelium of *C. puteana* was grown on malt-agar nutrient in sterile Kolle flasks at temperature 23±0.5°C and air relative humidity 75 %. Wood samples were thermally sterilized before tests for 30 minutes, and exposed to fungus for 8 weeks. After degradation, samples were removed from flasks, cleaned of surface mycelium and dried in oven to constant mass. Basing on the measurement results before and after exposure to fungus, mass loss caused by *C. puteana* was calculated according formula.

$$\Delta m = 100\ (m_k - m_p)m_p^{-1} \qquad (\%) \qquad (2)$$

where: Δm – mass loss,
m_k – mass after degradation by fungus,
m_p – mass before degradation by fungus.

In aim to maintain corresponding test conditions in control samples compressive strength tests, these samples were undergoing the same procedures as samples designated for fungus exposure.

Control samples designated for saturation (K B-72) and fungus decayed samples designated for saturation (G B-72) were consolidated with 15 % Paraloid B-72 toluene solution. Vacuum impregnation was performed in the following conditions: Vacuum pressure 0.1 MPa, temperature 121°C, time 30 min. After that pressure reactor was brought up to atmospheric pressure, samples remained in Paraloid B72 solution for another 24 hours. Samples were removed from the solution, cleaned off from remaining impregnate solution, and conditioned for 3 months at temperature 23±0.5°C and air relative humidity 75 %.

Compressive strength in along the grain was measured with Instron 3382, in accordance PN-79/D-04102 (1979) standard.

RESULTS AND DISCUSSION

Pine wood samples of average density in the oven dry state is 0.456 $g.cm^{-3}$ were used for testing. Measured density is lower than average density for this species (0.520 $g.cm^{-3}$) presented in Krzysik (1974).

Tab. 1: Basic parameters of pine wood samples (before saturation and destructive testing).

	Density in oven dry state ($g.cm^{-3}$)
Minimum	0.402
Maximum	0.538
Average	0.456
Standard deviation	0.029

Basic parameters of test material are presented in Tab 1. Initial density distribution was similar to Gaussian, insignificantly asymmetric on the right side (Ws=0.22) and flat (k= -0.42).

Wood samples with lower initial density showed higher loss of density after fungus. For initial density of 0.400 $kg.m^{-3}$ loss averaged of 20 %, with higher initial density of 0.540 $kg.m^{-3}$ only around 7 % (Fig. 1). Such results conform to literature data (Ważny 1959).

In case of control samples, Paraloid B-72 saturation caused visible increase of density (Fig. 2). Such increase was similar with wood samples of low and high initial density. High coefficient of determination r^2 testified about high dependence between analyzed factors. For wood decayed *C. puteana* similar dependence was noticed, but with much lower r^2 (Fig. 1). Similar dependence between density and saturation was confirmed Jankowská et al. (2010). For decayed wood with density 350 kg.m^{-3}, measured retention reached 160, again 500 wood retention equaled 130 kg.m^{-3}.

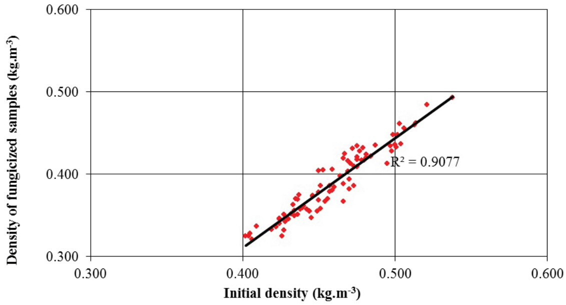
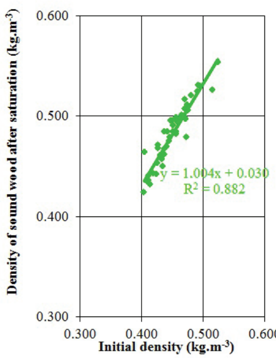


Fig. 1: Relation between densities of natural wood and wood decayed by brown rot fungus C. puteana.



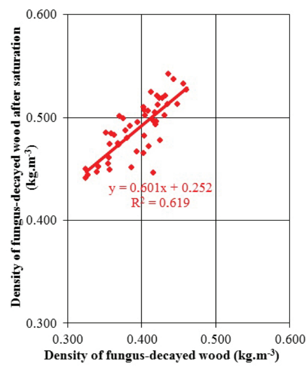


Fig. 2: Dependence between density of fungus-decayed wood before and after saturation with Paraloid B72.

Fig. 3: Dependence between density of sound wood before and after saturation with Paraloid B72.

Sound wood reinforced with Paraloid B-72 resulted in insignificant increase of compressive strength (Fig. 4). On the contrary, decayed wood reinforced with Paraloid B-72 achieved 50 % of strength. Even such high strength results of reinforced maerial did not match initial strength of natural wood.

Similar conclusions were achieved by Henriques et al. (2014). For Paraloid B-72 saturated wood, mass loss of 20 % (due to fungi decay) caused major axis compression strength loss from 50 to 10 MPa. In case of wood saturated by Paraloidem B-72 mass loss of 15 % resulted in strength lowered by half, from 50 down do 2 MPa.

It is necessary to remark, that consolidation is dedicated to protection against further destruction, and not thought as procedure aiming at full restoration of mechanical properties of wood. Consolidated wood should only be provided with strength and stability suitable for safe exposition, without worries about further depreciation (Kučerová 2012).

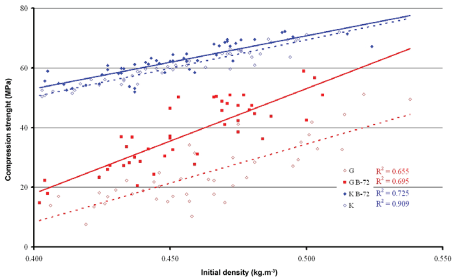


Fig. 4: Dependence between initial density of wood and paralel to grain compressive strength.

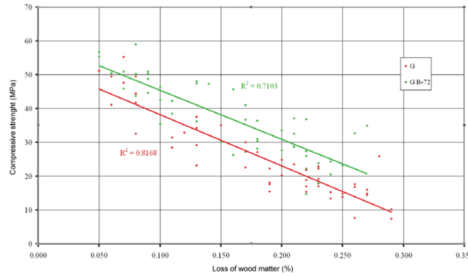


Fig. 5: Dependence mass losses of wood matter caused by C. puteana and parallel-to-grain compressive strength.

Mass loss of wood caused by *C. puteana* resulted in strength losses (Fig. 5.). In the case 5 % mass loss of wood, compressive strength was 45 MPa and for 30 % mass loss compressive strength decreased to 10 MPa. (Ważny 1959). Saturation with Paraloid B-72 causes increase of strength about 10 MPa, independently on percentage of wood mass losses. Similar dependence was described by Jankowska et al. (2010). For Paraloid B72 saturated wood sound samples showed strength of 80 MPa and fungi-decayed ones 49 MPa only. Control, unsaturated samples of sound wood reached strength of 71 MPa, again in decayed samples strength equaled 40 MPa only.

CONCLUSIONS

1. Weight loss caused by *C. puteana* fungus, results in consequent loss of density.
2. Loss of density of wood, caused by *C. puteana* fungus is accompanied by loss of compression strength in major axis.
3. Saturation of wood with Paraloid B-72 increases its strength, both natural and fungus-decayed ones.
4. Samples of natural wood while impregnated, showed lower retention of Paraloid B-72 than samples of *C. puteana* decayed wood.
5. Increased retention of Paraloid B-72 in the wood samples causes accompanying gain of its compression strength in major axis.
6. Wood samples decayed by *C. puteana* of lower initial density, showed higher strength increase after saturation with Paraloidem B-72 than samples of higher initial density.

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