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Strength Degradation of Wood Members Based on the Correlation of Natural and Accelerated Decay Experiments

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Abstract: An accelerated decay test and a natural decay test were conducted synchronically to explore the strength degradation of decaying wood members under long-term exposure to natural environment. A natural decay test was carried out to measure the bending strength, compressive strength parallel to grain and modulus of elasticity of the wood members, with 6 groups of specimens decayed in natural environment for 3 to 18 months respectively. To compare with corresponding decay test, in which 6 other groups of specimens were measured under accelerated conditions. The experimental data collected were evaluated by Pearson product-moment for the correlation. The results indicate that the mechanical properties of the accelerated decay were highly correlated with those in natural environment, both of which decreased in the same trend. Under the given test conditions, the mean value of the accelerated decay test data were curve-fitted to achieve the time-dependent degradation model of the bending strength, the compressive strength parallel to grain, as well as the modulus of elasticity. Due to the high correlation, the acceleration shift factors (ASF) of the two tests were derived, where the bending strength of 2.934, the compressive strength parallel to grain of 2.519 and the elastic modulus of 2.346 were employed to formulate the strength degradation models in the long-term natural environment. The results verify that the exponential function $\sigma = \sigma_0 e^{-\beta t}$ enables to exactly capture the degradation of the mechanical properties of wood members decayed in natural environment.

Keywords: Wood member; accelerated decay test; natural decay test; correlation analysis; degradation model

1 Introduction

In China, wood was the main material of building until it is forbidden because of severe lack of forest in 1980s. To date, many ancient wood buildings still exist, for example, Yingxian Pagoda was founded about almost 1000 years ago, which is the highest wood tower in the world with height of 67.31 m. However, it is challenging to maintain their durability, since wood is subjected to a variety of biotic and abiotic attack. Fungal decay is a main factor to degrade the wood buildings by reducing the strength and the geometrical properties of structural lumber [1,2] and degrading the strength of nail timber connections [3,4]. As such, the influence of wood decay on the safety of timber structure is always a highlight topic in wood science and a major concern in wood building preservation. Many scholars tried to find the relationship between the degradation of mechanical property and fungal decay, and used it to predict the service life or evaluate the safety of wood building. Some researches tested the old timber member in ancient buildings. Li [5] in-site measured and evaluated the safety of Yingxian pagoda, according to the measuring data, and proposed an empirical formula to predict the decay depth of ancient timber member and illustrated the connection of decay depth, time, tree-age, and test data. Chen et al. [6] carried out the tests on some old timber member removed from ancient building, illustrated that the mechanical properties of old wood such as compressive strength, bending strength, hardness and ductility decreased gradually. The correlation analysis between bending strength and wood decay by Liu [7] demonstrated that there is correlation between the mechanical properties of wood, wood decay extent and change of its chemical ingredients. This method can study the real old timber member, but is often subjected to limited specimens, wood species, uncertain service-life and long duration, making the research rather difficult. Some researchers carried out accelerated decay tests on wood specimens. Yang [8,9] and Curling [10] proposed different accelerated decay methods, and investigated the impact of wood decay fungi on the modulus of elasticity, modulus of rupture and modulus of elastics. Wang [11] further discussed the degradation model of mechanical properties of large-size Pinus tabulaeformis member in accelerated decay experiment. Venäläinen [12] conducted the accelerated soft rot testing of wood stakes in a special soil-filled box and measured the strength loss and mass loss, which showed that the strength loss preceded the mass loss and mass loss was not an effective index to predict the strength degradation in the initial decay phase. Such tests can be finished in a short time in the laboratory environment or under specific conditions, while they are difficult to be used to predict the service life of wood building directly.

Also there are some field decay tests on wood specimen in ground, above ground and under ground, which can investigate the decay impact on different parts of buildings. Leicester et al. [13,14] studied wood decay above ground and under ground theoretically and experimentally, and obtained a time-dependent law of the depth of wood decay under different conditions [15–17], which were used for the durability analysis and reliability design of timber member [18–20]. Kleindienst [21] used biochemical and physico-chemical data as inputs to predict strength loss of wood in-ground, which was validated by experimental measurement of the compressive strength parallel to the grain. Data from field tests are prohibitively expensive but are extremely useful. The duration of some tests is about 25 years.

Other scholars tried to find more convenient non destructive testing method to predict the strength degradation. Barré [22] carried out microbial decomposition test on 180 silver fir wood strips for 1.5 years, and developed two separate predictive models of degradation indicators using near infrared spectroscopy. Witomski [23], investigated the degradation of static bending strength, compressive strength parallel to the grain and modulus of elasticity of Scots pine wood decayed by fungus, and the results indicated that the static bending strength, compressive strength parallel to the grain and modulus of elasticity degraded in different ways in initial phase. Ge et al. [24] further validated the above results. Furthermore some researchers proposed to detect the decay and evaluate the remaining strength by nondestructive techniques [25]. Gao et al. [26,27] and Sharapov [28] explored the effect of decay on the electrical resistance and the drilling resistance of wood, and tried to find the relation between nondestructive parameters and strengths. This is a potential practical method, while it needs further study to determine the quantitive model. Therefore, a methodology is proposed in this paper to study the time-dependent mechanical properties degradation of wood in natural environment based on the correlation analysis of natural and accelerated decay experiments.

2 Materials and Methods

To obtain the time-dependent strength degradation of wood members in natural environment, a total of 130 large-size wood specimens were used to conduct an accelerated decay test and a natural decay test. The accelerated decay (AD) tests on 70 large-size wood specimens were conducted to obtain their time-dependent strength degradation model [11], while further experiments are required to validate whether this degradation law is applicable for the mechanical degradation in natural decay (ND) environment. Therefore, a control experiment of another 60 wood specimens was conducted in natural environment. Six groups of wood specimens with the same size as that in the accelerated decay test, were designed to be decayed for 3, 6, 9 and 18 months respectively in natural environment. Then each group of decayed wood specimens were tested to obtain the bending strength (BS), compressive strength parallel to the grain (CSPG) and modulus of elasticity (MOE). Subsequently, the relationship was investigated between the AD test and ND test, and the Pearson product-moment coefficient was employed to analyze their correlation. Finally, on ground of the correlation, the time-dependent degradation model of wood mechanical properties in natural environment was developed by acceleration shift factor (ASF) method.

The decay of wood specimens was accelerated in a chamber under constant temperature (28 ± 2)°C and humidity (RH = 75%), and the natural decay specimens were kept in laboratory in Wuhan University of Technology, China. Because this project focuses on the of material properties, the requirements are different from the Chinese national standards for the durability of wood [29], which concerns the decay extent of standard-sized specimens rather than the of material properties. This section briefly introduces the wood type, geometric size, number of specimens, type of fungi and the medium in the AD test and ND test.

2.1 Wood Specimens

Similarly to the accelerated decay test [11], Sawn Pinus tabulaeformis, generally used in Chinese ancient buildings, was selected to make the larger-size wood specimens. The specimen size for bending test was 15 mm (R) × 15 mm (T) × 300 mm (L), and each group has 10 specimens. The size of the specimens for compression test was 15 mm (R) × 15 mm (T) × 23 mm (L), cut from the ends of the bending test specimens, and each group has 20 specimens. No. 0 group was the reference group without decay and was used to test the initial mechanical properties. The groups from 1A to 6A were infected by wood-decay fungi and kept in a constant temperature and humility chamber for 1, 2, 3… and 6 months respectively. The other groups from 1B to 6B were infected by the same fungi while kept in natural indoor environment for 3, 6, 9… and 18 months respectively.

2.2 Experimental Fungi and Culture Medium

According to the current national standard of wood durability experiment [29], the fungi, Poria placenta (Fr.) Cooke [number: CFCC5608] and *Gloeophyllum trabeum* (Pers.) Murrill [number: CFCC86617] were provided by China Forestry Culture Collection Center. The *Gloeophyllum trabeum* (Pers.) Murrill was selected as the experiment fungi because of its short growth cycle and strong vitality based on Enzyme activity test. The culture medium containing river sand and sawdust was prepared according to the experiment standard [29]. More details are shown in Tab. 1. For the AD test, the incubators were plastic boxes with a size of 435 mm (L) × 335 mm (W) × 125 mm (T), and polyethylene bags with 0.04 mm thick were sterilised and used as incubator liner. The bag mouths were treated specially to keep the specimens from outside environment and provide sufficient oxygen for the wood-decay fungi. All the culture medium, specimen and wood decay fungi were placed in the bags in sterile operation as shown in Fig. 1. The incubators were placed in a constant temperature and humility chamber (T: (28 ± 2)°C, RH: 75%–85%), and for ND test, the boxes were placed in a laboratory, where the temperature and relative humidity change with season in one year as shown in Fig. 2.

2.3 Mechanical Test and Normalization

Static tangential bending strength (The height of the beam was tangential size), compressive strength parallel to the grain and modulus of elasticity of the wood specimens were measured by WDW universal

Table 1: Specific Medium Component [11]

Incubator number	Dry river sand/ kg	Masson-Pine sawdust/ kg	Corn flour/ g	Brown Sugar/ g	Maltose liquid/ L
1	3.2	0.320	179.4	21.33	2.133
2	3.25	0.325	184.2	21.67	2.167
3	3.5	0.356	201.7	23.73	2.373
4	3.15	0.315	178.5	21.00	2.100
Total	13.10	1.135	743.8	87.73	8.773

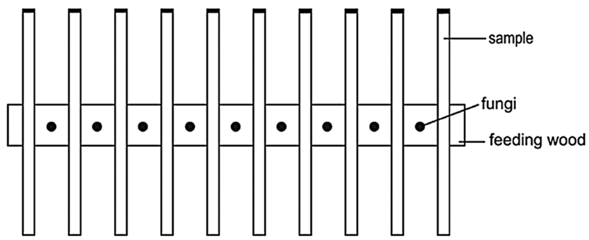

Figure 1: Fungal inoculation on feeder [9]

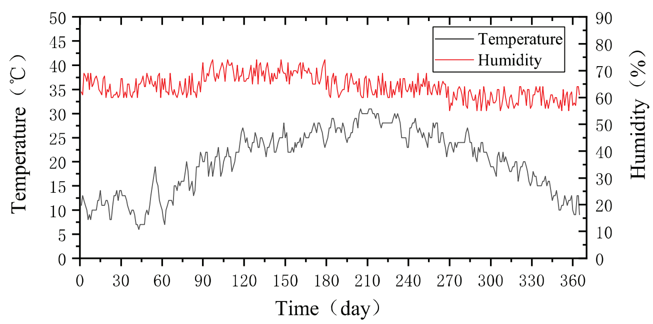

Figure 2: Experiment condition for ND test

electronic testing machine in Hubei Academy of Forestry, China. The fungal mycelia and the decayed surfaces were cleared off from the specimens, and moisture content was also regulated to 9%–15% before testing. According to the national standards [30,31] the MOE and static bending strength tests were conducted on the same wood specimens, 240 mm standard span, which were loaded on mid-span. According to the national standards [32], the 15 mm × 15 mm × 23 mm specimens cut from bending specimens were tested for compressive strength parallel to the grain. After the test, the accurate moisture content in wood specimen was measured to normalize the mechanical properties of wood with 12% moisture content.

3 Results and Analysis

The project included accelerated decay tests and natural decay tests. The method, process and results of accelerated decay test were presented in detail in reference [11]. This research mainly introduces natural decay test and compares the two experiments. The natural decay test lasted for 18 months, and one group was taken out every 3 months to measure its mechanical properties.

3.1 Experiment Description

Since the decay of specimens was accelerated in constant temperature and humidity environment, which was favorable for the growth of wood-decay fungus, while the ND specimens were placed in natural environment with varying temperature and humidity, the decay phenomena of the two tests were apparently different. After one month of accelerated decay in the chamber, the moisture content of the wood specimen increased, which was in a saturated state by visual inspection. As shown in Fig. 3a, the specimen surfaces were covered slightly with wood-decay fungus and their color was deeper. After decaying for 2 months the specimens were in a saturated state, their surfaces were covered partially with wood-decay fungus, as shown in Fig. 3b. After 5 months of accelerated decay fungus covered all the surface of the specimens, and the color change of the specimens was significantly intensified, as shown in Fig. 3c. Removing the fungus from the surface, the wood was found to be soft and degraded significantly. While no significant change was observed by visual inspection on the wood specimens in natural environment for the first 9 months. After that, some individual pieces bent and warped slightly, and some concave lines parallel to the grain appeared on the surface as illustrated in Fig. 3d. For the last group, more obvious concaves parallel to the grain occurred on most of the specimens, the deepest was measured up to 1 mm, where the wood became soft.

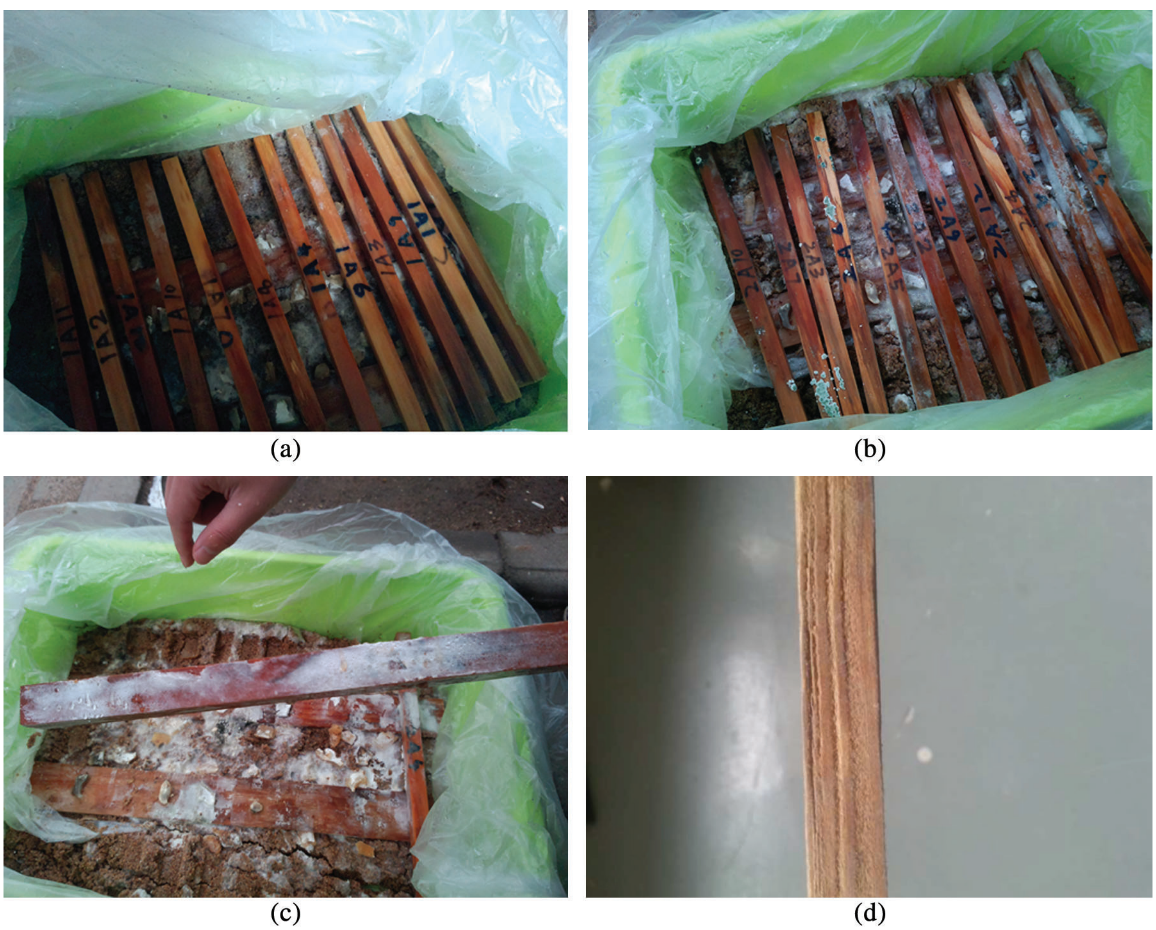

Figure 3: Decay phenomena of specimens. (a) 1 month in AD test, (b) 2 months in AD test, (c) 5 months in AD test, and (d) 9 months in ND test

3.2 Data Processing

For analysis of the correlation of the two test data conveniently, Tab. 2 was tabulated to list the statistic values of the wood specimens' bending strength, compressive strength parallel to the grain, modulus of elasticity and loss of mass in the accelerated decay test [11], corresponding normalized data are shown in Fig. 4. The 7 groups of normalized mechanical properties of wood specimens in ND test are shown in Fig. 5. Their mean value μ, standard deviation σ and coefficient of variation CV are shown in Tab. 3.

Table 2: Statistic values of mechanical properties under accelerated decay

Time of decay/Year		0	0.083	0.167	0.25	0.333	0.417	0.5
BS	μ/MPa	88.817	85.586	77.123	79.372	78.070	72.037	62.68
	σ/MPa	15.832	17.375	18.201	17.064	15.224	14.984	13.037
	CV	0.178	0.203	0.236	0.215	0.195	0.208	0.208
CSPG	μ/MPa	45.589	42.277	39.071	38.125	38.526	36.711	29.86
	σ/MPa	8.343	6.469	5.587	6.405	5.546	6.424	3.856
	CV	0.183	0.153	0.143	0.168	0.144	0.175	0.129
MOE	μ/MPa	10273	9687	8990	9190	8480	8122	7631
	σ/MPa	2857	2715	2253	2029	2248	2139	1852
	CV	0.278	0.279	0.251	0.221	0.265	0.263	0.243
Loss of Mass/%		0	27.3	36.3	38.8	42.4	45.0	48.7

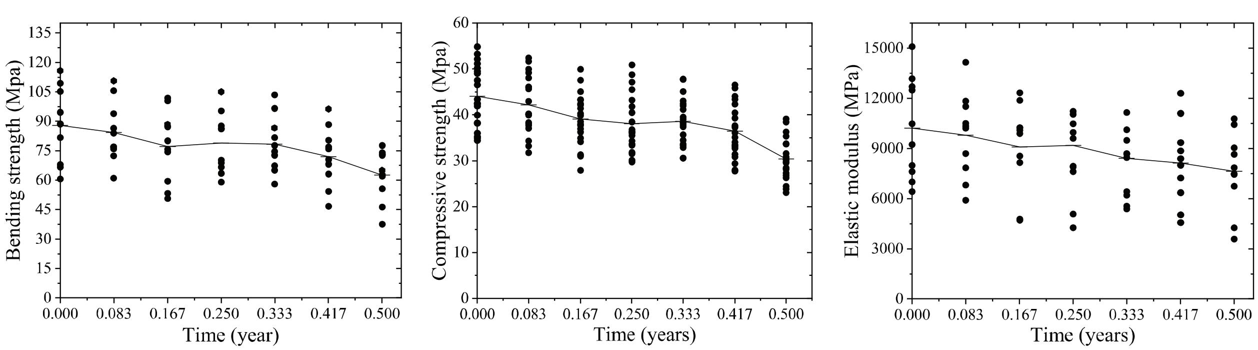

Figure 4: Normalized mechanical properties in AD test

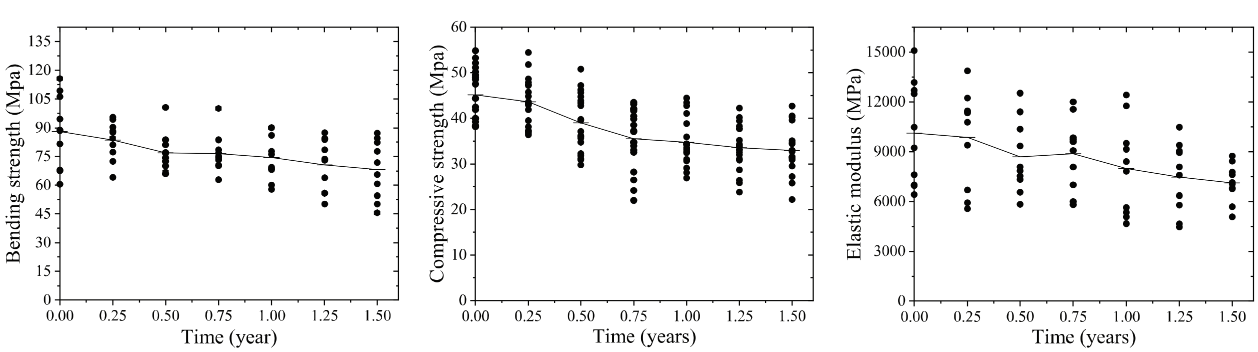

Figure 5: Normalized mechanical properties in ND test

Table 3: Statistic values of mechanical properties under natural decay

Time of decay/Year		0	0.25	0.5	0.75	1	1.25	1.5
BS	μ/MPa	88.817	83.77	76.937	76.585	74.536	70.701	67.663
	σ/MPa	15.832	13.847	15.162	15.951	13.415	16.686	15.832
	CV	0.178	0.165	0.197	0.208	0.18	0.236	0.234
CSPG	μ/MPa	45.589	43.594	38.978	35.248	34.318	33.458	32.778
	σ/MPa	8.343	5.363	6.314	6.439	5.354	4.985	5.448
	CV	0.183	0.123	0.162	0.183	0.156	0.149	0.166
MOE	μ/MPa	10273	9728	8693	9055	8054	7383	7013
	σ/MPa	2857	2370	2482	2287	2327	2337	2072
	CV	0.278	0.244	0.286	0.253	0.289	0.317	0.295
Loss of Mass/%		0	5.85	–	30.1	31.3	38.3	44.2

From Figs. 4 and 5, it is seen that the static BS, CSPG and MOE degrades greatly in both the AD tests and ND tests. For the AD test, the static BS, CSPG and MOE decrease by 29.4%, 34.5% and 25.7% respectively after 6 months decay. The degradation includes three phases. At the first two months, the mechanical properties degrade obviously. After decay for 2–4 months, the mechanical properties are relatively stable, and after that, the strengths decrease significantly again. For the ND test, the static BS, CSPG and MOE decrease by 23.8%, 25.9% and 31.7% respectively after one and a half years' natural degradation. At the first three months, mechanical properties degrade slightly by about 5%, the degradation mainly occurs at 3–6 months by about 15%, after natural decay for 6–9 months, the mechanical properties are relatively stable, and after that, the mechanical properties decrease significantly again about 10%. There is an internal connection between the phase characteristics and decay extent of wood members, especially the microstructure of decayed wood. Similarly to the accelerated decay, the natural degradation also includes three phases, but the mechanical properties keep stable at the beginning of the first phase from 0 to 6 months, which was not found in AD test. If the first group of specimen was decayed for less than one month in AD test, this kind of phenomena may be found, which need further test to verify.

Tab. 3 also shows the mechanical properties and loss of mass of the wood specimen decrease obviously. There is no obvious trend for the standard deviation and coefficient of variation. Nevertheless the CV of compressive strength of each group is less than the others. The reason may be, the more compression specimens there are and the smaller the size is, the smaller the variation coefficient is. However, all the average values illustrate the degradation trend of mechanical properties with decay time.

From Tabs. 2 and 3, it is seen that a slight difference is found in mass loss between AD and ND. In AD tests, due to the moderate humidity and temperature, in the first month, the mass of decayed wood decreases sharply by 27.3%. While in ND tests, the mass decreased very slightly in the first 3 months, namely, by 5.84%. After the incipient decay stage, the mass decreases steadily in both tests. It is because that, for AD test, after one month decay, due to the moderate temperature and humidity, the wood has passed through the incipient stage, the mass loss is great. However, for ND test, after three months, the wood is still in the incipient stage, the material is being degraded, but has not caused mass loss greatly, which is in accordance with the result in reference [23]. The more accurate relationship among mechanical property, mass loss and the microstructure of decayed wood will be further studied.

3.3 Correlation Analysis

Whether AD test can be used to assess the strength degradation of wood members in ND situation depends on the correlation of the two kinds of experiments. Their time-dependent curves are shown in Fig. 6, which demonstrates that the mechanical properties of the bending member in ND and AD tests decreased in a similar way. However, their correlation needs more quantitative analysis, where grey correlation analysis is very effective. Thereby Pearson product-moment coefficient is adopted to evaluate the data correlation from the two tests quantitatively.

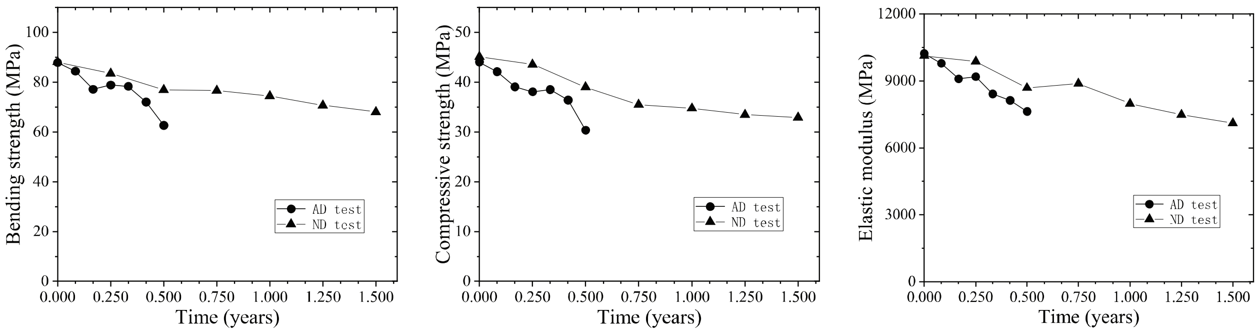

Figure 6: Time-dependent mean values of mechanical properties

In statistics, the Pearson correlation coefficient is used to estimate the correlation between two variables [33]. Suppose variables X and Y are the two sets of data obtained from the experiments and denoted as (X_i, Y_i) (i = 1, 2, …, n). The correlation coefficient R is given by,

$$R = \frac{\sum_{i=1}^{n}(X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \overline{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i - \overline{Y})^2}} \tag{1}$$

where $\overline{X}$ and $\overline{Y}$ are the average values of X_i, and Y_i (i = 1, 2, …, n) respectively, the correlation coefficient R is in the range [−1, 1]. When $|R|$ is close to 1, there is a higher correlation between X and Y. When $|R|$ = 1, the coordinates (X_i, Y_i) are on a straight line and the variables X and Y are perfectly correlated. When $|R| \geq 0.8$, the two variables are highly correlated.

Set the mean value row in Tab. 2 as the variable Y and the mean value row in Tab. 3 as the variable X, their relationship is shown in Fig. 7. By Eq. (1), the correlation coefficients of bending strength, compressive strength parallel to the grain and modulus of elasticity were 0.927, 0.865, and 0.947 respectively. Apparently, the two types of test data are highly correlated.

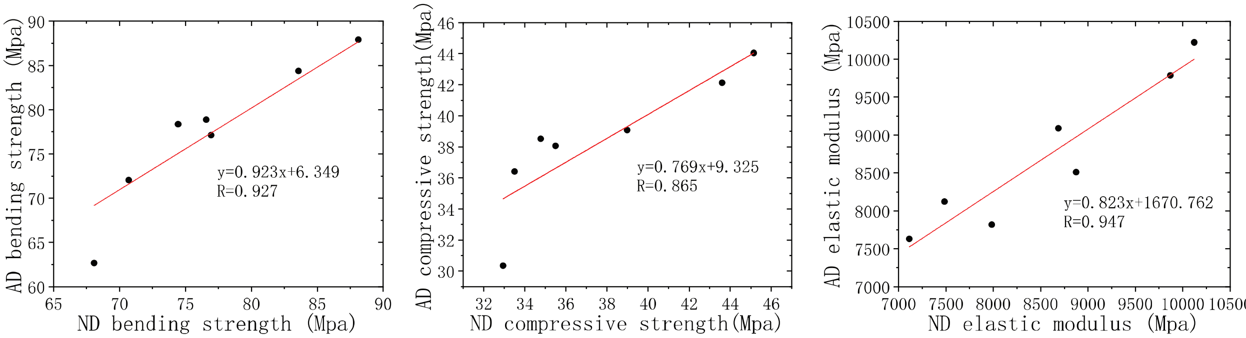

Figure 7: Correlation of mechanical properties in ND and AD tests

3.4 Residual Strength Model Based on Acceleration Shift Factor

Due to the high correlation, the AD test can be used to study the decay trend of wood specimens in natural environment, in which the acceleration rate can be evaluated by the acceleration shift factor (ASF), which is the ratio of the time required for wood decay in natural environment to that to the same degree in the man-made environment [34]. This method can be used to establish the relationship between the strength degradation of the wood members in AD and ND tests, and also to obtain the strength degradation model under natural environment based on the results in the AD tests.

By analyzing the accelerated decay data in Tab. 2, φ_b, φ_c and φ_E were designated as the residual factors of bending strength, compressive strength parallel to the grain and modulus of elasticity. Given that the residual factors are 1 in the initial condition ($t = 0$), and they approach to zero when the wood is completely decayed, the residual factors were curve-fitted exponentially. Because of improper treat on the bag mouths of incubator liner, the group of samples for 4 months was not decayed normally without sufficient oxygen, its data are higher than that after 3 months, which is apparently incompatible, this set of data was excluded when curve-fitting. The exponential function $y = e^{\beta x}$ can properly describe the attenuation by Eq. (2), and all the correlation coefficients are above 0.9 as shown in Fig. 8.

$$\varphi_{\mathrm{b}} = \frac{\sigma_b^a}{\sigma_{b0}} = e^{-0.5742t},\ \varphi_c = \frac{\sigma_c^a}{\sigma_{c0}} = e^{-0.7122t},\ \varphi_{\mathrm{E}} = \frac{\sigma_E^a}{\sigma_{E0}} = e^{-0.5952t} \tag{2}$$

where, σ_b^a, σ_c^a and σ_E^a are designated as the residual bending strength, compressive strength parallel to the grain and modulus of elasticity of wood members after t years' accelerated decay respectively, and σ_{b0}, σ_{c0} and σ_{E0} are the initial bending strength, compressive strength parallel to the grain and modulus of elasticity respectively.

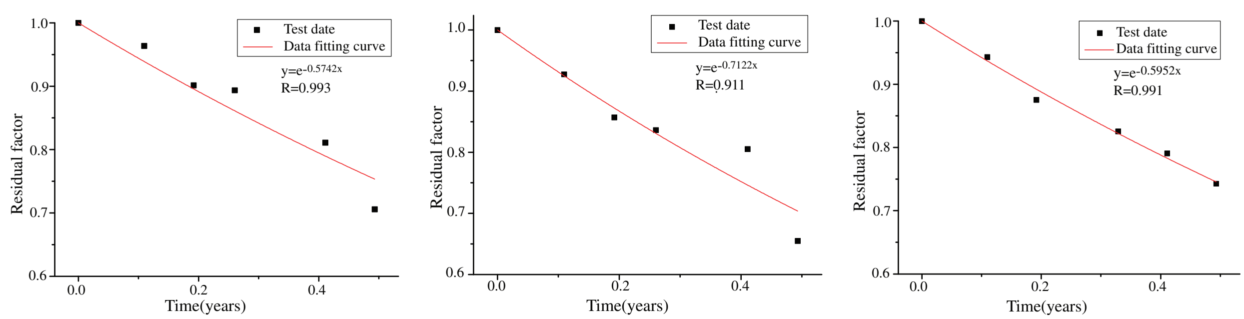

Figure 8: Degradation models of mechanical properties in AD test

According to Eq. (2), we obtain the AD time required for the same residual factors measured in the natural decay after 0–1.25 years, which are linearly fitted to the ND time in Tabs. 4–6, and the slopes are the acceleration shift factors.

Tabs. 4–6 show that the ASF of BS, CSPG and MOE are 2.934, 2.519 and 2.346 respectively. The strength degradation models in the ND tests can be obtained by dividing the time with ASF as in Eq. (3).

$$\sigma_b = \sigma_{b0}e^{-0.196t},\ \sigma_c = \sigma_{c0}e^{-0.283t},\ \sigma_E = \sigma_{E0}e^{-0.254t} \tag{3}$$

where, σ_b, σ_c and σ_E are designated as the residual BS, CSPG and MOE of the wood members after t years' decay in natural decay environment respectively. σ_{b0}, σ_{c0} and σ_{E0} are their initial BS, CSPG and MOE respectively.

Table 4: ASF, AD and ND Time to the same residual BS

ND time/year	Residual factor by ND test	AD time/year	ASF	Residual factor by Eq. (3)	Error/%
0	1	0	2.934	1	0
0.25	0.943	0.102		0.952	0.96
0.5	0.846	0.250		0.907	4.67
0.75	0.862	0.258		0.863	0.12
1	0.839	0.305		0.822	2.05
1.25	0.796	0.397		0.783	1.65
1.5	0.762	0.474	–	0.745	2.17

Table 5: ASF, AD and ND Time to the same residual CSPG

ND time/year	Residual factor by ND test	AD time/year	ASF	Residual factor by Eq. (3)	Error/%
0	1	0	2.519	1	0
0.25	0.956	0.063		0.932	2.57
0.5	0.855	0.220		0.868	1.53
0.75	0.773	0.362		0.809	4.60
1	0.753	0.399		0.754	0.10
1.25	0.734	0.435		0.702	4.34
1.5	0.719	0.421	–	0.654	9.04

Table 6: ASF, AD and ND Time to the same residual MOE

ND time/year	Residual factor by ND test	AD time/year	ASF	Residual factor by Eq. (3)	Error/%
0	1	0	2.346	1	0
0.25	0.947	0.094		0.938	0.89
0.5	0.846	0.281		0.881	4.08
0.75	0.881	0.212		0.827	6.23
1	0.784	0.409		0.776	1.06
1.25	0.719	0.555		0.728	1.29
1.5	0.683	0.641	–	0.683	0.08

To validate the degradation models, the residual factors after 0–1.25 year' decay were predicted by Eq. (3), its errors were also estimated in Tabs. 4–6, which indicate that all the errors of the mechanical properties were less than 10%. To further verify its extrapolation accuracy, the residual factors after 1.5 years' natural decay was extrapolated by Eq. (3), the errors to the measured data of BS, CSPG and MOE were 2.17%, 9.04% and 0.08% respectively. Therefore, it is reliable to use the exponential function $\sigma = \sigma_0 e^{-\beta t}$ to describe the mechanical properties of the wood members in natural environment.

4 Conclusions

This paper probed into the degradation problems of mechanical property in decaying wood members. The large-size wood specimens were designed and decayed to test their residual bending strength, compressive strength parallel to the grain and elastics of modulus. Pearson product-moment coefficient was used to investigate the correlation between the ND and AD tests. In view of the high correlation, degradation models in natural environment were further deduced by means of ASF. The results are listed as follows,

1. The bending strength, compressive strength parallel to the grain and modulus of elasticity degrades greatly in both the AD tests and ND tests. After 1.5 years' natural decay they decrease by about 23.8%, 25.9%, and 31.7% respectively. Similar to the accelerated decay, the degradation includes three phases. At the first phase, the natural decay begins at 3–6 months, the strengths degrade obviously for about 15%. At the second phase, after natural decay for 6–9 months, the mechanical properties are relatively stable, and after that, the strengths decrease significantly again about 10%. There is an internal connection between the phase characteristics, decay extent and microstructure of decayed wood.
2. Quantitative methods were used to analyze the correlation between the two test data. The results show that the test data of the two groups are highly correlated, although the external influential factors are different in accelerated decay and natural decay. Therefore, the accelerated decay method can be used to analyze the time-dependent degradation of mechanical properties in different wood members under natural environment.
3. Based on the strength degradation model of the accelerated decay wood members, the time-dependent degradation model $\sigma = \sigma_0 e^{-\beta t}$ in the natural decay environment is obtained by means of ASF method, which can be universally used to predict and estimate the strength degradation of other wood members. For different wood species, tree-age, geographical environments and climates, the exponential coefficient β would be different, which needs further study to determine the relationship between the parameter β and the above-mentioned influencing factors.
4. The mass loss, though highly related to mechanical properties, cannot be used as the parameter to assess and predict the latter. Thus, some parameters, which may be easier to measure and cause less damage to historic buildings, should be studied to estimate the residual strength of old wood members.

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