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Research of the Salinity Effect on Nail-holding Power of Dimension Lumber

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Abstract: This article mainly studied the effect of salinity on the nail-holding power in wood construction. The results showed that: in saline solution, the holding power of nails was smaller than that in purified water condition. With the increase of salt concentration, the surface and side nail-holding power of the wood specimens would both decline, but the differences between salinity treatments would be not significant. However, compared to the surface and side nail-holding power, the power on the edge was generally smaller and the difference was not obvious in the treatment of different salt concentrations. In the same concentration of salt environment, with the extension of the processing cycle, the performance of holding power of nails showed a downward trend, expect the temporary rise in the middle.

Introduction

Because of the many advantages of wood construction, China has witnessed a boom in the construction of wooden architecture [1] all over the country. Southern coastal areas have the climate characterized with high temperatures, high humidity and high salinity. High salinity environment has a certain impact on the life of wooden structures. In wood frame construction, each component transmits force through the connections [2]. There are many forms of connections, such as nail connection, tooth connection, bolt, pin connection and mortise and tenon joint connection. The nail connections are tough and flexible, easy to fabricate and closely connected. Therefore, it has become a wide connection in wood structure building. Nail connection node load can be divided into two directions, namely lateral shearing force perpendicular to the screw rod and pullout force parallel to the nail rod. Therefore the lateral bearing force and nail holding power are two basic strength indexes to value the connection properties.

Domestic and foreign scholars did researches about the nail holding power from the trees, the types of nails, wood density and wood moisture content, and other aspects. Fee BenHua [3] and others found that wood density had the greatest influence on the nail holding power, and screw diameter and screw holding capability had a linear relation. Dolan[4] researched about the influences of different physical properties by different moisture content of wood on nail holding power. He tested nail holding power with the moisture content of 19% and 12%. The experimental results showed that the latter was obviously higher than the former in nail holding power. But this was not well reflected in the current design specifications. So he suggested the environment adjustment coefficient should be added to the calculation formula of humidity to ensure the stability of the structure. Stern[5] found that in damp environment, the round nails hammered into steel studs even with the cover panel would also rust by 9.5mm above the surface of the wood because of moisture infiltration. Nail rusting will cause wood decay around the nail rod and make the nail holding power decrease significantly in the long term. Yet the salt solution can segregate and discolor wood and even speed up the rusting and deforming of metal connections, which harms the safety of timber structure buildings. However, domestic and foreign researches in this field is almost blank,the research of salinity effect on wooden structure connectivity is of great significance and practicality.

Test Materials

Nails

The nails used in wood structure construction can be divided into round nails, screw (including wood screw and square head screws), twist nails, U-nails and so on in terms of shape. According to *GB /T14018- 2009* Method of testing nail holding power of wood[6]and the actual production, the test chose spiral nails that were widely used in wood structure constructions. Specific parameters were showed in Tab.1.

Table 1. Specification of nails in Test

Type of Nails	Specifications		Galvanized
	Nail length/mm	Diameter/mm	
spiral nails	38	3.30	yes

Dimension Lumber

The test used Spruce-Pine-Fir(SPF), the type of which was spruce. According to *GB/T14018-2009*, *GB50005-2003*Code for design of timber structures[7] and the actual situation of production and processing,the size of specimen should be 150mm in length and 89mm×38mm in sectional dimension. The measured average air-dry density [8] was 460kg/m^3. Moisture content [9] was 15.4%. Before the test, the experimenter should clean the nails and mark at the place of 15mm away from the nail caps. Then as shown in Fig.1, drive the nail vertically into the specimen at constant speed until to the above mark on surface section, side section and edge section. The deviations were allowed within±1mm.

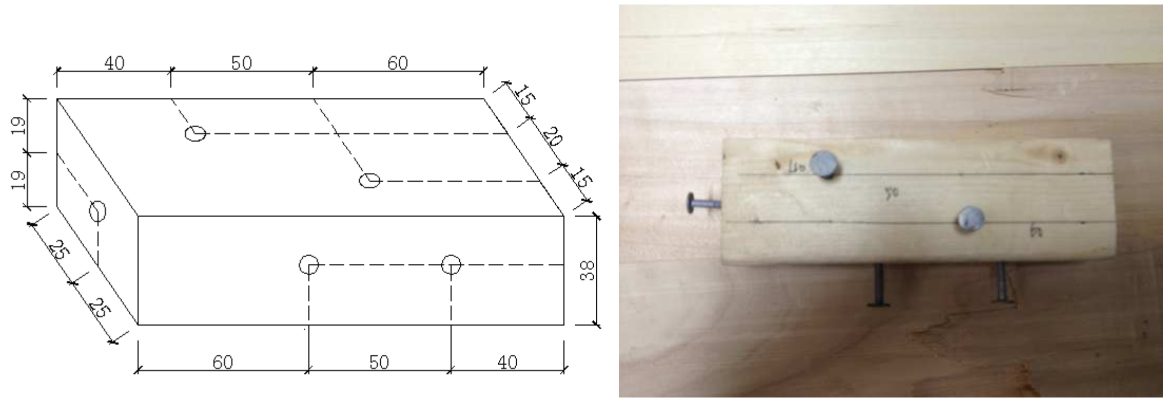

Fig. 1. Schematic diagrams for holding power test of nails

Salt Treatments

There were five concentration gradients, which were 0%,3%,3.5%,4%,4.5% respectively. The ratios of compounding ingredients were showed in Tab. 2.

Table 2. The proportion of high-salt simulated Solution

Salinity	Crude salt/kg	Pure water/l
0.0%	0.0	30.00
3.0%	1.0	32.33
3.5%	1.0	27.57
4.0%	1.5	36.00
4.5%	1.5	31.83

Place the same amount of specimens of the same type in different high-salt simulated solution, respectively, making sure that the specimens were fully submerged and not in contact with the tank wall. In order to study the salinity effect on the performance of lumbers, nail-holding power reasonably, one experimental period would be set as three days for soaking and two days for drying, and so on. Refer to Fig. 2. Six specimens were texted at each circle and concentration.

Fig. 2. Salt treatment

Test Methods

The equipment was Suns universal mechanical testing machine, the maximum load of which was 100*KN*. According to *GB /T14018- 2009*, position the test piece in the nail-holding force fixture by gripping the nail head with speed of 2*mm/min* and then pull the nail out within 1 ~ 2*min*. Record the maximum load accurate to 10*N* (Fig.3). Finally calculate the nail holding power according to the formula $P = P_{max} /L$. Accurate to 0.1*N /mm*.

Where

P is the nail holding power. The unit is *N /mm*.

P_{max} is maximal load. The unit is *N*.

L is the depth that nails into the specimen.

Fig. 3. Nail holding power test

Test results

From the test process, the slot of spiral nails was stuffed with small wood particles. Screw threads and wood were fully occlusive, which proved the method was reasonable. As showed in Fig.4, in the loading process, the nail holding power linearly increased rapidly as the displacement increased. At the same time, the nail holding power subjected to the frictional resistance and the occlusion between the screw threads and wood reached the peak load until the nails were pulled out when the occlusive wood fractured and slipped. Then the nail holding power was mainly affected by friction.

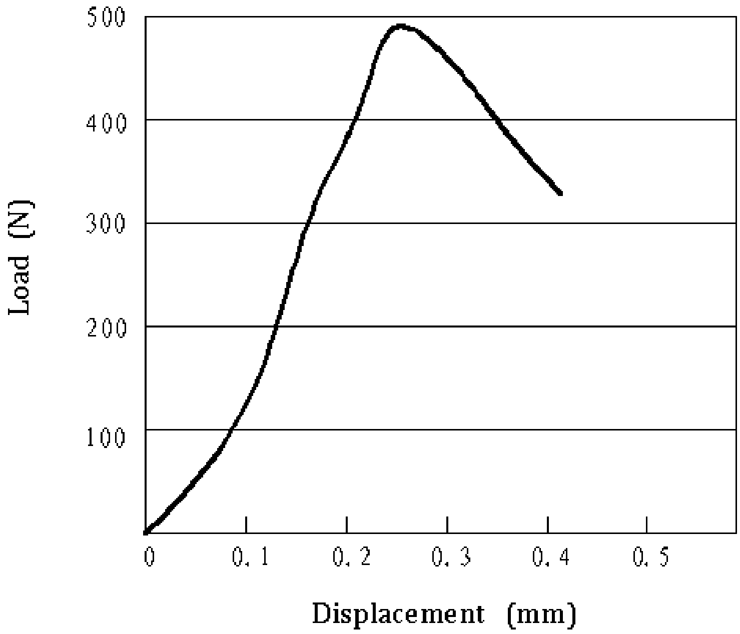

Fig. 4. The example of curves on withdraw tensile load and displacement for each nail

By testing untreated specimens, the average of surface holding power was 44.60 N/mm, the average of side holding power was 45.07 N/mm, and the average of edge holding power was 15.47 N/mm. In different concentrations and circles, the nail-holding power of three sections was showed in Tab.3.

Table 3. Nail-holding power after treated in different circles and concentrations

Holding power (N/mm) / Salinity (%)		0		3		3.5		4		4.5	
The first circle	S_1	24.52	-10.2	28.13	-7.9	33.2	-9.4	24.78	-10.3	30.26	-11.3
	S_2	21.39	-8.7	17.61	-9.2	29.87	-6.1	23.34	-10.1	19.3	-12.5
	E	5.73	-12	9.91	-3	9.86	-11	9.52	-5	7.57	-6
	M.C.(%)	20.4		19.9		24.6		21.7		18.3	
The second circle	S_1	21.67	-9.6	27.2	-8.5	34.27	-10.3	26.07	-6.1	27.48	-8.5
	S_2	19.07	-6.8	29.15	-6.5	31.71	-5.9	21.01	-9.9	28.4	-5.9
	E	12.35	-12	10.53	-10.1	19.31	-9.3	8.67	-8.2	15.02	-10.4
	M.C.(%)	22.6		24.6		28.1		25.7		21.7	
The third circle	S_1	23.04	-11	17.83	-10.3	18.1	-11.9	26.29	-11	16.78	-12.3
	S_2	25.5	-6.1	16.5	-8.1	17.03	-8.5	22.4	-9.4	17.6	-10.4
	E	11.67	-6.2	11.74	-8.8	12.08	-7.9	9.18	-6.3	12.26	-8.2
	M.C.(%)	29.8		30.4		33.6		29.1		35.1	

Top value indicates mean value.
The bracketed numbers indicates the coefficient of variance. (%)
M.C. is moisture content.
S_1 is surface section. S_2 is side section. E is edge section.

Experimental Analyses

The Same Salinity in Different Periods

Durability is an important factor to evaluate the reliability of a structure. To great extent, the nail holding power of wooden structure is connected with the processing time in salt environment. Under different treatment time, nail holding power of wooden structure changed accordingly. From the table 3, the nail-holding power of specimens in these five different concentrations reflected the similar changing trend with the increase of periods, of which the most typical one is in 4% concentration. At the same time, the period of 4% concentration extended to the sixth circle. Refer to Fig.4.

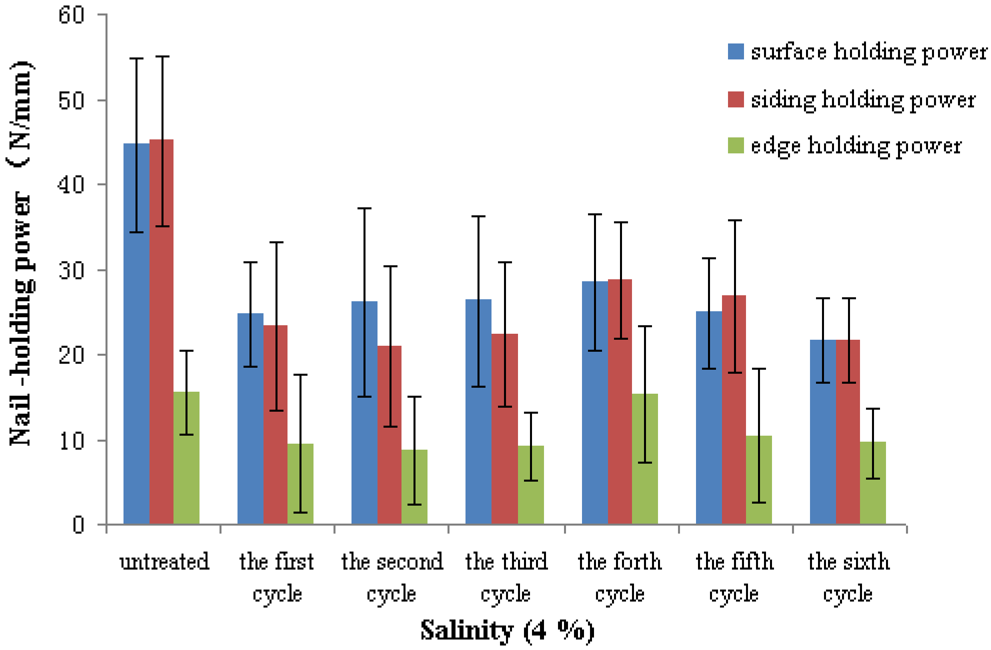

Fig. 4. Nails holding power of 4% salinity under different test periods

From the chart above, they could find that in the same salt environment, the edge nail holding force was smaller than the surface and side nail holding power. This was because the tangential shrinkage of the wood was much larger than the radial and longitudinal shrinkage, which made the edge of the wood apt to crack during the process of natural drying. As a result, the friction force became smaller between wood and nails, thus leading to the smaller edge nail-holding power. The nail holding performance of dimension lumber would decrease obviously in general as the fourth cycle increased slightly while the sixth cycle decreased greatly with the extension of the treatment period. However, the edge nail holding power decreased more slowly than the surface and side nail holding power. This was because wood was first soaked in brine and afterwards exposed to the fiery sun, leading to its shrinkage which made the distance become larger between the wood fiber and nails. So, that caused the obvious decrease of nail-holding power in first cycle. On the other hand,the nails in the sodium chloride solution formed a galvanic reaction. The cathode was $Zn\text{-}2e^{-}+2OH^{-}{=}{=}ZN\ (OH)^{2}$ and the anode was $O_2+2H_2O+4\ e^{-}{=}{=}4OH^{-}$. As the reaction progressed, the oxidization and gradual dissolution of zinc made the friction force become large. So the nail holding power increased slightly in the fourth cycle. But with the further reaction, Zinc was dissolved completely and the nail holding power would face a constant decline. The experiment also showed that backward from the fifth cycle, the nail has begun to rust, which also resulted from the dissolution of zinc.

The Same Circle in Different Salinities

Under different salt concentrations, the nail holding force would change. The size is determined by the concentration of the salt solution and the degree of hydrolysis [10].The third period was shown in Fig.5 as an example.

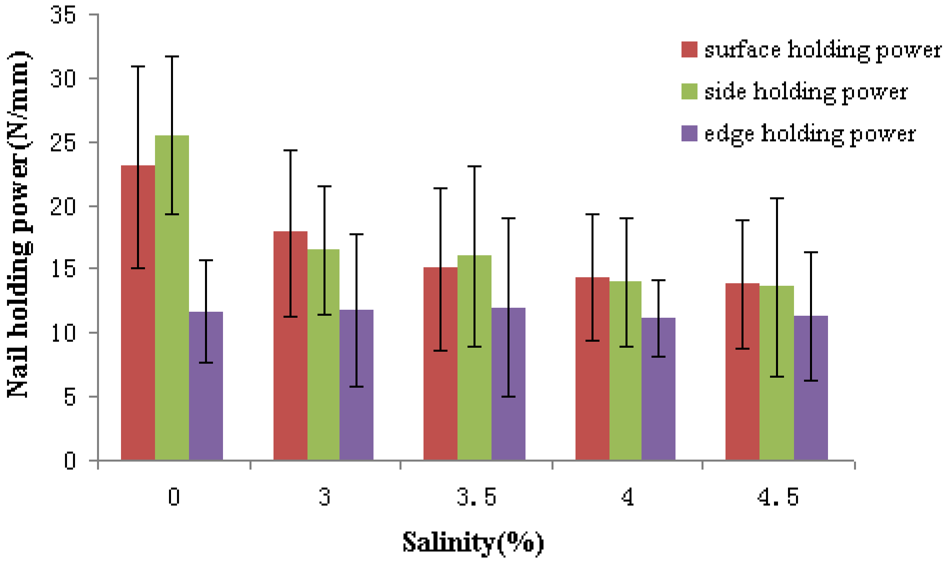

Fig. 5. Nail holding power of the third period under different salinity conditions

From the chart above, the holding power in saline solution was smaller than that in clean water. With the salinity increasing gradually, nail holding power showed a downward yet slow trend since the performance of wood in solution had something to do with its concentration and the hydrolysis degree. When wood was soaked and then dried in the sun, especially in high temperature, sodium chloride would react with water vapor in the air to form hydrogen chloride. Hydrogen chloride reacted with zinc oxide to form zinc chloride. When zinc dissolved gradually, the friction force between the nails and the wood fiber would reduce accompanied by corresponding reduce of nail-holding power. The more salt the solution had, the faster reaction became, and thus nail holding power would decrease with the increase of salinity. But as the water vapor in the experiment wasn't too much, the reaction wasn't complete. That's why the decline was slow and not obvious.

The Conclusion and Prospects

1) Edge nail holding power was smaller than surface and side nail holding power. But the stability of edge nail holding power was better.

2) Salinity could reduce nail holding power.

3) The more saline was, the smaller nail holding power was.

4) With the same salinity, the longer the treatment period was, the smaller the nail-holding power would become, expect the temporary rise in the middle.

5) Salt solution could make nails rust and discolor the wood.

Through the study,try to avoid building wood structure construction in high salinity areas. The study focused only on one mechanical property---nail holding power. Other connection performance of wood construction will be researched in the following days. At the same time, processing cycles should be increased in the test so as to get more reliable and valuable data and phenomena.

Acknowledgements

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References

[1] H.B Zhou, Current and future status of wood structure in china. China wood industry 2012; 26(1):7-10.

[2]J.B. Fei, P. Wang, Summary and analysis of wood structure. Shang Xi Architecture 2010; 36(19):100-101.

[3] B.H. Fei, Nail withdrawal strength of Chinese fir plantation.Wood Processing Machine 2008; 05:31-34.

[4] J.D Dolan, W. S. John Variability and effects of moisture coment on the withdrawal characteristics for lumber as opposed to clear wood.Paper CIB-W18/28-7-7.Process of Working commission W18-Timber Structures. Denmark. 1995.

[5] E G. Stern, Deterioration of green wood along steel-nail shank and its influence on the nail-holding properties. The Virginia journal of science 1950;1(3):200-218.

[6] GB/T 14018-2009 Method of testing nail holding power of wood.

[7] GB50005-2003 Code for design of timber structures.

[8] GB/T 1993-2009 Method for determination of the density of wood.

[9] GB/T 1931-2009 Method for determination of the moisture content of wood.

[10] Y. Zhang, L.S. Xie, Detection and evaluation of wood structure building. China Forestry Publishing House. 2011.