THE EFFECTS OF THE CELLUTREAT 'CREAM' DIP TREATMENT OF GREEN WOOD ON THE MECHANICAL PROPERTIES OF DRIED TIES

Documentation of Research Internship

at

University of Tennessee

for

Marshall Plan Scholarship Programm

Lisa Vesely

Salzburg University of Applied Sciences

Department of Forest Products Technology & Timber Construction

Supervisor

Dr. Adam Taylor (University of Tennessee)

Dr. Timothy Young (University of Tennessee)

Dr. Alexander Petutschnigg (University of Applied Sciences Salzburg)

ABSTRACT

Rail road ties are an important product of the hardwood industry. They need to be air dried to a moisture content of approximately 40%, prior to pressure treatment. During the drying period they are unprotected and thus they can be easily attacked by fungi that can weaken their mechanical properties. A solution could be to treat the ties with borates before air drying. To figure out if this treatment works, appropriate mechanical properties tests are essential. The goal of this experiment was to test hardness of ties using the standard Janka ball hardwood test and compare it with similar tests using larger-diameter balls.

Keywords:

Rail road ties

Borate

Hardness Test

Janka Test

CONTENTS

1 INTRODUCTION

Wooden rail road ties also called “railway sleepers” are an important product of the hardwood forest products industry in the United States. They have been used since 1831 and account more than 30 percent of the volume of the whole treated wood products marked (Chow et al., 1987, ASTM, 2000). Today wooden rail road ties have to compete with alternative materials like concrete (Chow et al., 1987). The problem of untreated railway sleepers is that they can be attacked by fungi, during the pre-treatment drying process, which reduces the service life (Chow and Bajwa). Rail road ties have to be air dried before chemical pressure treatment is possible. They are open stacked outside to reach a moisture content of approximately of 40%, which requires about 6 to 10 months (Taylor et al., 2013). During this time the wood is unprotected and has high moisture content. Thus it is no common for fungi like white-rots to attack the ties and produce fruiting bodies, which is also called “stuck burn” (Taylor et al., 2013). This process likely has a negative effect on the mechanical properties of the ties; research has shown that 2% of weight loss caused by decay fungi can lead to a 50% reduction of strength (Wilcox, 1978).

A solution for that problem could be a treatment with the cellutreat ‘cream’ dip. This is a high concentration colloid of borate (DOT) in water. Borates have been used as a preservative against insects and funguses for the last 70 year. It has the advantages that it is inexpensive, low risk to mammals and environmentally friendly (Kim et al., 2011). The negative effect of borates is the high leachability when expose it to water like rain (McIntyre & Lake, 2011). Jordan engaged herself with this topic during her Marshall Plan internship in 2012 (Jordan, 2012).

To reduce the leachability, borate treatment is combined with creosote or copper naphthenate to treat rail road ties (Taylor et al., 2013). This may occur in a one step process but to prevent stuck burn a two step process is used. First the ties are dip treated with borate for 3 minutes. After that they are stacked outside for 6 to 10 month to reach the required moisture content of 40% to get a pressure treatment with creosote or copper naphthenate. The advantage of this process is that the ties have a protection against any wood destroying organisms during seasoning, which should improve the subsequent mechanical properties.

There is no direct data available about these improved mechanical properties. Thus a study comparing the mechanical properties of traditional treated and the two step treated rail road ties is necessary to prove the concept. A test on large scale with 408 ties, including 2 species (oak and gum), 2 locations, 51 replicates and 2 treatments, will be done. This project includes several mechanical properties tests like toughness, bending (MOE & MOR)- and hardness testing. To plan this study certain pretests are necessary. A toughness test was already done and reported by Taylor et.al (Taylor et al., 2013).

This report presents the development of the hardness test component of the larger study. Hardness is the resistance of a material against a penetrating or denting body which causes a deformation of the material. This deformation and the force which is needed to indent a tool (usually a ball) are measured in a hardness test. In this study the Janka test is applied, which was developed by Gabriel Janka an Austrian wood researcher (Janka, 1906). In this method, the hemisphere of a steel ball with a diameter of 0.444 inch is embedded under static load into a wood sample. The force to embed the ball halfway is measured and referred to as the Janka hardness (Green et al., 2006) which is specified in ASTM standards D 143 (ASTM, 2000).

The Janka test is normally used for thin, uniform materials such as hardwood flooring. For the purpose of testing rail road ties four larger balls with different diameters were used to get results from deeper into the (relatively large and potentially non-uniform) cross-section. Poo Chow tested the hardness of railway sleepers as well by using a 2 inch diameter ball which proves to be a successful method (Chow, 2007) (Chow et al., 1995).

The objective of this study was to get an idea how the balls of different diameters work on different treated rail road ties, and how the data obtained compare with the standard Janka test. The study was split in two tests. In the first test untreated pieces of ties including oak, gum and hickory samples were used to try the different balls to get to know them and to choose the best one for further tests. The second part includes several tests on untreated, treated and green ties including oak and gum. Tests outside on the surface and also inside (by cutting a board off) were conducted.

2 MATERIAL

2.1 Test 1

20 wood blocks cut from untreated rail road ties were used for this test. There were gum, hickory, and oak samples. Some of them were freshly sawn (new) and some were stored outside for one year (old). Neither type was treated with chemicals. The size varied a lot, especially in length (Table 1).

Table 1: Species, storage, and sizes of the samples used in test 1

sample	species	old/new	size of the cross section [in]			length [in]
1	gum	old	6	x	8	12
2	oak	old	6.25	x	7.5	12
3	oak	old	6	x	7.5	11.75
4	gum	old	5.75	x	8	11.5
5	gum	old	5.75	x	8	12
6	oak	old	6	x	7.5	12
7	gum	new	6.75	x	8.5	7.5
8	gum	old	5.75	x	7.5	11.75
9	oak	new	7	x	7.75	10.75
10	oak	old	7	x	8.5	7
11	gum	new	7	x	9	4
12	hickory	new	7	x	8	3.5
13	oak	new	7	x	9	10
14	oak	old	6	x	7.75	12
15	oak	old	6	x	7.5	11.5
16	oak	old	7	x	9	7
17	oak	new	7	x	9	6
18	gum	old	7	x	8	5
19	oak	old	6	x	7.5	6
20	oak	new	7.25	x	9.25	4.5
Average			6.48	x	8.14	8.89

2.2 Test 2

Twelve rail road ties were used for the hardness test, which included two different species (oak and gum) and three different treatments. Four of the ties were treated with borates. The ties were dipped for three minutes in borates and then stored outside for 6 to 12 month to dry. These ties have a cross section of 7 by 9 inches. Another four ties were dried outside as well for 6 to 12 months but without treating them before. The cross-sections of these ties were 6 by 8 inches. The last four ties were dip treated with borates as the first ties but they were not stored outside and were still green. They have as well a size of 7 by 9 inches. The length of all ties was 100 inches.

For the hardness test the ties were cross-cut in smaller pieces to handle them easier. A section 12 inches long was cut from the end to avoid a possible influence from the edge. Then a section 16 inches long was cut to test the exterior hardness. Another piece of 20 inches long was cut to test the hardness inside; from these sections a board two inches thick was removed from the surface, providing an interior surface for hardness testing.

The ties were numbered from 1 to 12: 1-4 were untreated and dried, 5-8 were treated and green, and 9-12 were treated and dried. Each group included two oak and two gum samples (table 2).

Table 2: Assignment of the samples used in Test 2

Sample	Age/Treatment	Species
1	untreated	oak
2	untreated	oak
3	untreated	gum
4	untreated	gum
5	green	oak
6	green	gum
7	green	oak
8	green	gum
9	treated	oak
10	treated	gum
11	treated	oak
12	treated	gum

Moisture Content

After cutting the samples from the rail road ties, a piece of 1 inch long was cut off to measure the moisture content.

3 METHODS

For the hardness tests, a MTI-machine was used which embeds a steel ball into the surface of the wood at a rate of 0.5 inch/minute and measures the force generated. This kind of hardness test is called Janka test (Janka, 1906), which is specified in ASTM standard D 143 (ASTM, 2000). The equipment using to embed the ball consists of a shaft, flexible collar, a lever and the ball (Green et al., 2006). This method is commonly used in the flooring industry, where a clear surface is available. But for the purpose of testing rail road ties, balls with larger diameters were tested to investigate the effect of ball size and the relationship of data generated with larger balls with the standard Janka test.The sizes of the balls are shown below (table 3).

Table 3: Sizes of the balls

	Diameter [in]	Radius [in]	Half radius [in]
Ball 1 (Janka ball)	0.4504	0.2252	0.1126
Ball 2	1.5748	0.7874	0.3937
Ball 3	1.9686	0.9843	0.49215
Ball 4	2.3622	1.1811	0.59055
Ball 5	3.1442	1.5721	0.78605

There are two methods to measure to get comparable values:

- The Janka ball can be indented just until the depth of its radius. If the ball gets more indented the load increases rapidly, because of the shape of the equipment. Thus, by graphing the force/distance data, the point at which the ball is indented into the depth of its radius can easily be determined. This method is usually applied.
- The second variant is to measure the force when the ball is indent exactly into the depth of its radius or its half radius. Lidia Helińska-Raczkowska and Moliński Waldemar did a study with different wood species using a similar method and found a correlation between the indention into the depth of the radius and half radius (Helińska-Raczkowska and Moliński, 2003).

After preliminary testing, the second method was chosen for these tests. The larger balls were not manufactured in such a way as to permit easy visualization of the point at which the ball was embedded to the radius.

3.1 Test 1

This test was used to get an idea how the balls with different sizes (figure 1) would work. The first two samples were tested with all the ball sizes. On the other 18 rail road pieces balls 1 to 4 were used once on each sample. The Janka ball, ball 1 (0.45039 inch) was used twice on each side of each piece. Ball 2 (1.5748 inch) was indented in each side once. Ball 3 (1.9685 inch) was tested on 3 sides. On the fourth side ball 4 (2.3622 inch) was used.

Figure 1: ball 2 to 5 (left to right)

3.1 Test 2

Through the previous testing of the balls, ball 1 (Janka ball) and ball 4 were selected for further tests.

Outside: Both balls are indented into each side once, so each sample was tested for times with each ball.

Inside: On the inner surface a hardness test was performed twice with the Janka ball and once with the larger ball.

Moisture Content: The initial weight (M_{init}) of the wood samples was measured. Afterwards the samples were oven dried at 103°C and weighted again (M_{od}) to calculate the moisture content ($MC\%$) with this formula:

$$MC\% = \frac{M_{init} - M_{od}}{M_{od}}$$

4 RESULTS

4.1 Test 1

4.1.1 Initial testing of different ball sizes

Tests at sample 1 and 2

The average loads to imbed the balls half way (=radius of the ball) or quarter way (=half radius of the ball) of all balls including both samples were calculated. In the graph (figure 2) the relation between the average load [lbs] and the displacement [in] (= radius or half radius of the ball) is shown. The values belonging to the radius are separated from those to the half radius, to be able to compare them as well.

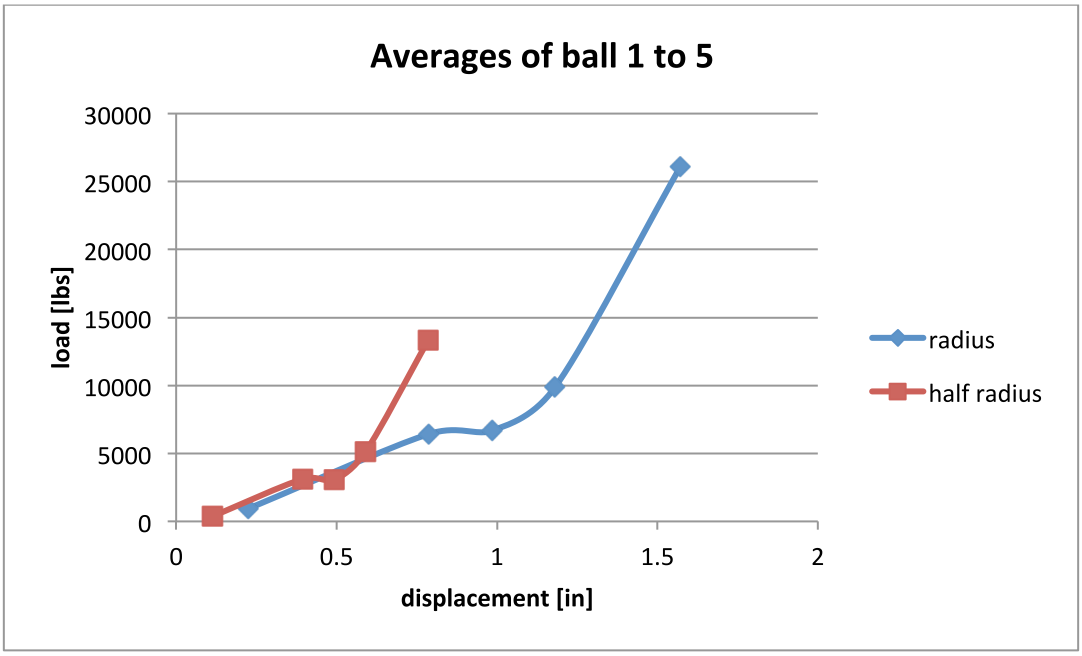

Figure 2: The relation between the displacement (=radius or half radius of the ball) and the average load to embed the ball to the depth of its radius or half radius

Because of random testing there is not data of each sample from each ball available. Also the number of tests varied a lot, e.g. there were 12 tests with ball 1 and just 1 test with ball 5. The reason for that was the space on the sample, which was needed to embed the ball. For the larger balls, some of the penetrations caused cracks, which more or less deformed the sample. Some tests with ball 3 and 4 resulted in cracks, especially if both test were performed on one side of the sample. The cracks usually extended to the edge of the sample or to another penetration. The test with ball 5 caused a lot of cracks; much more than with ball 3 or 4 and almost split the whole wood block. Thus the sample got deformed and further tests were not possible. Another influence of the data beside the cracks was mold; especially on one side of sample 2, a lot of mold was seen. On this side tests with ball 1, 2 and 5 (only) were performed.

4.1.2 Average values of test 1

Sample 3 to 20

The table (table 4) below presents the average load of each ball and each sample for test 1, except the first two pretesting samples, which are mentioned at chapter 4.1.1. Information about the species and the storage length is included under the sample name. "Old" means the wood blocks are stacked outside for approximately one year to season. The "new" ones are freshly sawn.

The load which is needed to embed the hemisphere as well as half hemisphere of the ball was calculated, to enable a comparison between the radius and half the radius. The results varied here as well; it has to be considered that the samples had different treatments and species but there were also other influences like fungal decay and cracks. Especially the bigger balls caused large cracks. Often the wood block even broke, like sample 11, 12, 16, 18 and 20. Thus further tests were not possible. These samples are marked with "broke" in the table.

Table 4: Average load [lbs] to embed the ball to the depth of its radius or half radius

Average load [lbs] to embed the ball to the depth of its radius or half radius		BALL 1	BALL 2	BALL 3	BALL 4
sample 3	radius	957.93	8788.00	13898.93	7621.51
oak, old	half radius	394.67	4020.68	6001.55	3506.15
sample 4	radius	946.86	4652.83	7907.60	9126.55
gum, old	half radius	328.42	2931.84	4829.51	5341.21
sample 5	radius	945.84	4428.09	9420.10	12826.12
gum, old	half radius	360.73	2580.34	4086.63	6817.15
sample 6	radius	869.06	8766.78	16939.32	16482.54

oak, old	half radius	340.04	3973.64	6882.06	8803.96
sample 7	radius	609.25	3858.91	6133.58	7691.32
gum, new	half radius	423.42	1915.42	3214.41	3799.40
sample 8	radius	824.14	4251.33	9801.78	9775.21
gum, old	half radius	333.25	2348.08	5020.22	5335.38
sample 9	radius	1052.33	12157.23	15499.87	18260.77
oak, new	half radius	540.65	5954.01	7147.38	10327.51
sample 10	radius	975.99	10244.05	14642.70	19521.92
oak, new	half radius	511.54	4681.21	6854.47	11143.72
sample 11	radius	broke			
gum, new	half radius				
sample 12	radius	broke			
hickory, new	half radius				
sample 13	radius	1007.68	10270.13	14048.66	14204.44
oak, new	half radius	459.59	4710.56	6459.92	9238.56
sample 14	radius	1018.30	8491.52	14246.89	19986.45
oak, old	half radius	412.46	3930.14	6624.07	8616.54
sample 15	radius	1009.59	7893.65	13087.53	21112.90
oak, old	half radius	410.46	3734.33	6077.50	11007.28
sample 16	radius	741.39	8480.44	12371.72	broke
oak, old	half radius	325.30	3919.81	5088.20	
sample 17	radius	707.06	8377.25	11393.90	12334.84
oak, new	half radius	311.77	3865.98	5296.55	7093.18
sample 18	radius	broke			
gum, old	half radius				
sample 19	radius	693.31	7698.97	11849.58	7293.37
oak, old	half radius	314.98	3959.48	5977.22	3684.69
sample 20	radius	broke			
oak, new	half radius				

4.1.3 Measuring the load at the point where the load increased rapidly

Tests of samples 3 to 9

On the sample 3 to 9 the force at the point where the load rapidly increased was also measured. The table (table 5) shows the load, the displacement where the load rapidly increase and the radius. The difference between the actual displacement and the radius varied a lot, except for the Janka ball (ball 1). The displacement of ball 2 was 33% higher than the radius. Ball 3 had a 6% lower and band ball 4 a 5% higher displacement. That can be seen as well on the graph (figure 3) below, where the same data is present in a chart. The line is not linear because of the high variation of penetrations, thus also the load varied as well.

Table 5: Average load of each ball when measuring the point when the load is rapidly increasing

	ball 1	ball 2	ball 3	ball 4
load average of each ball	695.0567	7837.482	8511.119	9924.046
displacement where the load rapidly increase	0.218313	1.047421	0.925554	1.236816
radius of the ball	0.2252	0.7874	0.9843	1.1811

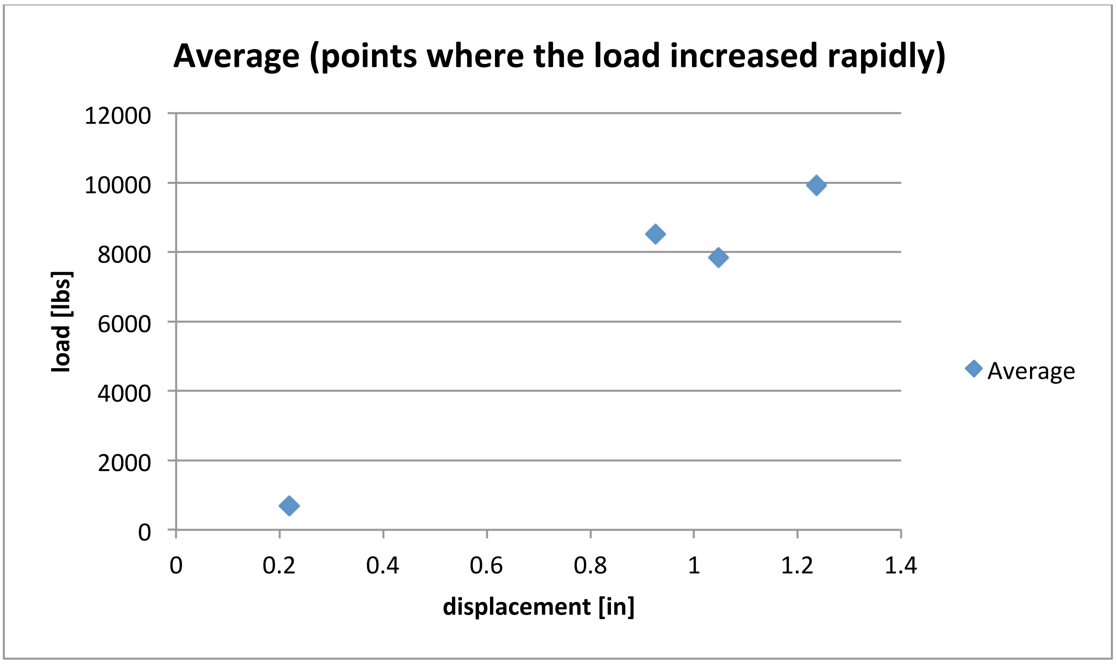

Figure 3: Average load (measured by the point where the load is rapidly increasing) compared to the displacement

4.1.4 Comparison between the Janka ball and larger balls

Test of sample 3 to 20

To get a more reliable comparison between the different sized balls a graph (figure 4) using the values of samples 3 to 20 was complied. The chart shows the average force which was needed to embed the ball to the depth of its radius respectively half radius compared to the length of the radius or half radius. Further linear trend lines were placed over the chart lines, which almost correspond.

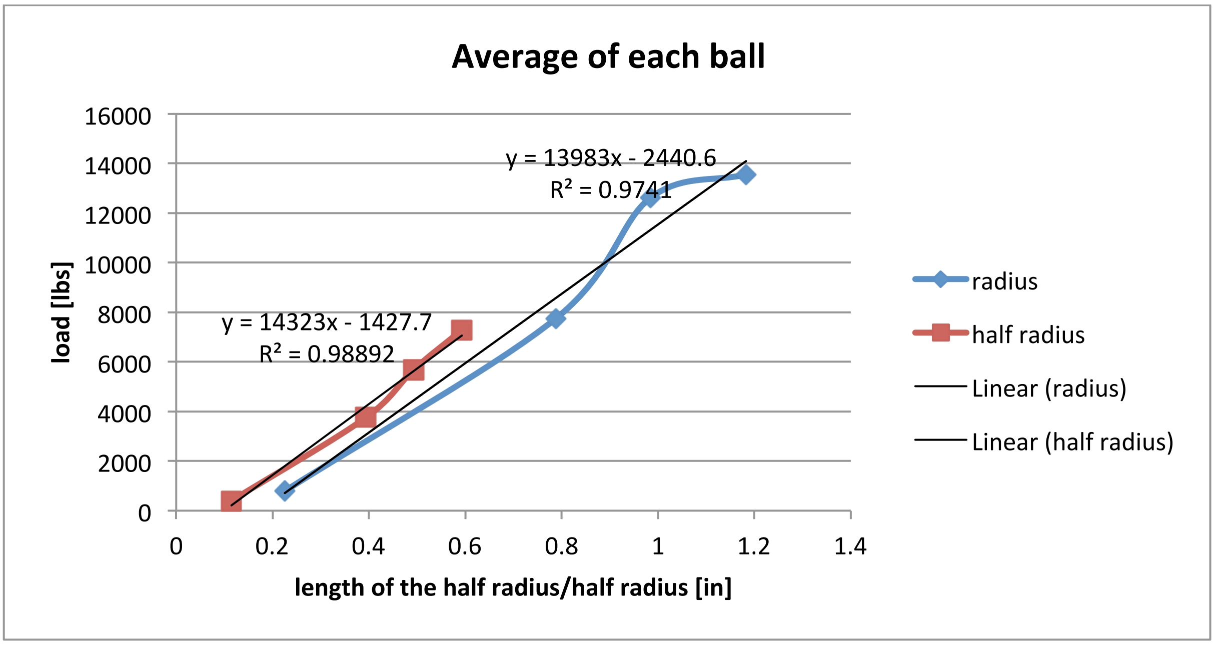

Figure 4: Average force to embed the ball of its radius or half its radius of sample 3 to 20

A further comparison was made by looking to the relation between the average force to imbed larger balls halfway (=radius of the ball) into wood [lbs] and the average force to imbed the Janka ball halfway (figure 5). The different colors present a size of ball. A connection between the balls could be seen here as well although it is not that obvious as on figure 3.

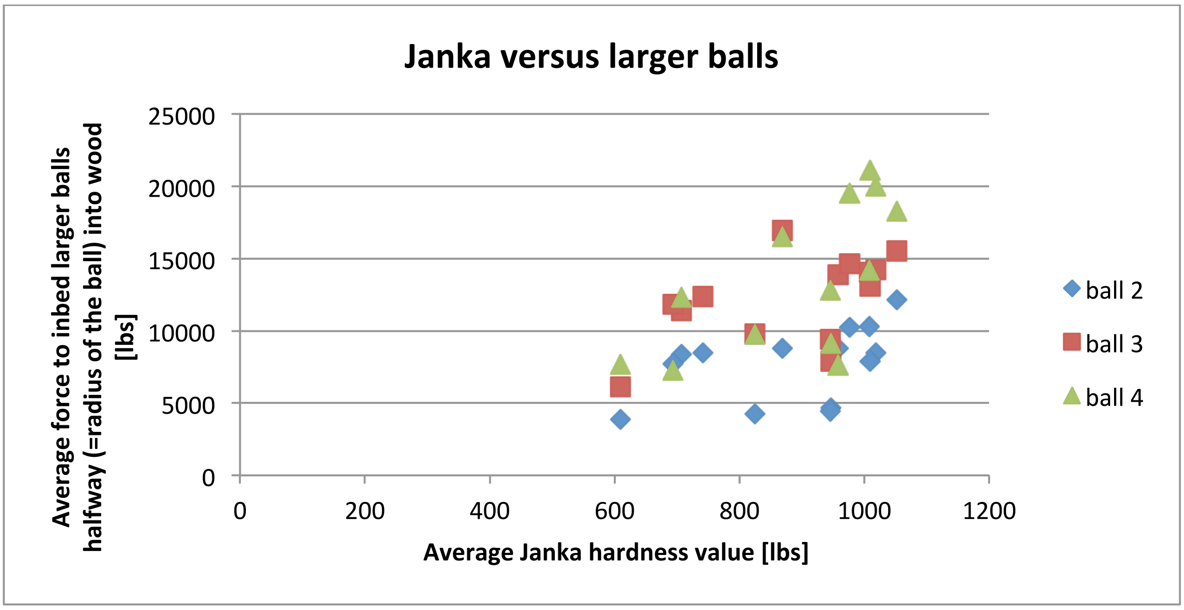

Figure 5: Comparison between Janka ball and larger balls

4.1.5 Comparison of the wood species

Tests of sample 3 to 20

Oak is harder than gum, that can be seen at the graph (figure 6) below. The relation between the load and the penetration depth (=radius or the half radius of the balls) is shown. Radius and half radius are separated, both show that oak is definitely harder than gum.

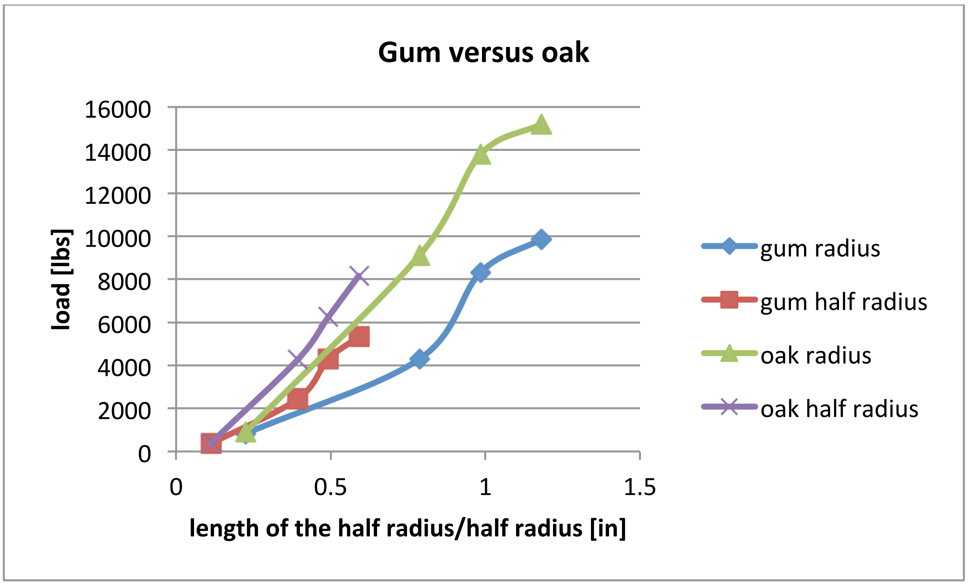

Figure 6: Average of each ball selected by species to compare gum and oak

4.2 Test 2

4.2.1 Average values of test 2

The average loads to embed the ball to the depth of its radius or half radius of test 2 are presented below (table 6). The values were separated by the treatment/storage, wood species, penetration depth (radius/half radius) and place (inside outside). A comparison of the different treatments/storages and wood species can be found in the following pages. Between the load inside and outside there was no obvious difference. Most values measured by the Janka ball are higher inside than outside. In contrast to ball 4 the values are mainly lower inside than outside.

The average coefficient between the values of the radius and half radius was 2.295, which is compared to the coefficient of 1.94 which Lidia Helińska-Raczkowska and Moliński Waldemar calculated higher (Helińska-Raczkowska and Moliński, 2003).

Table 6: Average load [lbs] to embed the ball to the depth of its radius or half radius to compare kind of storage/treatment, outside/inside and wood species

Average load [lbs]		OUTSIDE				INSIDE			
		Janka ball		Ball 4		Janka ball		Ball 4	
		radius	half radius	radius	half radius	radius	half radius	radius	half radius
untreated	oak	1165	593	25171	11515	1261	570	25785	12108
	gum	864	390	17529	8295	818	345	18752	9435
green	oak	1053	470	22148	12432	1100	481	24647	10866
	gum	921	381	17695	8756	862	288	15311	7204
treated	oak	1021	423	25302	11747	1296	603	20791	10538
	gum	1084	557	20065	10109	2037	414	17800	7973

An initial hole could be found in sample number 9 which influenced the average data of treated oak. The value of treated oak with ball 4 measured by the depth of the radius would be 7% higher when ignoring sample 9. The average load would be than 27,045 lbs. Further influences could be cracks caused by ball 4.

4.2.2 Comparison between the Janka ball and ball 4

At the graph below (figure 7) the Janka ball and ball 4 are compared. The relationship between the average Janka hardness values (presented as well in table 7) and the average force to imbed ball 4 into the wood sample is shown with markers, which are colored depending on the penetration (radius/half radius).

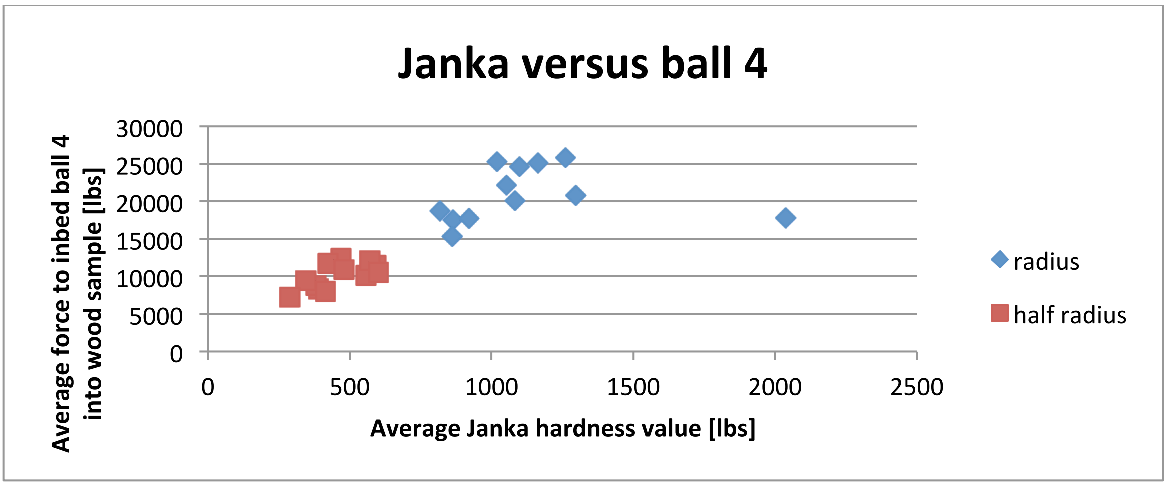

Figure 7: Relation between the Janka ball and ball 4

4.2.3 Comparison of the treatment/storage

The average hardness values to compare the different treatments respectively storages are presented below (table 7). The green rail road ties were obvious softer than the untreated and treated ones, which had had the opportunity to dry. Between the untreated and treaded samples there was no clear difference. Comparing the values of ball 4 outside the treated ties were harder, but looking to the data inside of ball 4 the untreated samples were harder than the treated ones.

Table 7: Average hardness values to compare the different treatments or storages of the rail road ties

AVERAGE Treatment/storage	OUTSIDE				INSIDE			
	Janka ball		Ball 4		Janka ball		Ball 4	
	radius	half radius	radius	half radius	radius	half radius	radius	half radius
untreated	1015	491	21350	9905	1039	457	22268	10771
green	987	425	19922	10594	981	385	19979	9035
treated	1052	490	22684	10928	1667	509	19295	9255

4.2.4 Comparison of the wood species

Oak ties were clearly harder than the gum samples; on average 27%. The average Janka hardness with ball 4 outside of oak amounted 24207 lbs and inside 23741 lbs. In contrast gum had a hardness tested by ball 4 outside of 18430 lbs and inside 17287 lbs (table 8).

Table 8: Average hardness values to compare the oak and gum rail road ties

Average load [lbs]	OUTSIDE				INSIDE			
	Janka ball		Ball 4		Janka ball		Ball 4	
	radius	half radius	radius	half radius	radius	half radius	radius	half radius
oak	1079	495	24207	11898	1219	551	23741	11170
gum	956	442	18430	9054	1239	349	17287	8204
difference	**13%**	**12%**	**31%**	**31%**	**-2%**	**58%**	**37%**	**36%**

4.2.5 Moisture content

The moisture content of each sample and averages of the different treatments are presented below (table 9). The average moisture content of green ties was 85.2% which is distinctly higher as the other ones. The untreated rail road ties had a moisture content of 28.7% and an average moisture content of 38.5% could be measured of the treated samples. The single values within the same treatment varied a bit, but not more than 17%.

Table 9: Moisture content [%] when cutting the rail road ties

Sample	Moisture content [%]
1	36.2%
2	26.6%
3	24.4%
4	26.5%
5	83.1%
6	90.3%
7	83.6%

8	85.2%
9	43.3%
10	28.0%
11	44.2%
12	34.5%
Average untreated	28.7%
Average green	85.2%
Average treated	38.5%

5 DISCUSSION

5.1 Test 1

5.1.1 Initial testing of different ball sizes

The results of the first two samples did not show a linear relationship, which could be caused by the uneven distribution of tests, e.g. there were tests with ball 3 and 4 on the first sample and tests with ball 1, 2, 4 and 5 on the second sample. It was clear that the results are hard to compare since two different wood species were used, which can be expected to have different hardness properties. That can be seen as well on the results at chapter 4.2.4. The cracks and the fungal decay also probably influenced the results. Also the numbers of tests differed a lot, so more tests of the bigger balls may make the results more consistent.

5.1.2 Average values of test 1

It has to be taken in account that the number of tests per sample differed a lot. There was just one test with ball 4 compared to the Janka test ball with 8 tests, thus the “average” of values of ball 4 in reality was for just one data point. Another factor was the small size (length) of some of the samples, which resulted lots of cracks. The size varied a lot (see chapter Materials 2.1) and was mostly too small. All small samples broke because the balls caused too much stress in the wood. That led to cracks which went until the edge and split finally the rail road tie piece. There was too little wood available which could resist against these cracks. Because of this problem, larger rail road tie samples were used in test 2.

5.1.3 Measuring the load at the point where the load is increased rapidly

The high difference of the radius and the actual displacement was caused by the different shaped penetration tools. These balls were not standardized and not exact enough for such precise testing. The difference between ball 2 and ball 3 can be seen in the figure (figure 7). The load/deflection curve of ball 2 deflected after embed it to the depth of its radius, in contrast to the load/deflection curve of ball 3 which deflected before the ball embedded halfway.

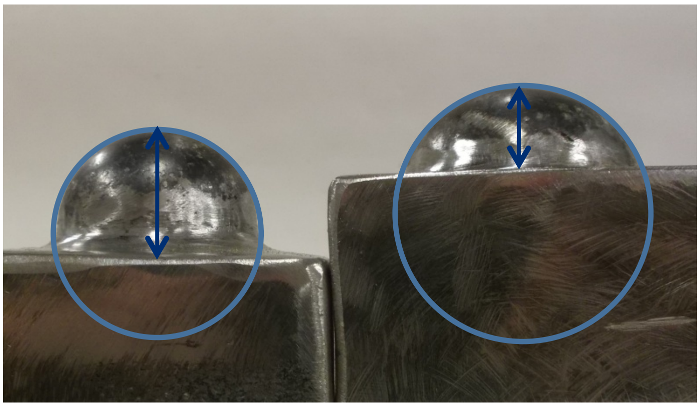

Figure 8: The shape of Ball 2 (left) and 3 (right)

5.1.4 Comparison between the Janka ball and larger balls

The values to imbed the balls halfway or quarter way were almost in a linear line except ball 3 when looking at the values of the radius. As mentioned, the load of ball 3 deflected before it reached the radius. Thus more force was necessary to penetrate it halfway. That can be seen in the chapter 4.1.4 in figure 3. The values resulting from load at half radius were more linear, including ball 3, when comparing them to those of the radius. The load at half of the radius was not influenced by the shape of the penetration tool and thus provided consistent results.

5.2 Test 2

5.2.1 Average values of test 2

The values shown on table 7 were averages of a total of 12 railroad ties. A higher number of ties and tests likely would improve the validity of the results. A sample with a defect, e.g. an internal hole, wouldn't influence the overall results that much. Also larger samples would help to prevent cracks, although the samples were bigger than in test 1.

5.2.2 Comparison between the Janka ball and ball 4

The relation between the load of the Janka ball and ball 4 in test 2 were clearer than in test 1. A linear correlation could be found. The load averages of the half radius were more consistent than those of the radius.

5.2.3 Comparison of the treatment/storage

The green ties, which were treated with borates, had definitely the lowest hardness. The reason for that could be the high moisture content, which is mentioned more in detail below (5.3.2 Moisture Content). The treated and seasoned rail road ties had mostly the highest hardness, which proved the effectivity of the borates treatment. But they were almost as hard as the untreated ties. It has to be mentioned that one of the treated samples had an internal hole which decrease the values especial at ball 4. The Janka ball had just a small penetration, thus it was not influenced by the hole.

5.3 Influential factor of hardness

5.3.1 Wood species – Density

Oak resulted in to be definitely harder than gum both test (test 1 and test2). That can be easily explained by the density. Red oak has an average green specific gravity of about 0.6 which is higher than that of gum (about 0.46) (Foerest Products Laboratory, 1987). Gabriel Janka mentioned the relation between hardness and specific gravity (Janka, 1906), which is the ration between the density of the wood and the density of water (Hoadley, 2000). Hardness increases when the specific gravity increases (Janka, 1906).

5.3.2 Moisture Content

Janka's observation that hardness increases when the moisture content decreases (Janka, 1906) could be seen also at this study. The green rail road ties had very high moisture content because they had not seasoned. Consequently they had the lowest hardness. The lowest moisture content of 28.7 % belonged to the untreated ties, although the hardness in the most cases was not the highest one. The treated ties had a 10% higher moisture content than the untreated one, but mostly the highest hardness. The reason for that could be fungal decay on the untreated ties, which would prove the efficacy of the treatment.

6 CONCLUSION

Through the first test a linear correlation between the Janka ball and the larger balls could be found. Ball 2 and 3 are not correct enough and ball 5 seemed to split the whole sample, which depends on the size of the rail road tie as well. Ball 4 was the best choice, the ratio between the rail road tie and the ball size works and the ball does not split the sample if the tie has a length of at least 16 inch. The hardness of the different treatments could not be clear distinguished because of the small amount of replicates.

As in the introduction mentioned further steps of the project will be mechanical tests on a large scale. For the hardness test ball 4 should be chosen, to get great results.

LITERATURE REFERENCES

ASTM 2000. ASTM D 143-94. *Standard test methods for small clear specimens of timber.* American Society for Testing and Materials.

CHOW, P. 2007. Mechanical properties with eight integrico composite crossties. Urbana: University of Illinois.

CHOW, P. & BAJWA, D. S. Weathering Effects on the Decay Resistance of Creosote-treated Oak.

CHOW, P., LEWIS, S., REINSCHMIDT, A. & BARENBERG, E. 1987. Effects of Natural and Accelerated Aging on Oak Crossties. *Proceedings of the American Wood Preservers Association, Toronto, Canada*, 308-329.

CHOW, P., REINSCHMIDT, A. J., DAVIS, D. D., LAINE, K., CHOROS, J. & KALAY, S. 1995. Propposed strength properties tests for wood crossties. University of Illinois Urbana, AAR, Chicago, M. .

FOREST PRODUCT LABORATORY 1987. *Wood handbook: Wood as an engineering material*, United States Government Printing.

GREEN, D. W., BEGEL, M. & NELSON, W. 2006. *Janka hardness using nonstandard specimens,* Madison, WI, U.S. Dept. of Agriculture, Forest Service, Forest Product Laboratory.

HELIŃSKA-RACZKOWSKA, L. & MOLIŃSKI, W. 2003. The effect of the Janka ball indentation depth on the hardness number determined for selected wood species.

HOADLEY, R. B. 2000. *Understanding wood: a craftsman's guide to wood technology*, Taunton press.

JANKA, G. 1906. Härte des Holzes.

JORDAN, B. 2012. Leachability of borate treated southern pine influenced by coppper napthenate treatment. Marshall Plan Scholarship Programm.

KIM, J.-W., TAYLOR, A. M. & KÖSE, C. 2011. Ambient-temperature borate dip-diffusion treatment of green railroad crossties.

MCINTYRE, C. R. & LAKE, M. A. 2001. Fixed Borates Anyone? : The International Research Group on Wood Protection.

TAYLOR, A., JORDAN, B. & LLOYD, J. 2013. Pre-treatment decay of railroad ties and its prevention. University of Tennessee, Knoxville, TN USA; Salzburg University of Applied Science, Kuchl Austria; Nisus Corporation, Knoxville, TN USA.

WILCOX, W. W. 1978. Review of literature on the effects of early stages of decay on wood strength. *Wood and Fiber Science,* 9**,** 252-257.

PICTURE REFERENCE

CHART AND TABLE REFERENCES

THE UNIVERSITY OF TENNESSEE
INSTITUTE OF AGRICULTURE

Center for Renewable Carbon
Department of Forestry, Wildlife
and Fisheries
2506 Jacob Drive
Knoxville, Tennessee 37996-4570
(865) 946-1129
FAX (865) 946-1109

EMPLOYMENT VERIFICATION MEMORANDUM

1 October 2013

To Whom It May Concern:

This memo serves as evidence of on-campus employment for Ms. Lisa Vesely, who is an J-1 scholar at the University of Tennessee.

I will be Lisa's immediate supervisor, and Lisa will be working in the Center for Renewable Carbon, led by Dr. Timothy Rials. The student's job description is to carry out research on improving processing in the hard wood industry, as part of her internship. Her actual start date is June 24, 2013 and the number of hours per week is 40 and her last day of employment is Sept. 24, 2013.

My contact information is:

Adam Taylor

Employer's signature

Adam Taylor

Signatory's Job Title:

Associate Professor

Employer's Telephone number: 946-1125

Employer's email:

AdamTaylor@utk.edu