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 [73] Assignee **Koppers Company, Inc.**
a corporation of Delaware
Continuation-in-part of application Ser. No.
710,105, Mar. 4, 1968, now abandoned.

[56]

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[54] **REINFORCED WOOD RAILROAD TIE**
6 Claims, 9 Drawing Figs.

[52] U.S. Cl..... **238/29,**

238/83, 238/264, 238/283

[51] Int. Cl..... **E01b 2/00,**

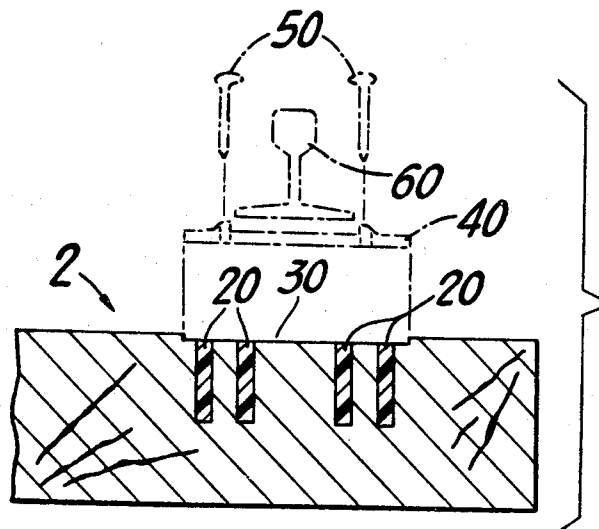
E01b 3/26, E01b 9/42

[50] Field of Search..... **238/83,**

29.50, 91, 264, 283, 284, 285, 286, 287, 306;

52/404, 406, 408

ABSTRACT: A wooden structure having a load-bearing surface for supporting a load is reinforced with reinforcing members disposed beneath the load-bearing surface and embedded in the wooden structure. The reinforcing members are composed of a nonshrinking material having a compressive strength greater than the wood and bonded to the wood.



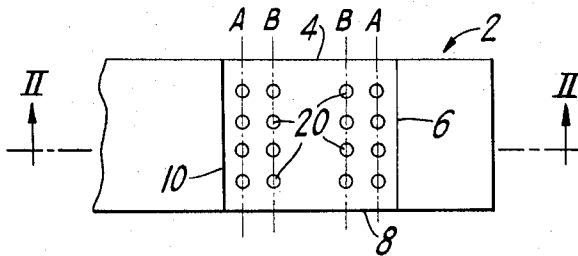


FIG. 1

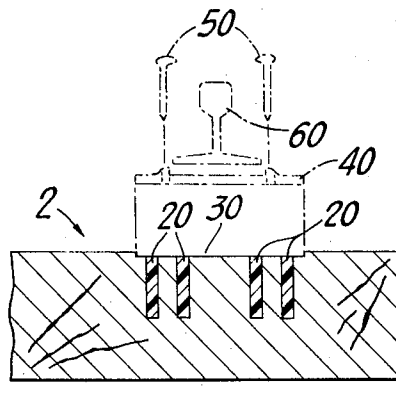


FIG. 2

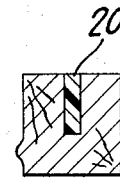


FIG. 8

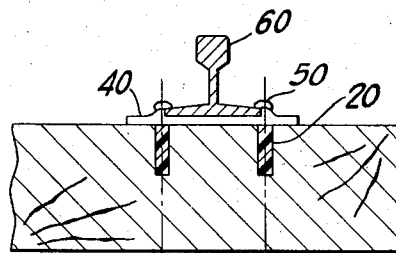


FIG. 3

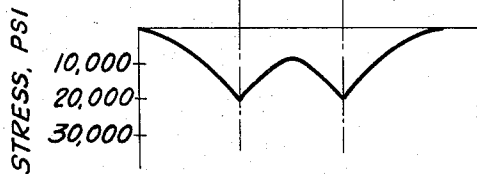
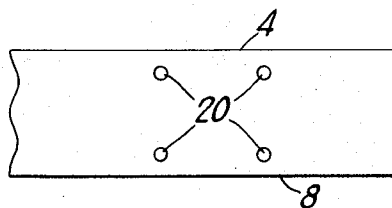


FIG. 4



INVENTOR.
CHARLES J. PENNINO

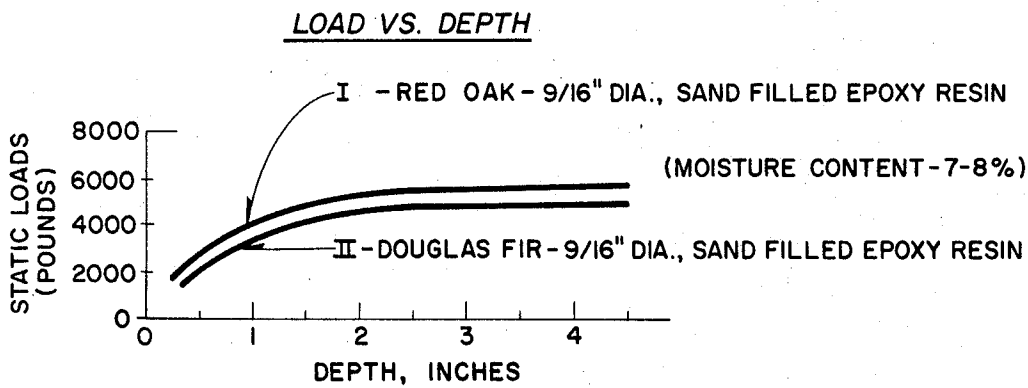


FIG. 5

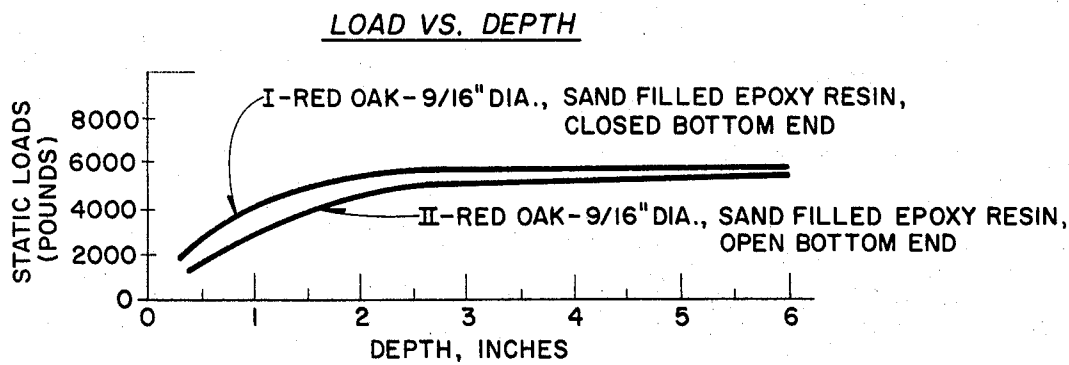


FIG. 6

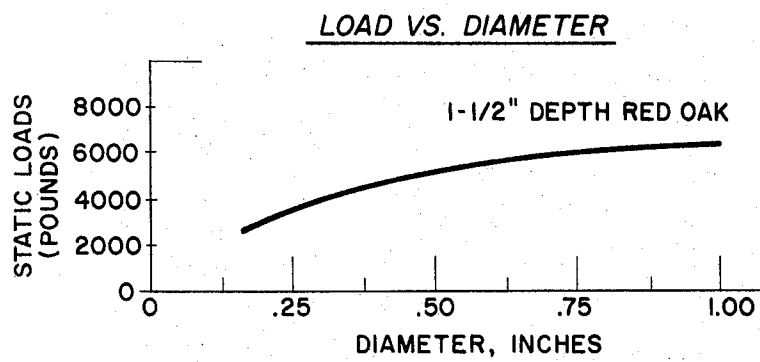


FIG. 7

INVENTOR.
CHARLES J. PENNINO

SAMPLE	KIND OF WOOD	WOOD SIZE	14" TIE PLATE	NUMBER OF ROWS OF REINFORCING MEMBERS	NUMBER OF MEMBERS PER ROW	DIAMETER OF REINFORCING MEMBERS	DEPTH OF REINFORCING MEMBER	TYPE OF RESIN	INDENTATION AFTER 2.5 MILLION CYCLES
A	CREOSOTED OAK	7" X 8" X 2'	YES	4	2 IN OUTER ROW 3 IN INNER ROW	OUTER ROW 3/4" INNER ROW 5/8"	2"	SAND FILLED RESIN	0.08"
E	CREOSOTED OAK	7" X 8" X 2'	YES	—	—	—	—	—	0.17"
B	CREOSOTED OAK	7" X 8" X 2'	NO	4	4 PER ROW	OUTER ROW 3/4" INNER ROW 5/8"	2"	SAND FILLED RESIN	0.125"
F	CREOSOTED OAK	7" X 8" X 2'	NO	—	—	—	—	—	0.50"
C	CREOSOTED OAK	7" X 9" X 2'	NO	2	4 PER ROW	ALL 5/8"	2"	CLEAR RESIN	0.03"
D	CREOSOTED OAK	7" X 9" X 2'	NO	2	2 PER ROW	ALL 5/8"	2"	CLEAR RESIN	0.06"
G	CREOSOTED OAK	7" X 9" X 2'	NO	—	—	—	—	—	0.23"
H	CREOSOTED PINE	7" X 8" X 2'	NO	4	4 PER ROW	ALL 5/8"	2"	SAND FILLED	MUCH DEEPER THAN SAMPLE B
I	CREOSOTED PINE	7" X 8" X 2'	NO	—	—	—	—	—	COMPLETE FAILURE AFTER 300,000 CYCLES

FIG. 9

INVENTOR
CHARLES J. PENNINO

REINFORCED WOOD RAILROAD TIE

CROSS-REFERENCE TO RELATED APPLICATION

This is a continuation-in-part of application Ser. No. 710,105, filed Mar. 4, 1968, entitled, "Reinforced Wood Railroad Tie," now abandoned.

BACKGROUND OF THE INVENTION

This invention relates to a railroad wooden crosstie and more particularly to a wooden tie reinforced in the area of wear.

In the conventional construction of the railroad wooden crosstie, a tie plate carrying a rail is disposed upon a surface of the wooden tie to spread and distribute the load or weight transmitted to the tie from the rail supporting a passing train. This area of the tie beneath the tie plate is commonly referred to as the wear area because this is the area that tends to disintegrate sooner than the other areas of the tie.

Conventionally the tie plate and the rail are secured to the wooden tie by spikes driven through holes disposed near the lateral edges of the tie plate. These spikes secure the rail to the tie plate; and likewise, secure the tie plate to the wooden tie to restrict horizontal and vertical movements of the rail as the train passes over the rails.

Customarily, each of the two rails of a railroad track are canted inwardly by the tie plate being disposed at a slope of one unit of rise to 40 units of run to improve the load-bearing qualities and to help maintain the gauge (distance between the rails) of the rails particularly when a train passes. Actually the spikes primarily hold the gauge. Because each rail is canted inwardly of the track, the passage of train wheels over the track tends to cause a slight amount of horizontal movement to occur, in conjunction with a slight amount of vertical movement, of the rail. This movement simulates a wave. This combination of vertical and horizontal motion tends to effect a rocking movement of the tie plate on the tie which movement, in turn, causes an indentation in the tie, a phenomena known in the art relating to the railroad industry as "plate cutting," i.e., the cutting or wearing of the wooden tie in the wear area of the tie plate.

This "plate cutting" is accelerated by a number of other factors. For instance, moisture under the tie plate softens the wood fibers of the wear area. Dust and abrasive particles from the road bed are likewise trapped under the tie plate. The rocking movement of the tie plate under the load and vibration of passing trains literally grind the abrasive particles under the tie plate into the tie destroying the supporting characteristics of the wood fibers of the tie in the wear area. In fact, when such a worn condition was studied by the use of time-delay motion picture techniques, the results actually showed the destroyed wood fibers flexing, causing wood preservatives such as creosote, to exude from the wooden tie. Eventually, the fibers under the wear area were compressed and failed by fracture at the grains or fibers of the wooden crosstie.

DESCRIPTION OF PRIOR ART

Remedies have been proposed for the problem of "plate cutting." My U.S. Pat. No. 3,358,925, provided as one solution the bonding of a nonmetallic tie plate to the tie with the result that the tie surface was protected from dust, moisture and the like; the tie plate could not move with respect to the tie; and the tie-plate material provided a good wear surface for the movement of the rail therein. Another approach was reported by Arno Burmester in his article entitled, "Improvement Of The Resistance Of Wood To Transverse Pressure," in the German publication, "Holz-Zentralblatt," dated Oct. 11, 1965, wherein he suggested improving the resistance of wood by impregnating the individual cells of the wood with a plastic resin to increase their resistance to stress. Burmester suggested drilling holes in the tie of 0.5 cm. in diameter and 3 cm. deep and spacing these holes at a distance of 1 centimeter from one another, and subsequently filling the holes with a

liquid plastic which impregnates the surrounding fibers and grains of the wooden tie. He stated that the impregnation process actually fills the lumina of the cells of the wooden crosstie and increases the strength of the wooden tie by increasing the strength of individual cells. Burmester's process has several undesirable limitations. The expense of drilling many holes at a distance of 1 cm. apart is great. Also, the resin must have an extremely low viscosity in order to impregnate the cells of the wood. A greater disadvantage of this process is that positioning the holes 1 cm. apart causes the wood in this region to become severely weaker; the impregnation is, therefore, a necessity in order to return the wood to its original level of strength.

My invention on the other hand, distributes the stresses in the tie and makes no effort to increase the strength of the lumina of the cells in a wood crosstie. My invention distributes the stresses occurring internally within the crosstie so that individual wood cells may successfully sustain the load. Since the wood cells are not particularly changed physically or chemically, my invention can make use of a wide range of resin systems.

SUMMARY OF THE INVENTION

In accordance with my invention, a wooden structure having a load-bearing surface for supporting a load is reinforced with a material having a higher compressive strength than the wooden structure. A plurality of reinforcing members are disposed generally perpendicular of the load-bearing surface and embedded in the wooden structure and bonded thereto at locations where stresses greater than the strength of the wood will bear may occur when a load is applied. The reinforcing members are separated apart by a minimum distance of 1 1/4 inches whereby the reinforcing members disperse and distribute the stresses away and apart from the load-bearing surface of the wooden structure.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a top view of a reinforced crosstie;

FIG. 2 is a side sectional view of the crosstie of FIG. 1 along lines II-II;

FIG. 3 is a side sectional view of the preferred embodiment of the invention including a diagram illustrating a typical stress profile of a railroad crosstie;

FIG. 4 is a top view of FIG. 3;

FIG. 5 is a graph of load versus depth of a reinforcing member in red oak and douglas fir wood;

FIG. 6 is a graph of load versus depth comparing the results of a reinforcing member disposed in an opening in a crosstie having a closed bottom end and an opening in a crosstie having an open bottom end;

FIG. 7 is a graph of load versus diameter of a reinforcing member in red oak;

FIG. 8 is an end view illustrating the formation of bulges appearing on the sides of a test specimen of soft wood with a reinforcing member; and

FIG. 9 is a chart summarizing the results from the examples actually tested.

DETAILED DESCRIPTION

In FIG. 1, the rectangular area bounded by lines 4, 6, 8 and 10 of a wooden railroad crosstie 2 has been reinforced by reinforcing means 20 preparatory to the placing of a rectangular tie plate 40, FIG. 2 thereon. The tie plate 40 may be mounted flush with the upper surface of the tie or it may be recessed in to a cutaway groove 30 or an adzed area as shown in FIG. 2 as desired. The reinforcing members 20 are conveniently disposed in 4 rows; with 4 reinforcing members per row, arranged in two outer rows (A) and two inner rows (B) as shown in FIG. 1.

The wooden railroad crosstie 2 is of conveniently available wood, such as oak (a hard wood), douglas fir (a soft wood) or

pine (a soft wood) or the like. The wooden tie is conventionally impregnated with creosote for preserving wood from the corrosive nature of water, fungus, insects, and the like. The dimensions of the crosstie vary according to its application and railroad manuals set forth the standard dimensions for the railroad crossties for particular applications.

FIG. 3 illustrates the preferred embodiment of the invention without a recess and shows a typical stress profile in the crosstie as illustrated in The American Railway Engineering Association Proceedings of the 44th Annual Convention, 1944, Vol. 45. When a railroad tie is loaded, stresses concentrate at two peaks in the crosstie beneath the edges of the railroad rail. In accordance with the invention, the reinforcing members 20 are disposed directly beneath these concentrated areas of stress. The reinforcing members thus are placed at the location where the greatest tendency for wear occurs in the region of the highest stress concentrations as shown in FIG. 3. The stress values are plotted in FIG. 3 in pounds per square inch (p.s.i.).

I have found that the reinforcing of railroad wooden crossties generally depends upon three major considerations: 1) the quality of the wooden tie; 2) the quantity and size of the reinforcing members 20; and 3) the resin system of which the reinforcing members are composed.

To optimally reinforce wood, a careful selection of a suitable wooden crosstie must include the consideration of the type of wood, the surface hardness of the wood, the moisture content of the wood, and the grain structure of the wood. I have found that the wood most advantageously used in accordance with the invention is white or red oak (a hard wood) having a surface hardness of approximately 800—1200 lbs. with the grain oriented perpendicularly to the load-bearing surface and having a very low moisture content of approximately 12 percent. Of course, other woods, such as douglas fir and the pines, are suitable for use with this invention, but the strengths of these woods should be compensated for by the reinforcing members being disposed at greater depths as will be discussed later.

The effect of moisture content on wooden crossties can best be illustrated by an examination of table I which includes the test results from the AAR (American Association of Railroads) Tie Wear Machine on conventional creosoted pine crossties and on creosoted pine crossties reinforced in accordance with the invention.

The AAR Tie Wear Machine test, developed by the American Association of Railroads (AAR) and reported in their Report No. ER-54, simulates the actual road conditions of 10 to 15 years of service of moderately heavy traffic (or 190 million gross tons of traffic) in a relative short period of time of 2 to 3 weeks. Typically, a specimen includes a portion of a tie, fitted with a 14 inch metal tie plate and a spiked down rail. The specimen is placed in the tie wear machine and subjected to alternate loading at 129 cycles per minute for 2.5 million cycles. After 2,000 cycles, sand and water are periodically added to the tie to simulate environmental conditions. At the end of the cycle, the depth to which the tie plate cuts the tie is measured. Also, time elapse movies are taken at time intervals of 2½minutes or 24 frames per hour.

I have modified this test procedure by subjecting the tie specimen during the test to alternative temperature extremes of -40 to +150° F. to simulate environmental conditions, and further, by testing tie specimens, in some instances, without

the use of a tie plate in order to subject the specimen to more severe conditions.

The test results are naturally comparative; i.e., the depth of surface indentation on a reinforced tie using my invention is compared with the depth of surface indentation on a crosstie without reinforcing members.

TABLE I

	Indentation, inches	Cycles, million	Time in test	Moisture content, percent
Sample*:				
1-----	0.53	0.32	42 hours...	20
2-----	0.50	0.053	7 hours....	41
3*-----	0.47	2.2	12 days....	18
4**-----	0.31	2.2	12 days....	20
5***-----	0.44	1.64	8.8 days...	43

* Reinforced with two rows of four reinforcing members per row at a depth of 2 inches and at a diameter of three-fourths inch per reinforcing member.

** Reinforced with four rows of four reinforcing members per row at a depth of 2 inches and at a diameter of three-fourths inch for the outer rows and five-eighths inch for the inner rows per reinforcing member.

*** Reinforced with four rows of four reinforcing members per row at a depth of 5 inches and at a diameter of three-fourths inch for outer rows and five-eighths inch for the inner rows per reinforcing member.

+ Reinforcing members composed of sand filled epoxy resin cured for 16 hours at 60° C., disposed in creosoted pine crossties.

In the test results of table I, the rail was spiked directly to the tie to more severely subject the tie specimens to the loads of the tie wear machine. Because the crossties are composed of creosoted pine (a soft wood), the effects of moisture are most dramatically observed. Generally, as the moisture content of the crosstie increases the resistance of the tie to the indentation by the rail decreases; and as the moisture content decreases, the resistance of the tie to indentation increases. With a plurality of reinforcing members 20, the resistance to indentation is greatly improved, particularly in samples 3, 4, and 5, each of which successively sustained a longer period of exposure in the tie wear machine. In fact, the resistance to surface indentation is greatly improved by disposing the reinforcing members at a greater depth into the tie, especially in soft woods having a relatively high moisture content, as illustrated in sample 5 where the depth is 5 inches.

As previously mentioned, the grain structure plays a predominating role in the ability of the tie to resist indentation. In table II, the results of static load (Type A) tests are summarized which illustrate that douglas fir loaded with the grain structure, i.e., parallel with the grains, is superior to wood loaded against the grain structure, i.e., transverse to the grains. Type A static load tests are determined by applying loads to large wood specimens (5 inches × 7 inches × 12 inches) in a Tinius-Olsen Machine through a ¾ × 3 × 9 smooth cold-rolled steel plate. In this test, a series of reinforcing members are disposed in the wood beneath the steel plate. The required loads for a certain amount of indentation are recorded.

TABLE II

	Indentation, mils				Orientation of grain to load direction	No. of Rows**	Depth, in.
	25	50	75	100			
Sample*:							
1-----	16,500	19,500	20,300	21,500	Wood tangentially cut with the load transverse with grain.	Not reinforced	2
2-----	17,800	27,100	29,400	30,500		1	2
3-----	27,900	34,000	34,300	34,200		2	2
4-----	33,200	41,200	41,600	41,600		2	3
5-----	33,400	41,300	43,300	43,600		2	4
6-----	45,800	49,700	52,600	51,300	Wood radially quarter sawn with load aligned with grain.	Not reinforced	5
7-----	21,600	25,700	30,000	34,800		2	2
8-----	42,400	47,500	47,500	47,500		2	4
9-----	53,000	58,500	59,100			2	4
10-----	60,000					2	5

* Samples composed of douglas fir. Reinforcing members composed of sand filled epoxy resin cured for 16 hours at 60° C.

** Four reinforcing members per row.

It should be noted in table II that as the depth of the reinforcing members is increased, the resistance to "plate cutting" or surface indentation is improved; however, as will be discussed later, this trend approaches a limit making it unnecessary to dispose the reinforcing members to greater depths especially in the hard woods.

Were it possible to select a wood having high surface hardness so cut that the grain structure of the tie is oriented with the load direction and maintained at a constant low moisture content in the tie, reinforcement of the crosstie, in accordance with this invention, would not be required. These ideal condition, however, usually cannot be found or provided and reinforcement of the wood in accordance with the invention is, therefore, a necessity.

The consideration of the quality of the wood as hereinbefore described is relevant in determining the quantity and size of the reinforcing members. These considerations dictate the disposition of the members at the location of higher stress concentrations; the depth and diameter of the members; the minimum distance separating these members; the number required for adequate reinforcement; and the shape and configuration of the members.

A critical feature in the disposition of reinforcing members 20 is the minimum distance between each reinforcing member in the tie. The minimum distance from the center to center of each reinforcing member is 1 1/4 inches as illustrated in FIG. 1 of the drawings. This arrangement contemplates the greatest number of reinforcing members in a tie. Wooden crossties having four rows of four reinforcing members in each row were tested in the AAR Tie Wear Machine and compared with wooden ties similarly tested having 304 reinforcing members with the dimensions of 0.5 cm. in diameter and 3 cm. in depth and spaced apart a distance of 1 cm. The results of these tests are conveniently summarized in table III.

TABLE III

Sample ⁺ :	Indentation, inches	Cycles, million	Moisture content, percent
1*	.28	0.312	17
2*	.47	0.186	50
3**	.09	0.378	20
	.81	2.2	
4**	.125	0.266	46

+ Cross Tie composed of creosoted pine crossties.

* Samples 1 and 2 having 304 holes filled with sand filled epoxy having the dimension of 0.5 centimeter in diameter and 3 cm. depth and spaced a distance of 1 centimeter apart.

** Samples 3 and 4 having 4 rows of 4 reinforcing members per row having the dimension of five-eighths inch in diameter and 2 inches depth and spaced apart by 1 1/4 inches.

The results of these tests demonstrate that the distance at which the reinforcing members are spaced apart is critical in order to obtain substantial reinforcement.

The theories explaining this behavior of reinforcement in accordance with this invention are not clearly understood. It is believed, however, that individual reinforcing members reinforce or distribute the load in essentially two ways. First, the reinforcing member distributes the load from its end (the end bearing effect) which is embedded in the wood. In fact, I have observed in the soft woods that bulges occur on the lateral surfaces of test specimens at a depth equal to the depth of the reinforcing member as shown in FIG. 8. Apparently, when the reinforcing members are placed too closely together, stresses emanating from the ends of the reinforcing members accumulate to a stress level exceeding the strength of the individual wood cells. Secondly, the reinforcing members distribute the load by the bonded area between the resin and the wood (the

bonding effect). The stresses emanate outwardly from the reinforcing member along its entire length. By placing these members too closely together, the stresses are accumulated to a stress level exceeding the strength of the individual cells.

As previously indicated, the depth to which each reinforcing member is embedded, in the crosstie depends on the characteristics of the wooden tie itself. However, the proper depth is readily determined by one skilled in the art. The optimum depth in red oak and douglas fir has been found to be approximately 2 inches. This result is best seen in FIG. 5 where individual reinforcing members were tested using static load tests (Type B). It should be added that the static load values are plotted in pounds (LBS) in FIGS. 5, 6, and 7. Load vs. depth is shown in FIGS. 5 and 6 and load vs. diameter (in inches) is shown in FIG. 7.

Type B, static load tests are determined by applying loads to a rod which has a slightly smaller diameter than the singular reinforcing member in an Instron Machine. The reinforcing member is disposed in a wood specimen having the dimensions of 2 inches x 2 inches x 6 inches. In this test, the load required to move the reinforcing member bonded to the wood is measured.

Curve I of FIG. 5 illustrates that beyond a depth of 2 in., substantial resistance to a load is not significantly increased in red oak. Curve II of FIG. 5 illustrates a similar relationship for douglas fir (a soft wood). In both cases the moisture content was 7 to 8 percent, and sand-filled epoxy resin was used in these tests from which FIGS. 5 and 6 were prepared. These results are typical of most woods.

As mentioned earlier, the theory explaining the reinforcing mechanism of the reinforcing members is attributable to two sources, the end bearing effect and the bonding effect. From FIG. 6, the major contribution appears to come from the bonding effect. Curve I indicates the results from placing a static load (Type B) directly on a reinforcing member embedded within an opening having a closed-bottom end in a red oak crosstie as mentioned for FIG. 5 while curve II illustrates the results from placing a static load directly on a reinforcing member disposed within an opening having an open bottom end passing completely through the same red oak tie and bonded to the wood. The differences are small, again suggesting the importance of the bond between the resin and the wood.

These results suggest that the principal reinforcing effect is the result of the bond between the resin and the wood. Stresses will, nonetheless, emanate outwardly from these members, and it is, therefore, essential that each reinforcing member is separated by a minimum distance so that these stresses do not accumulate to a stress level in excess of the strength of the individual cells of the wood.

The minimum diameter of the reinforcing member is one-half inch in red oak as illustrated in FIG. 7. A further increase in diameter beyond one-half inch on a reinforcing member at a depth of 1 1/2 inches does not provide a substantial increase in reinforcing quality.

The bonding strength between the wood and the resin is not only dependent upon the nature of that bond, but also dependent upon the total surface area of each reinforcing member between the wood and the resin. By increasing the surface area of the each individual reinforcing member, the bonding strength or the reinforcing strength may be increased. However, it is evident from FIGS. 5-7 that beyond a certain area, further increase in the surface area does not contribute substantially to the reinforcing ability of the reinforcing members 20.

The shape of these members is cylindrical and this is the convenient shape; little benefit is obtained by altering that shape. In fact, a conical reinforcing member was tested and the results of that test in comparison with the performance of the cylindrical reinforcing members disposed at the same depth were similar. For convenience, in the construction of reinforced ties, cylindrical reinforcing members are easier to install and require simply a simple bore into the crosstie. The

members should be disposed at substantially a perpendicular angle to the load-bearing surface of the crosstie. The arrangement of FIGS. 3 and 4 is preferred.

As mentioned earlier the number of reinforcing members required to adequately reinforce wood depends on the quality of the wood. In FIG. 1, a total of 16 reinforcing members are disposed in four rows. This arrangement contemplates the greatest number of reinforcing members in accordance with my invention. In FIGS. 3 and 4 there are a total of four reinforcing members disposed in two rows. I have found this arrangement is satisfactory in red oak. Naturally, other configurations are conceivable in accordance with the invention.

In the matter of construction, FIG. 2 shows in phantom lines, a tie plate 40, spikes 50 and a rail 60 to be placed over the reinforced area. Normally two to four spikes are driven into the tie through preformed holes in the tie plate. Therefor, it is advantageous to position the reinforcing member 20 about, but not directly in the path, of the spike. In this embodiment, as shown in FIG. 1, four rows (A&B) of reinforcing members, each row comprising four members equidistantly spaced apart a minimum distance of $1\frac{1}{4}$ inches, are positioned respectively beneath the rail and the tie plate.

As illustrated in FIG. 2, the positioning of Rows A and B is preferably such that the spike will enter the tie between the rows or at least in such a position as to avoid entering the reinforcing member since this would be self-defeating.

The reinforcing members 20 are constructed of a material which has a higher compressive strength than that of the wood tie. The material should also be a substantially nonshrinking material under temperature and moisture parameters encountered in railroad environments because the invention contemplates the bonding of the reinforcing member to the tie itself and deleterious shrinkage could well disrupt this bond.

Conveniently, the reinforcing members 20 are made of a thermosetting plastic material such as an epoxy resin or a polyester resin or the like. These materials can be poured in place. They have strengths greater than the wood and form bonds with the wood. Of course, these materials may be filled and reinforced with various fillers such as sand, mica, glass fibers and the like to increase their strength and reduce the cost by reducing the amount of resin in the mixture. The three necessary requisites; namely: 1) a compressive strength greater than the tie; 2) the capacity of being bonded to wood; and 3) shrinkage less than the wood must be met for a material to qualify for use as a reinforcing member in the invention.

The preferred resin system comprises a bis-phenol A diglycidyl ether (Epon 828) cured with a curing agent, having an equivalent weight of 175—200 of epoxy content, preferably 180—195, such as an aliphatic amine, a fatty polyamide, a blend of these two or an eutectic aromatic amine. The preferred curing agent is a liquid blend of the fatty polyamide and an aliphatic amine such as Versamid 140, a product produced by General Mills, Inc. Other curing agents such as a fatty polyamide and a catalyst such as tri-(dimethylamino methyl) phenol, catalyst are satisfactory. Various fillers useable in the resin system include sand, calcium carbonate, Cab-O-Sil (a thix-o-tropic agent) composed of a colloidal silica, clay and the like. Reactive diluents and flexibilizers may also be used such as Cardolite NC 513, produced by 3-M Company which is a fluid resin designed as a chemically-bound flexibilizer having an epoxide content of 475—575.

As an example of this invention, several samples (A through I inclusive) were prepared from creosoted oak railroad crossties. Sample A was cut to the dimensions of 7 inches in depth by 8 inches in width by 2 ft. in length. A portion of a face of the tie was adzed to receive a metal tie plate. A total of four rows of openings for reinforcing members were drilled to a depth of 2 inches in the ties with the two outer rows having two reinforcing members with $\frac{3}{4}$ inch diameter and the two inner rows having three reinforcing members with $\frac{5}{8}$ inch diameters. The reinforcing members of resin were formed in these holes. The resin was made by mixing together 72 parts by weight of Epon 828 (a bis-phenol A diglycidyl ether); 2

parts by weight of Versamid 140 (a curing agent), a polyamide; 10 parts by weight of Cardolite NC-513 (a reactive epoxy diluent), manufactured by 3-M Company; 2 parts by weight of tri(dimethylaminomethyl) phenol catalyst; and 416 parts of a silica sand filler (a weight ratio of 4 parts by weight of sand to 1 part by weight of resin). The resin mixture was thoroughly blended and deaerated by centrifuging. The resin mixture was subsequently poured and packed into the openings of the tie and allowed to cure in situ for 18 hours at 60° C. The cured resin was found to be firmly bonded to the sidewalls of the opening.

Sample B was prepared from the creosoted oak crosstie having the dimensions of 7 inches in depth $\times$ 8 inches in width $\times$ 2 feet in length. Four rows of four openings per row for the reinforcing members (a total of 16) were drilled with the two outer rows having $\frac{3}{4}$ inch diameters and the two inner rows having $\frac{5}{8}$ inch diameter in the same pattern as illustrated in FIG. 1. The same resin was subsequently poured into the openings and cured in situ. The load-bearing surface was canted at a slope of 1:40 to receive a rail (no tie plate).

Sample C was prepared from the creosoted oak crosstie and cut to the dimensions of 7 inches in depth by 9 inches in width by 2 feet in length. The surface was canted at a slope of 1:40 to receive a rail (no tie plate). In this canted area eight holes having the dimensions of five-eighths inch in diameter and 2 inches in depth were drilled. Again the reinforcing members of resin were formed in these holes. The same resin was prepared from 72 parts of Epon 828 (a bis-phenol A diglycidyl ether), 20 parts of Versamid 140, and 10 parts of Cardolite NC-513 (a reactive epoxy diluent), and 2 parts of tri-(dimethylamino methyl) phenol catalyst. No filler was used for the reinforcement of this resin. This resin mixture was poured into the openings of the tie and allowed to cure in situ for 18 hours at 60° C. The cured resin was found to be bonded firmly to the sidewalls of the opening. Sample D was similarly prepared, however, four openings were drilled into the canted area having the same dimensions of five-eighths inch in diameter and 2 inches in depth as shown in FIG. 3 and similarly filled with the same resin as prepared in Sample C.

Samples E and F were prepared from the creosoted oak crosstie having the dimensions of 7 inches in depth by 8 inches in width by 2 feet. Sample E was adzed to receive a tie plate and Sample F was canted at a slope of 1:40 to receive a rail. Further, sample G was prepared having the dimensions of 7 inches in depth by 9 inches in width by 2 feet. These three samples served as controls and were not reinforced with any resin.

Each of the samples (A-G inclusive) were tested in the AAR Tie Wear Machine, according to the AAR procedures, with some modification as will be indicated.

The reinforced tie of sample A was fitted with a 14 inch metal tie plate and the rail spiked down to the adzed area and was placed in the tie wear machine. During the testing in the Tie Wear Machine, time elapse movies taken at time intervals of $2\frac{1}{2}$ minutes or 24 frames per hour indicated little if any breakdown of the fibers of sample A and even after 2.5 million cycles (which is equated to 10—15 years in normal service). The tie was cut by the tie plate to a depth of 0.08 inch after 2.5 million cycles.

To provide a test condition more severe, the AAR Tie Wear Machine procedure was modified. Sample B was fitted with a rail spiked directly to the reinforced area of the oak tie without a tie plate to distribute the load. After 2.5 million cycles in the AAR Tie Wear Machine, with cycling temperature extremes of -40 to $+150^\circ$ F., the tie was found to have been cut by the rail an average depth of 0.125 inches.

Sample C was fitted with a rail spiked directly to the canted area of the tie and placed in the AAR Tie Wear Machine. After 2.5 million cycles with temperature extremes of -40° F. to $+150^\circ$ F., the tie was cut by the rail to a depth of 0.03 inch. Sample D was tested similarly and the tie was cut by the rail to a depth of 0.06 inch.

Sample E as a control with sample A was fitted with a tie plate and a rail spiked directly to the adzed area of the tie and placed in the AAR Tie Wear Machine. After 2.5 million cycles with cycling temperature extremes of -40 to $+150^{\circ}$ F., the tie was cut by the tie plate to a depth of 0.17 inch. Likewise, sample F was used as a control with sample B in which a rail was spiked (no tie plate) directly in the canted area of the tie and placed in the tie wear machine. After 2.5 million cycles, with cycling extremes of -40° to $+150^{\circ}$ F., the tie was cut by the rail to a depth of 0.50 inch with fiber damage extending as far as 1 inch below the indented surface of the tie. In fact, after 0.7 million cycles, the tie was cut by the rail to a depth of 0.375 inch.

Sample G was used as a control with sample C in which a rail was spiked (no tie plate) directly to the canted area of the tie and placed in the tie wear machine. After 2.5 million cycles the tie was cut by the rail to a depth of 0.23 inches. These good results of sample G are attributable to the high surface hardness of this particular sample, again indicating the importance of carefully selecting wood for the crosstie.

Substantially the same trends were observed when a creosoted pine tie with sixteen reinforcing members (sample H) and a creosoted pine tie without reinforcing members (sample I) were tested in the AAR Tie Wear Machine. In sample H with the rail spiked directly to the tie having 16 reinforcing members as illustrated in FIG. 1, the tie was cut much deeper than that shown in sample B of the reinforced oak tie with a rail spiked directly to the tie. This result was expected due to the differences in the hardness of these two wood species. On the other hand, sample I the unreinforced pine tie was tested similarly, but failed in less than 300,000 cycles. In fact, the wood fibers beneath the rail became so spongy, that it was difficult to maintain the required loads of the AAR Tie Wear testing procedure even up to the level of 300,000 cycles.

For convenience, the test results of samples A-I have been tabulated in FIG. 9.

To produce a reinforced railroad crosstie a suitable piece of timber is selected considering the qualities of the wood as herein described. The timber is shaped to the proper dimensions as specified according to railroad manuals. The rail support surface is adzed to receive a tie plate so that the plate fits flush with the surface. In the adzed area a plurality of openings are bored to the required depth and diameter according to the desired arrangement. The liquid resin is prepared and poured into these openings. Subsequently the tie may be creosoted and impregnated with wood preservatives. The heat from the creosoting procedure will cause the resin to cure in situ forming a bond between the resin and the wood. The reinforced tie is then ready for use with railroads. Of course reinforcing members may be placed in wood already creosoted.

This invention has been described with the understanding that the optimum railroad supporting means comprises a wooden tie with reinforcing members disposed beneath the tie plate carrying the rail. The advantage obtained from the use of a tie plate is the distribution of the loads from the rail. Of course, better distribution of loads obtains with the use of reinforcing members in accordance with the invention. In applications where heavy railroad traffic does not occur, for instance, in railroad sidings, the invention may be used without tie plates, a decided cost advantage.

The preferred application of the invention is illustrated above, but those skilled in the art will recognize that the invention is not restricted to applications with a railroad tie plate carrying a rail or metal on wood applications. The invention may be used on wood applications, particularly where crossties are positioned on a railroad bridge having longitudinal wooden braces to support the crossties. The wooden structure having a load-bearing surface then has a plurality of reinforcing members disposed generally perpendicular of this surface and embedded in the structure in a manner as hereinbefore described.

This novel invention of embedding reinforcing members of epoxy or polyester resins into a crosstie beneath the tie plate

in the load-bearing area disperses and distributes the stresses caused by a train passing over the rails. Because the properties of wood are so variable, reinforcing members by their proper disposition tend to render all reinforced woods more uniform in their ability to withstand stresses. Rather than strengthening the individual cells of the wood, my invention disperses the stresses without the necessity of impregnating the wood cells. Also, my invention may be used with a variety of resin systems. Furthermore, only a small number of openings need to be drilled into the crosstie to accomplish satisfactory reinforcement.

I claim:

1. A wooden structure having a load bearing surface for supporting a load thereon comprising:

a plurality of reinforcing members comprised of a thermosetting plastic material having a compressive strength greater than that of wood; said reinforcing members being generally elongate, cylindrical solid bodies that are disposed generally perpendicular of the load bearing surface and embedded in the wooden structure so that said members extend from said load-bearing surface into said structure at locations where stresses greater than the strength of wood may occur; said members being bonded to the wood in which the bond is between said thermoplastic material and the wood;

said reinforcing members separated apart by a minimum distance of $1\frac{1}{4}$ inches whereby the reinforcing members disperse and distribute the stresses away and apart from the load bearing surface of the wooden structure.

2. The wooden structure of claim 1 wherein: the wood is an oak hardwood and each reinforcing member has a minimum diameter of one-half inch and a minimum depth of 2 inches.

3. The wooden structure of claim 2 wherein the reinforcing members are made of cured epoxy resin.

4. The wooden structure of claim 3 wherein four reinforcing members are disposed in two rows having two reinforcing members per row with each row disposed.

5. A wooden railroad crosstie having an upper support surface supporting a metallic tie plate carrying a railroad rail and a lower opposite surface comprising:

a plurality of reinforcing members comprised of a thermosetting plastic material having a compressive strength greater than that of the wooden crosstie; said reinforcing members being generally elongate cylindrical solid bodies having a minimum diameter of one-half inch;

said reinforcing members disposed generally perpendicular of the rail support surface and embedded in the crosstie and bonded thereto in which the bond is between said thermosetting plastic material and said wood; said reinforcing members being disposed at locations where stresses greater than the strength of the wooden crosstie may occur from the tie plate when a train passes over the rail;

said reinforcing members extending into said crosstie from the rail support surface to a point intermediate said upper rail support surface and said lower opposite surface;

said reinforcing members separated apart by a minimum distance of $1\frac{1}{4}$ inches whereby the reinforcing members disperse and distribute the stresses away and apart from the rail support surface of the crosstie.

6. In a wooden railroad crosstie having an upper support surface supporting a metallic tie plate that carries railroad rails and having a lower spaced apart opposite surface wherein the improvement comprises:

a series of elongate, generally cylindrical solid bodies composed of thermosetting plastic materials having a compressive strength greater than that of the wooden crosstie; each of said elongate solid bodies having a minimum diameter of one-half inch; said reinforcing members being disposed generally perpendicular of the upper support surface and embedded in the wooden crosstie; each of said elongate bodies extending from said upper support surface to a point that is intermediate said upper support surface and said lower opposite surface;

11

each of said elongate solid bodies being bonded to said wooden crosstie in which the bond is between said thermosetting plastic material itself and said wooden crosstie; each of said elongate solid bodies being separated apart by a minimum distance of $1\frac{1}{4}$ inches and all of said elongate solid bodies being disposed in rows at locations where

12

stresses greater than the strength of said wooden crosstie may occur from said metallic tie plate when a train passes over said rails whereby said elongate solid bodies disperse and distribute the stresses away and apart from said upper support surface of the wooden crosstie.

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