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Efficiency of Wooden Tension Joints

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Efficiency of Wooden Tension Joints.

Object:-

To determine the efficiency of wooden tension joints and to compare the relative strengths of long leaf yellow pine and oak Also to determine whether the values generally used for compression and tension of oak and pine are good average values for wood such as is used in ordinary practice and obtainable at any good lumber yard.

Method:-

We used the Tinius Olsen testing machine in the Mechanical Laboratory at M.A.C. This machine is constructed to break steel and iron and is not exactly suitable for a test of wood.

The first difficulty was in holding the ends of the joint. We first tried bolting two pieces of iron on the joint and allowing the strain to come against these irons. This method failed because the bolts and friction of the iron on the wood was not sufficient to stand the strain though we endeavored to increase the friction by roughing the surface of the iron with a chisel The machine not being built for this purpose did not provide sufficient room for more bolts and it was quite difficult to put in the

two that we used. This method was then abandoned and we decided to grip the ends of the joint with wedges as that is the way in which iron and steel are gripped in the machine.

The pulling apparatus on the machine consisted of two plates with 2-3/8" x 2-3/8" holes in the center. It was necessary to make some smaller wedges than those belonging to the machine These we made of cast iron and cut grooves in them to increase the friction of the wedges against the wood. The wedges had a surface of about 4 inches by 2 inches which pressed against the wood.

There was no accurate way in which we could calculate the crushing force applied to the wood, but we concluded that the eight sq. inches on the wedges would give the wood sufficient area to resist crushing. We found by trial that the wood did not crush evenly and besides breaking our wedges the crushing allowed the wedges to slip through the plate on the machine, thus losing their hold on the wood. We tested three joints by this method however and then some of the stronger ones gave us trouble. We then bored two 3/8" holes in the partof the wood subjected to crushing and inserted two 3/8 " rods so that when the wood would not stand the crushing force the pressure would be partially sustained by these rods. This method was pursued to the end of our experiments.

The timber used in the tests was of good quality but was not thoroughly seasoned though perhaps as good as would ordinarily be used in construction.

In the design of the joints we took the following values as safe:

Tension = 1100 # per sq. inch

Compression = 1300 # per sq. inch.

Crushing on pins =750 # per sq. inch.

Shearing in plane of fibres =130 # per sq. inch.

Crushing against ends of fibres =1200 per sq. inch.

In order to determine the efficiency it was necessary to ascertain the strength of a solid piece of wood the same size as the joint. as we could not test such a large piece on account of the difficulty of holding the ends we made six test pieces of wood with three quarters of inch cross section and portion enlarged where wedges were applied.

Tests of sticks of oak and yellow pine ; area of cross section of each stick is 3/4 sq. in.

No. of stick.	Kind of wood.	Failed at.	Stress per sq. inch.	Average
I	Oak	4000.#	5333.#	#
2	"	3900.	5200.	
3	"	3000.	4000.	
				4844#
		#	#	
I	Pine	7900	10533	
2	"	3200.	4267	
3	"	3700.	4933	
				6578

Test of iron fish plate joint of oak designed for 2000#

5 - i/4 " bolts on each side.

I 1/2"x I 1/2"

This joint failed under a tensile stress of 8200#. It broke out through one of first bolt holes. The joint pulled apart about 1/8 inch before breaking.

Area to resist breaking was ,

I 1/2" X I 1/2" - 1/4 X I 1/2" = I 7/8sq"

8200 ÷ 15/8 = 65600/15 = 4373# per sq. inch that the wood stood in tension. Real factor of safety = 8200 ÷ 2000 = 4.1
Efficiency = 8200 ÷ 3/2 X 3/2 X 4844 = 75.23 %.

Test of a table scarf join of oak designed for 1000# with a factor of safety approximately 8- 1/4" bolts.

See accompanying diagram b.

Showed large bending movement due to shape of joint.

The tension is assumed to be along the neutral axis of piece while the resultant of resisting forces is applied at 1/4" ~~o~~ outside of neutral plane.

Showed no sign of crushing or shearing but started to ~~fa~~ fail at both small sections at nearly same time. Unless the bendig moment is taken into account the joint will not hold what it is intended. Area of failure = I 3/8 sq." Tension per sq. inch =

Efficiency = 3310 ÷ I 3/4 X2 X 4844 = 19.52 %.

Test of long leaf yellow pine;keyed scarf joint designed for 700# with a theoretical factor of safety of 8.

See diagram c. 3/16" bolts.

We only used two bolts in this joint in order to discover the effect on the joint if it was insufficiently bolted. There should have been two more boltsused as the keys tend to turn up on edge throwing the joint apart.

There was a bending moment produced in the two sections as shown ,due to the fact that the resistance of the keys is eccentric with the neutral axis.

This joint failed by shearing off the tables. The oak pins were partly crushed but ends of fibres which pressed against the oak were not crushed.

Ultimate strength = 2900

Real factor of safety 2900 ÷ I 1/2 X I 1/2 X 6578 =4.1+

Area of failure = 2 1/4sq inches.

2900 ÷2 1/4 X2 =650.

Efficiency = 2900 ÷ I 1/2 X I 1/2 X 6578 =15.54 %.

Test of a table fish plate joint made of oak and designed for 1000# with a factor of safety of 8.

Crushing occurred on one of the tables on the fish plate. This threw an unequal amount of strain on the other fish

platecausing a table to shear off.

Area crushed = 5/16 X 3/2 = 15/32 sq. inches.

Area sheared = 2 3/4 X 3/2 = 4 1/8 sq. inches.

Valve per sq inch crushing = 7040 #

Valve per sq. inch shearing = 825#

Two bolts seemed to be sufficient to hold the jointtogether. the joint pulled apart about 3/8 " when failure occurred.

Ultimate strength = 3300.

Real factor of safety = 3300 ÷ 1000 = 33.

Efficiency = 3300 ÷ 1 1/2 X 1 1/2 X 4844 = 30.28 %

Test of keyed fish plate of oak designed for 2000#

See diagram d.

Joint failed by shearing off two keys which were 2 1/4" X 1" X 3/4". Area of failure = (2 1/4 X 1)2 = 4 1/2

Ultimate strength was 9300#.

The shearing value in this case was 9300 ÷ 2 X 4 1/2 = 516.5# per sq. inch It was probably more than this because the keys on the other side crushed some thereby throwing more strain on one side causing the failure.

The efficiency = 9300 ÷ 2 X 1 3/4 X 4844 = 54.85 %.

Real factor of safety = 9300 ÷ 2000 = 4.65.

Test of a table fish plate joint designed for 1000# with a factor of safety of 8 and made of long leaf yellow pine.

See diagram e.

This joint failed by shearing off the tables as shown in sketch. No crushing at any point was evident. Two bolts only were used and they secured amply sufficient to hold the joint together.

Ultimate strength = 3050 #.

Real factor of safety = 3050 ÷ 1000 = 3.05.

Efficiency = I 1/2 X I 1/2 X 3578 = 80.61 %.

Area of failure = 4.1/8 sq. inches.

Shearing value per sq. inch = 3050 ÷ 4 1/8

Test of oak wooden fish plate joint designed for 2000 #.

Joint failed by breaking in two in a section through first bolt hole. Used 5 1/4" bolts on each side. See diagram f.

In this case the wood crushed quite a little in front of the bolts. The bolts also were bent all out of shape. The joint pulled apart about 1/4" before breaking. Failure occurred under a strain of 7,200 #.

Real factor of safety was 7200 ÷ 2000 = 3.6.

Efficiency = 7200 I 1/2 X I 1/2 X 4844 = 66.06 %.

Area crushed against bolts = 1/4 X 3/2 X5 = I 7/8.

7200 ÷ I 7/8 = 3840 # per sq/inch.

Test of a yellow pine joint with wooden fish plate designed for 2000 # taking safe values having a factor of safety of about 8. Using 5 1/4 " bolts on each side. See diagram g.

We were unable to pull the joint entirely intwo but we reached its ultimate strength. The two parts of the joint separated one inch when under maximum strain. Failure occurred by crushing of bolts in wood also bolts were bent.

Ultimate strength = 8960#.

Area crushed = 1/4 X 3/2 X 5 = I 7/8 sq. inches or 4778# to sq. inch resistance to crushing at ends of fabric.

Real factor of safety = 8960 ÷ 2000 = 4.48.

Efficiency = 8960 ÷ I 1/2 X I 1/2 X 6578 = 6054 %.

Test of a table scarf joint of yellow pine designed for I000 #. See diagram h.

Joint failed at 4460# by shearing off a table.

There were no signs of crushing nor of breaking at section. Two bolts seemed sufficient to hold the joint together. This is a simple joint, very easily made which produces a comparatively good strength.

Ultimate strength = 4460 #

Real factor of safety = 4460 ÷ I000 = 4.46.

Factor of safety used in design = 8.

Efficiency = 4460 ÷ 8 X I 3/4 X 6578 = I9.37 %.

Area of failure = 8.

Shearing value # per sq. inch = 558.

Test of a yellow pine iron fish plate joint designed for 2000 #.

Used 5 1/4 inch bolts on each side. See diagram i.

Broke at point where bolt takes out part of area.

I 1/2 X I 1/2 =2 1/4 sq/ inches.

I8 ÷8 ,-3/8 = I 7/8.

6335 ÷ I 7/8 = 3379 # per sq inch was all the wood stood in tension.

Ultimate strength = 6335 #

Real factor of safety = 6335 ÷2000 = 3.17 -

Efficiency = 6335 ÷ I 1/2 X I 1/2 X 6578 = 42.80 %

Test of a keyed scarf oak tension joint designed for 7000# with a theoretical factor of safety of 8.

See diagram j.

This joint failed by breaking of fibers at section where the bolt takes out part of the area. There was also a bending moment developed in this section causing failure at much less tension than was expected. The resistance of the pins is to one side of the neutral axis and this of course causes the bending moment.

Ultimate strength = 2300

Real factor of safety = 2300 ÷ 700 =3.3.

Efficiency = 2300 ÷ I 1/2 X I 1/2 X4844 = 2I. I0 %

Area of failure = I inch ; stress per sq. inch not considering bending moment= 2300.

Test of keyed fish plate of pine designed for 2000#.

See diagram k.

Joint failed under a load of 3910# in tension.

We had but two bolts in the joint as we wished to get a value affected only by the resistance of keys and shearing of the table but we found that there should be bolts in every table in order to hold the joint together. Under stress the keys tend to turn up on edge causing a bending moment in the plate.

Also the keys turning as they do when joint is insufficiently bolted presents less crushing area for keys.

The keys were crushed some but the wood at the end of the fibres was not crushed thus showing that the crushing strength at the ends of the fibre on Texas pine is greater than the crushing strength on the side of oak fibre.

The efficiency = 3910 ÷ 2 x 1 3/4 x 6578 = 16.98%.

Real factor safety = 3910 ÷ 2000 = 1.95.

Value of shearing strength = 3910 ÷ 4 = 977.5# of oak pins.

Yellow Pine Joints

Designed for #	Kind	Ultimate strength	Efficiency %	Factor of safety	Compression (Values obtained, #'s per sq. inch)	Shearing (Values obtained, #'s per sq. inch)	Tension (Values obtained, #'s per sq. inch)
1000	Table Fish Plate	3050	20.61	3.05	----	740	----
700	Keyed Scarf	2900	15.54	4.1	----	650	----
2000	Wood Fish Plate	8960	60.54	4.48	4776	---	----
1000	Table Scarf	4460	19.37	4.46	-----	558	----
2000	Keyed Fish Plate	3910	16.92	1.95	----	---	----
2000	Iron Fish Plate	6325	42.80	3.17	----	---	3379
					4778	649	3379 Average

Oak Joints

Designed for #	Kind	Ultimate strength	Efficiency %	Factor of safety	Compression (Values obtained, #'s per sq. inch)	Shearing (Values obtained, #'s per sq. inch)	Tension (Values obtained, #'s per sq. inch)
1000	Table Fish Plate	3300	30.28	3.3	7040	825	----
700	Keyed Scarf	2300	21.10	3.3	----	---	2300
2000	Fish Plate	7200	66.06	3.6	3840	----	----
1000	Table Scarf	3310	19.52	3.3	----	----	2648
2000	Keyed Fish Plate	9300	54.85	4.65	----	516	----
2000	Iron Fish Plate	8200	75.23	4.1	-----	---	4373
					5440	670	3107 Average

Conclusions

1. Our results indicate that a higher factor of safety should be used in timber construction on account of the varying strength. As an example of this two of our test pieces cut from same piece of timber showed a difference in tensile strength of 5000#.

2. Southern pine or yellow pine is stronger in tension than oak but weaker in crushing and shearing strength.

3. Oak timber is more liable to contain flaws than pine.

4. That Trautwine's values for ultimate strengths are rather high for the timber obtainable nowadays.

5. That the very best joint will be only about three-quarters as strong as a solid stick of same size.

6. That our iron fish plate gives higher efficiency and bolts are not as liable to become bent allowing the joint to give.

7. That it is better to use iron or steel for tension on account of the difficulty in making wooden tension joints strong enough for required strain.

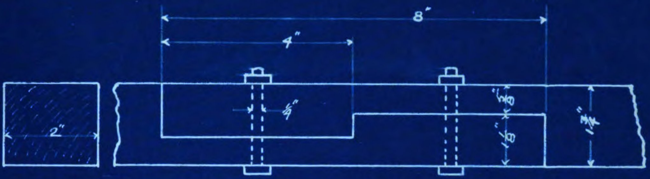
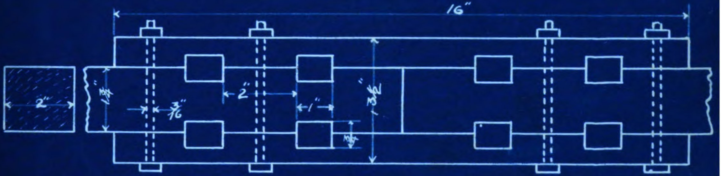


TABLE SCARF JOINT SCALE 1/2" = 1"
DESIGNED FOR 1000 # TENSION



KEYED FISH PLATE SCALE 7/8" = 1"
DESIGNED FOR 2000 # TENSION

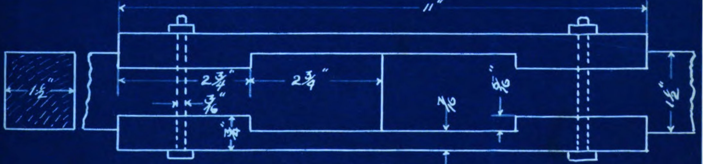
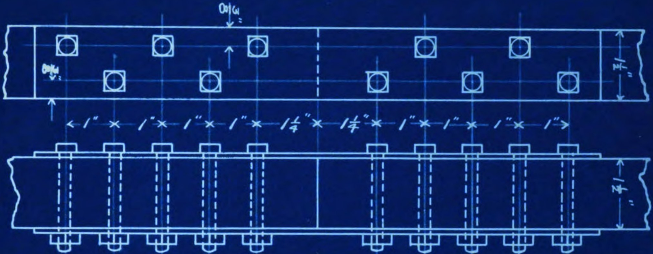
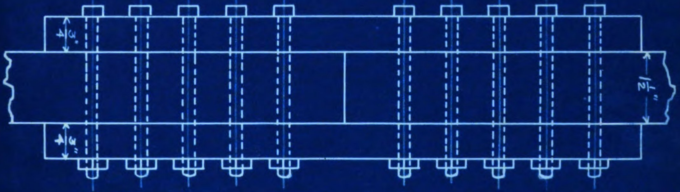


TABLE FISH PLATE SCALE 1/2" = 1"
DESIGNED FOR 1000 # TENSION



IRON FISHPLATE JOINT SCALE ½" = 1"

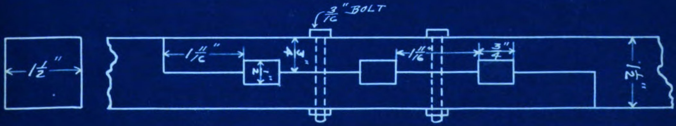
DESIGNED FOR 1000 # TENSION



WOODEN FISHPLATE JOINT DESIGNED FOR 1000 #

TOP VIEW SAME AS FIGURE ABOVE

¼" BOLTS USED IN BOTH OF ABOVE JOINTS



KEYED SCARF JOINT SCALE ½" = 1"

DESIGNED FOR 700 # TENSION