Testing of Laminated Timber Crossarms

Western Archrib[1]

1990

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ABSTRACT

Three hundred and sixty Glued- Laminated Timber Crossarms were tested to failure in flexure.

Crossarms were manufactured in two different sizes and three different species of Canadian Lumber.

Measurements were taken to allow for a comparison between different crossarms based on average breaking strength.

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INTRODUCTION

Traditionally the source of crossarms, transmission line spars and poles for the utility companies has been solid sawn Douglas Fir. This source in the last decade has become increasingly precarious resulting in higher prices, extended delivery and in some cases nonavailability. This situation has become critical in the past 24 months.

A further problem is that there exists no definitive standard with regards to the performance required, the practice being to rely on the traditional product "to do the job". Even though this product is no longer readily available and in many cases the loads have significantly increased, without a standard it is difficult to propose an alternate in Westlam.

A market survey of the users across Canada revealed:

1) The common expectation for the crossarms was an average modulus of rupture of 5500 p.s.i. There was however, no verification of whether or not this was being achieved.

2) Douglas Fir was the species used; however there was no prejudice towards the use of Spruce/ Pine or towards a laminated product.

3) Availability was an acute problem; not only in crossarms but in spar arms and certain poles; consequently price had increased significantly and it had become necessary to buy ahead eighteen months to assure supply.

1.1 OBJECTIVES

The general objective was to develop a product and a manufacturing standard which would meet the needs of, and gain acceptance from the utility companies. The specific objective was to evaluate the bending strength of Glued-Laminated Crossarms made to a specified manufacturing standard in both traditional (D.Fir) and non- traditional (spruce/Pine) lumber species, and to compare these results to the accepted strength values for solid sawn D.Fir crossarms. The intent was to do only enough testing to establish a general sense of direction for a more comprehensive testing program in the future.

2.0 MANUFACTURE

Cross arms were manufactured from 3 different species of Canadian lumber: Douglas Fir, Spruce, and Lodgepole pine. In addition the D.Fir crossarms were separated into 3 subgroups : Coastal Fir, Interior Fir, and visually graded Interior Fir (V.G.I.F) All crossarms, with the exception of the V.G.I.F. samples, were manufactured in accordance with a proposed Western Archrib Manufacturing standard for Power Crossarms made from Laminated Timber. (1)

The V.G.I.F. samples represent an experimental grade combination not covered by the existing manufacturing standard. The grade combination used is given in Table 1.

Crossarms were made in 2 sizes, a 3 ply 2x4 arm and a 4 ply 2x6/1x6 arm resulting in cross-sectional sizes of 3 1/4" x 4 1/2" and 5 1/8" x 5 1/4". The V.G.I.F. arms were produced in the 3 ply 2x4 size only.

Table 1: Grade combination for visually graded Interior Fir Crossarms.

PLY DESIGNATION	GRADE
Tension Lamination	CSA 0122 - B*
Middle Lamination	CSA 0122 - D*
Compression Lamination	CSA 0122 - C*

* - Visual grading rules only.

3.0 TEST PROCEDURES

All 360 flexural tests were preformed by the Alberta Research Council. The methods of testing, equipment used and full test results are presented in Alberta Research Council report FPLE-311 April 25, 1990.(2) Test methods were in accordance with ASTM standard D-198-84. (3)

Crossarms were tested for bending strength about both major axes (i.e. with the laminations horizontally and vertically oriented to the applied load).

4.0 TEST RESULTS

The test results are presented in Tables 1 through 10. The term "Modulus of Rupture" (M.O.R.) refers to the level of outer fibre bending stress at failure.

TABLE 2: TEST RESULTS

SPECIES: D.FIR(INTERIOR) VERTICAL LAMINATIONS
LUMBER: 2X4

SAMPLE NUMBER	WIDTH (IN)	DEPTH (IN)	M.O.R. (PSI)	DENSITY (LB/FT3)	MOISTURE CONTENT (%)
1	4.45	3.29	8580	35.5	8
2	4.51	3.27	7629	35.2	7
3	4.48	3.27	6663	33.9	9
4	4.50	3.27	4574	32.6	8
5	4.51	3.29	6539	33.5	8
6	4.51	3.28	5298	34.7	7
7	4.50	3.25	4365	32.8	8
8	4.46	3.26	8382	33.4	8
9	4.50	3.26	7518	33.8	8
10	4.52	3.29	6696	32.8	8
11	4.47	3.26	9301	33.2	8
12	4.47	3.26	5817	31.9	12
13	4.49	3.27	8800	31.1	10
14	4.48	3.26	7533	32.5	9
15	4.49	3.27	7541	33.5	9
16	4.48	3.28	6832	32.7	9
17	4.46	3.26	6309	30.8	9
18	4.46	3.26	8506	31.2	9
19	4.46	3.27	6059	32.6	8
20	4.46	3.25	8452	33.5	11
AVERAGE:	4.48	3.27	7070	33.1	9

TABLE 2A: TEST RESULTS

SPECIES: D.FIR(INTERIOR) HORIZONTAL LAMINATIONS
LUMBER: 2X4

SAMPLE NUMBER	WIDTH (IN)	DEPTH (IN)	M.O.R. (PSI)	DENSITY (LB/FT3)	MOISTURE CONTENT (%)
1	3.27	4.50	6076	33.1	7
2	3.27	4.51	6921	35.0	7
3	3.28	4.49	7787	35.3	8
4	3.25	4.47	8421	35.0	8
5	3.26	4.45	8458	33.2	8
6	3.26	4.44	6222	33.4	9
7	3.27	4.51	5052	31.9	8
8	3.27	4.50	7294	33.7	9
9	3.26	4.50	6922	34.8	8
10	3.26	4.50	6731	33.9	8
11	3.24	4.47	7681	32.6	10
12	3.25	4.44	10869	33.3	8
13	3.26	4.48	7600	32.2	8
14	3.27	4.36	8324	33.3	11
15	3.27	4.46	8756	31.6	8
16	3.26	4.48	8396	33.3	10
17	3.28	4.47	7947	30.6	11
18	3.26	4.47	8872	33.3	10
19	3.26	4.47	8421	33.9	9
20	3.26	4.46	7280	32.4	10
AVERAGE:	3.26	4.47	7702	33.3	9

TABLE 3: TEST RESULTS
VERTICAL LAMINATIONS

SPECIES: D.FIR(INTERIOR VISUAL GRADE)
LUMBER: 2X4

SAMPLE NUMBER	WIDTH (IN)	DEPTH (IN)	M.O.R. (PSI)	DENSITY (LB/FT3)	MOISTURE CONTENT (%)
1	4.50	3.27	7227	33.4	10
2	4.50	3.26	6674	33.1	8
3	4.52	3.27	5961	31.7	8
4	4.51	3.28	5228	30.6	8
5	4.49	3.27	5354	30.6	7
6	4.52	3.27	8777	31.8	6
7	4.49	3.28	6399	30.9	8
8	4.51	3.30	6174	32.9	9
9	4.51	3.26	6852	31.2	7
10	4.50	3.25	6362	34.4	9
11	4.47	3.26	8629	32.9	8
12	4.46	3.26	6947	32.6	9
13	4.47	3.26	8647	32.9	9
14	4.48	3.26	7339	29.7	9
15	4.48	3.26	6246	30.1	10
16	4.47	3.27	9349	31.3	8
17	4.46	3.26	5813	32.0	8
18	4.48	3.26	6034	30.1	7
19	4.47	3.27	6995	31.8	8
20	4.48	3.25	9266	34.0	8
AVERAGE:	4.49	3.27	7014	31.9	8

TABLE 3A: TEST RESULTS
HORIZONTAL LAMINATIONS

SPECIES: D.FIR(INTERIOR VISUAL GRADE)
LUMBER: 2X4

SAMPLE NUMBER	WIDTH (IN)	DEPTH (IN)	M.O.R. (PSI)	DENSITY (LB/FT3)	MOISTURE CONTENT (%)
1	3.26	4.51	5511	31.6	7
2	3.26	4.50	6057	30.8	7
3	3.27	4.49	6205	31.1	9
4	3.27	4.51	8727	31.2	8
5	3.27	4.51	6037	32.2	8
6	3.28	4.50	5451	34.2	8
7	3.26	4.50	5153	31.8	9
8	3.26	4.52	5688	32.6	10
9	3.27	4.51	5746	32.4	10
10	3.27	4.50	6355	33.3	8
11	3.28	4.46	10428	34.0	8
12	3.26	4.47	7518	31.5	8
13	3.28	4.46	9604	32.9	10
14	3.28	4.48	7924	32.1	11
15	3.26	4.46	7746	31.0	8
16	3.26	4.47	6293	32.1	8
17	3.26	4.47	8111	32.4	8
18	3.25	4.48	7649	30.3	8
19	3.27	4.48	10022	31.5	8
20	3.27	4.47	6968	16.5	7
AVERAGE:	3.27	4.49	7160	31.7	8

TABLE 4: TEST RESULTS

SPECIES: D.FIR(COASTAL) VERTICAL LAMINATIONS
LUMBER: 2X4

SAMPLE NUMBER	WIDTH (IN)	DEPTH (IN)	M.O.R. (PSI)	DENSITY (LB/FT3)	MOISTURE CONTENT (%)
1	4.48	3.26	6810	34.3	9
2	4.53	3.27	7335	34.1	8
3	4.52	3.32	7773	35.3	7
4	4.48	3.27	8575	34.1	7
5	4.51	3.27	8274	34.4	8
6	4.51	3.29	9464	32.9	7
7	4.49	3.32	7892	34.6	8
8	4.47	3.27	7891	32.1	7
9	4.47	3.25	9109	35.2	8
10	4.50	3.27	9863	36.1	9
11	4.46	3.26	9091	32.1	11
12	4.48	3.26	9368	33.1	12
13	4.48	3.26	8645	31.4	11
14	4.46	3.25	7346	31.1	10
15	4.47	3.26	7939	35.2	10
16	4.49	3.26	7059	33.3	12
17	4.45	3.26	6323	33.7	10
18	4.44	3.25	6269	31.5	12
19	4.46	3.25	6740	33.5	12
20	4.47	3.26	6153	31.5	11
AVERAGE:	4.48	3.27	7896	33.5	9

TABLE 4A: TEST RESULTS

SPECIES: D.FIR(COASTAL) HORIZONTAL LAMINATIONS
LUMBER: 2X4

SAMPLE NUMBER	WIDTH (IN)	DEPTH (IN)	M.O.R. (PSI)	DENSITY (LB/FT3)	MOISTURE CONTENT (%)
1	3.25	4.51	11385	34.5	10
2	3.27	4.50	7573	30.7	10
3	3.31	4.49	10549	30.9	7
4	3.30	4.48	10210	31.4	7
5	3.25	4.47	10190	33.7	8
6	3.26	4.53	8413	31.5	8
7	3.29	4.53	7958	32.7	7
8	3.26	4.48	11041	33.7	10
9	3.26	4.52	8576	33.1	10
10	3.27	4.48	9062	34.1	9
11	3.26	4.48	8191	32.6	8
12	3.30	4.48	6417	33.5	9
13	3.27	4.47	9398	34.3	12
14	3.25	4.46	5119	35.1	10
15	3.26	4.48	4866	33.9	8
16	3.26	4.48	9898	31.7	11
17	3.28	4.47	5563	34.4	9
18	3.27	4.46	6883	32.1	10
19	3.26	4.47	5790	31.2	10
20	3.26	4.48	6162	32.2	10
AVERAGE:	3.27	4.49	8161	32.9	9

TABLE 5: TEST RESULTS

SPECIES: SPRUCE VERTICAL LAMINATIONS
LUMBER: 2X4

SAMPLE NUMBER	WIDTH (IN)	DEPTH (IN)	M.O.R. (PSI)	DENSITY (LB/FT3)	MOISTURE CONTENT (%)
1	4.47	3.28	5275	27.4	10
2	4.48	3.27	4612	26.9	9
3	4.49	3.28	5773	27.2	8
4	4.47	3.28	6900	26.8	7
5	4.53	3.27	6035	28.5	9
6	4.46	3.28	4061	26.1	8
7	4.49	3.26	5897	26.8	9
8	4.50	3.29	6070	29.0	11
9	4.47	3.27	5501	26.4	10
10	4.50	3.27	6145	26.6	9
11	4.49	3.25	6394	25.9	13
12	4.47	3.27	5167	28.1	11
13	4.45	3.28	4579	26.7	10
14	4.49	3.26	6091	26.8	10
15	4.49	3.27	6106	28.1	10
16	4.49	3.26	5844	26.2	11
17	4.46	3.26	5848	27.5	11
18	4.49	3.26	5527	27.0	12
19	4.48	3.27	5541	28.0	11
20	4.48	3.27	6821	27.9	12
AVERAGE:	4.48	3.27	5709	27.2	10

TABLE 5A: TEST RESULTS

SPECIES: SPRUCE HORIZONTAL LAMINATIONS
LUMBER: 2X4

SAMPLE NUMBER	WIDTH (IN)	DEPTH (IN)	M.O.R. (PSI)	DENSITY (LB/FT3)	MOISTURE CONTENT (%)
1	3.27	4.45	5150	27.7	7
2	3.26	4.48	6984	27.5	10
3	3.26	4.48	4314	28.0	9
4	3.26	4.47	6113	26.6	10
5	3.26	4.44	6731	26.9	9
6	3.26	4.48	5918	27.7	9
7	3.26	4.47	5648	27.5	9
8	3.26	4.47	4978	27.0	9
9	3.26	4.46	4003	28.1	9
10	3.26	4.46	3938	26.3	9
11	3.26	4.46	5661	27.2	9
12	3.25	4.48	5409	28.4	8
13	3.27	4.49	4613	27.6	7
14	3.26	4.47	4655	26.7	9
15	3.27	4.45	4592	26.3	11
16	3.27	4.45	5812	27.4	10
17	3.27	4.49	6320	27.5	10
18	3.27	4.48	4915	27.1	11
19	3.27	4.48	5405	28.9	12
20	3.26	4.45	5647	26.5	7
AVERAGE:	3.26	4.47	5730	27.3	9

TABLE 6: TEST RESULTS

SPECIES: PINE VERTICAL LAMINATIONS
LUMBER: 2X4

SAMPLE NUMBER	WIDTH (IN)	DEPTH (IN)	M.O.R. (PSI)	DENSITY (LB/FT3)	MOISTURE CONTENT (%)
1	4.52	3.27	4536	28.3	8
2	4.51	3.27	6497	30.2	8
3	4.53	3.26	8305	30.8	10
4	4.53	3.27	6520	30.8	8
5	4.54	3.27	6921	31.8	8
6	4.52	3.28	8568	33.0	9
7	4.53	3.28	6257	30.2	7
8	4.52	3.28	4543	29.1	9
9	4.50	3.27	5761	32.4	9
10	4.54	3.28	6432	30.3	7
11	4.52	3.27	4797	29.9	8
12	4.54	3.27	6108	30.0	7
13	4.54	3.27	7146	29.5	8
14	4.50	3.28	6246	31.5	8
15	4.55	3.26	6375	32.7	7
16	4.54	3.27	7527	32.2	9
17	4.51	3.26	6537	29.6	8
18	4.54	3.27	5900	31.8	10
19	4.52	3.28	8257	32.4	7
20	4.51	3.27	6201	29.7	8
AVERAGE:	4.53	3.27	6472	30.8	8

TABLE 6A: TEST RESULTS

SPECIES: PINE HORIZONTAL LAMINATIONS
LUMBER: 2X4

SAMPLE NUMBER	WIDTH (IN)	DEPTH (IN)	M.O.R. (PSI)	DENSITY (LB/FT3)	MOISTURE CONTENT (%)
1	3.27	4.52	6956	30.4	6
2	3.27	4.50	5861	29.5	7
3	3.26	4.52	4112	29.8	7
4	3.27	4.50	5772	30.1	7
5	3.28	4.54	7144	30.1	7
6	3.26	4.53	2938	30.6	7
7	3.27	4.52	8902	30.0	8
8	3.27	4.57	5510	30.3	7
9	3.28	4.53	7114	30.8	7
10	3.27	4.51	5923	31.8	9
11	3.28	4.54	6536	29.8	8
12	3.29	4.54	5909	29.2	8
13	3.28	4.52	6468	29.3	9
14	3.29	4.54	7531	29.4	8
15	3.31	4.52	6608	30.7	10
16	3.30	4.53	7827	30.1	8
17	3.29	4.51	8598	30.4	8
18	3.31	4.51	4354	30.7	11
19	3.28	4.53	6839	30.5	8
20	3.27	4.51	6327	29.8	10
AVERAGE:	3.28	4.52	6762	30.2	8

TABLE 7: TEST RESULTS

SPECIES: D.FIR(INTERIOR) VERTICAL LAMINATIONS
LUMBER: 2X6

SAMPLE NUMBER	WIDTH (IN)	DEPTH (IN)	M.O.R. (PSI)	DENSITY (LB/FT3)	MOISTURE CONTENT (%)
1	5.28	5.16	8395	34.2	9
2	5.29	5.13	6655	33.8	10
3	5.28	5.12	5632	34.7	8
4	5.25	5.15	8862	35.6	10
5	5.27	5.16	8980	34.0	10
6	5.29	5.12	7190	34.0	9
7	5.30	5.15	8223	33.3	10
8	5.27	5.17	6977	34.0	8
9	5.29	5.17	8483	33.1	10
10	5.25	5.14	8015	34.3	10
11	5.27	5.16	7794	33.1	9
12	5.26	5.12	6585	33.9	9
13	5.27	5.16	7166	35.4	9
14	5.29	5.14	8348	34.7	10
15	5.26	5.14	8160	34.9	10
16	5.27	5.12	6652	35.0	11
17	5.28	5.14	8647	34.5	9
18	5.27	5.16	8130	35.2	9
19	5.25	5.14	6335	34.4	9
20	5.26	5.15	8129	35.8	9
AVERAGE:	5.27	5.15	7668	34.4	9

TABLE 7A: TEST RESULTS

SPECIES: D.FIR(INTERIOR) HORIZONTAL LAMINATIONS
LUMBER: 2X6

SAMPLE NUMBER	WIDTH (IN)	DEPTH (IN)	M.O.R. (PSI)	DENSITY (LB/FT3)	MOISTURE CONTENT (%)
1	5.13	5.26	7954	35.4	7
2	5.13	5.29	6179	36.3	10
3	5.13	5.26	8333	33.8	9
4	5.13	5.32	8412	36.7	10
5	5.13	5.27	7317	33.3	8
6	5.13	5.25	6822	32.3	9
7	5.12	5.27	7136	32.7	10
8	5.13	5.30	8219	33.6	9
9	5.11	5.28	7152	36.1	7
10	5.16	5.30	8612	32.9	7
11	5.13	5.26	7771	34.9	9
12	5.16	5.25	6556	34.2	8
13	5.14	5.26	9055	35.1	9
14	5.14	5.26	9368	36.3	9
15	5.15	5.26	7269	34.0	9
16	5.16	5.25	7879	35.0	11
17	5.15	5.25	6072	33.6	8
18	5.14	5.26	7614	34.7	8
19	5.14	5.25	8467	32.6	10
20	5.15	5.28	7489	34.7	8
AVERAGE:	5.14	5.27	7884	34.1	9

TABLE 8: TEST RESULTS

SPECIES: D.FIR(COASTAL) VERTICAL LAMINATIONS
LUMBER: 2X6

SAMPLE NUMBER	WIDTH (IN)	DEPTH (IN)	M.O.R. (PSI)	DENSITY (LB/FT3)	MOISTURE CONTENT (%)
1	5.30	5.13	4914	28.5	8
2	5.31	5.14	5353	30.2	8
3	5.28	5.16	4965	31.1	9
4	5.29	5.15	5029	29.4	10
5	5.29	5.14	5193	29.8	8
6	5.26	5.12	7176	32.5	8
7	5.30	5.16	5554	28.2	8
8	5.28	5.12	5146	29.3	8
9	5.27	5.13	7153	31.2	9
10	5.28	5.15	6412	28.7	10
11	5.29	5.13	6058	31.4	8
12	5.30	5.14	7211	30.4	8
13	5.29	5.15	6783	31.1	8
14	5.29	5.13	6046	28.9	8
15	5.33	5.18	4170	28.5	9
16	5.27	5.13	5839	29.5	8
17	5.29	5.17	4966	29.3	8
18	5.29	5.14	5974	30.2	9
19	5.31	5.13	4616	29.2	8
20	5.29	5.13	4368	29.1	9
AVERAGE:	5.29	5.14	5646	29.8	8

TABLE 8A: TEST RESULTS

SPECIES: D.FIR(COASTAL) HORIZONTAL LAMINATIONS
LUMBER: 2X6

SAMPLE NUMBER	WIDTH (IN)	DEPTH (IN)	M.O.R. (PSI)	DENSITY (LB/FT3)	MOISTURE CONTENT (%)
1	5.14	5.30	5352	30.0	8
2	5.14	5.27	6273	29.3	8
3	5.20	5.34	3694	28.3	10
4	5.16	5.32	5919	29.4	9
5	5.13	5.28	4047	28.9	10
6	5.13	5.30	4803	28.5	7
7	5.13	5.32	4490	28.9	8
8	5.15	5.31	6276	30.0	9
9	5.13	5.31	6736	29.7	7
10	5.15	5.30	5075	30.3	10
11	5.13	5.27	6002	29.3	9
12	5.13	5.28	6050	30.2	10
13	5.17	5.32	3737	29.3	8
14	5.13	5.30	5456	30.6	9
15	5.16	5.31	5086	29.8	8
16	5.14	5.26	5428	28.0	10
17	5.15	5.31	6132	29.4	8
18	5.13	5.30	5147	30.2	10
19	5.13	5.32	4745	30.2	10
20	5.14	5.32	6132	30.6	7
AVERAGE:	5.14	5.30	5338	29.5	9

TABLE 9: TEST RESULTS

SPECIES: SPRUCE VERTICAL LAMINATIONS
LUMBER: 2X6

SAMPLE NUMBER	WIDTH (IN)	DEPTH (IN)	M.O.R. (PSI)	DENSITY (LB/FT3)	MOISTURE CONTENT (%)
1	5.26	5.15	5058	26.1	9
2	5.26	5.18	5844	28.0	8
3	5.29	5.13	4899	27.9	8
4	5.25	5.16	4855	26.6	10
5	5.27	5.11	4987	27.0	9
6	5.22	5.13	4947	26.8	10
7	5.27	5.15	5841	27.2	8
8	5.26	5.14	7054	28.5	8
9	5.28	5.16	4923	27.5	9
10	5.27	5.17	4389	27.3	7
11	5.28	5.15	5351	28.4	8
12	5.22	5.18	4678	26.6	8
13	5.27	5.12	6871	27.8	9
14	5.25	5.14	4809	27.2	9
15	5.26	5.13	4739	26.0	10
16	5.24	5.13	6420	26.6	8
17	5.23	5.14	5325	26.1	8
18	5.25	5.12	5054	27.4	7
19	5.28	5.17	7101	26.7	8
20	5.26	5.15	5527	26.4	9
AVERAGE:	5.26	5.15	5434	27.1	9

TABLE 9A: TEST RESULTS

SPECIES: SPRUCE HORIZONTAL LAMINATIONS
LUMBER: 2X6

SAMPLE NUMBER	WIDTH (IN)	DEPTH (IN)	M.O.R. (PSI)	DENSITY (LB/FT3)	MOISTURE CONTENT (%)
1	5.13	5.27	4381	25.9	8
2	5.17	5.30	4014	25.7	8
3	5.15	5.24	4687	28.0	9
4	5.14	5.20	6128	27.3	10
5	5.11	5.25	5714	26.3	10
6	5.16	5.26	6060	26.5	10
7	5.14	5.25	6184	29.3	9
8	5.15	5.28	6763	27.0	9
9	5.17	5.28	6976	26.8	8
10	5.18	5.30	4601	26.9	10
11	5.14	5.26	5641	25.8	11
12	5.14	5.25	5319	26.2	8
13	5.12	5.28	5173	27.6	9
14	5.14	5.23	5126	26.3	9
15	5.12	5.27	5659	27.0	9
16	5.13	5.26	5167	27.6	8
17	5.14	5.30	6597	29.3	8
18	5.16	5.25	6001	26.9	10
19	5.12	5.27	5387	27.9	9
20	5.16	5.26	4719	27.7	8
AVERAGE:	5.14	5.26	5515	27.1	9

TABLE 10: TEST RESULTS

SPECIES: PINE VERTICAL LAMINATIONS
LUMBER: 2X6

SAMPLE NUMBER	WIDTH (IN)	DEPTH (IN)	M.O.R. (PSI)	DENSITY (LB/FT3)	MOISTURE CONTENT (%)
1	5.29	5.12	6118	28.7	10
2	5.30	5.15	4858	30.2	9
3	5.27	5.13	7189	30.3	9
4	5.29	5.13	5587	28.1	11
5	5.29	5.13	6106	28.9	9
6	5.30	5.11	6944	29.5	9
7	5.31	5.13	5356	29.7	9
8	5.24	5.13	5379	28.9	10
9	5.29	5.12	5918	29.3	10
10	5.27	5.13	5015	29.5	10
11	5.27	5.14	5068	28.8	9
12	5.28	5.12	5887	30.0	10
13	5.28	5.10	5694	29.5	9
14	5.30	5.13	6107	29.5	10
15	5.31	5.14	6006	29.3	7
16	5.32	5.12	6083	27.6	9
17	5.29	5.13	5811	29.6	8
18	5.28	5.13	5078	29.4	8
19	5.30	5.13	5926	29.7	8
20	5.27	5.12	6013	29.7	9
AVERAGE:	5.29	5.13	5807	29.3	9

TABLE 10A: TEST RESULTS

SPECIES: PINE HORIZONTAL LAMINATIONS
LUMBER: 2X6

SAMPLE NUMBER	WIDTH (IN)	DEPTH (IN)	M.O.R. (PSI)	DENSITY (LB/FT3)	MOISTURE CONTENT (%)
1	5.13	5.27	5235	31.2	10
2	5.16	5.27	4021	28.4	9
3	5.14	5.33	4527	29.9	8
4	5.12	5.29	5247	29.2	9
5	5.12	5.29	6033	29.2	9
6	5.12	5.32	6133	29.3	9
7	5.16	5.32	5332	29.9	10
8	5.13	5.31	5714	30.0	10
9	5.13	5.28	6760	29.7	10
10	5.13	5.32	4906	28.9	7
11	5.12	5.28	5355	30.8	10
12	5.14	5.28	6689	30.2	12
13	5.15	5.28	5552	29.9	9
14	5.13	5.29	5974	29.3	8
15	5.11	5.32	4902	29.4	10
16	5.13	5.33	5418	28.5	10
17	5.16	5.33	4613	31.2	9
18	5.14	5.31	4932	30.5	9
19	5.17	5.28	4476	30.2	10
20	5.17	5.28	6271	29.0	10
AVERAGE:	5.14	5.30	5405	29.7	9

5.0 DISCUSSION OF RESULTS

Table 11 presents a summary of the mean M.O.R. and coefficient of variation for each of the species, cross-sectional sizes and orientations tested. For comparison purposes the last two columns of Table 11 give the accepted values of mean M.O.R. and coefficient of variation (C.V.) for Class 1 solid sawn Crossarms as taken directly from Appendix F of CSA standard 0116 - 1969. (4) Comparison of the mean M.O. R. values of the laminated crossarms to the accepted value for solid sawn crossarms shows the laminated values range from 148% to 97% of the solid sawn values.

An examination of the test data on both 3 1/4" X 4 1/2" and 5 1/8" X 5 1/4" D. Fir crossarms reveals that the average density of the 5 1/8" X 5 1/4" Coastal Fir arms is significantly lower than that of the same size arm made from Interior Fir (i.e. 29.6 pcf vs 34.4 pcf). This fact is not evident when comparing the average densities of the 3 1/4" X 4 1/2" Coastal and Interior Fir Crossarms. It can be further noted that the mean M.O.R. value for the 5 1/8" X 5 1/4" Coastal Fir crossarms is significantly lower than that value for all other D. Fir arms. Since density and M.O.R. are correlated positively these facts would tend to suggest that the 5 1/8" X 5 1/4" Coastal Fir arms produced, do not form a representative sample.

A statistical analysis performed on the mean M.O.R. values within a given species and size indicates that no significant difference exists (at the 5% level) between the means of crossarms tested with the laminations either vertically or horizontally oriented towards the applied load. Table 12 summarizes these findings.
A determination of near minimum strength properties has not been provided because the sample size in each of the test groups was too small to make any such calculations meaningful.

TABLE 11 SUMMARY TABLE: MEAN M.O.R. AND COEFFICIENT OF VARIATION

SAMPLE DESCRIPTION	ORIENTATION OF LAMINATIONS	MEAN M.O.R. (psi)	C.V. (%)	CLASS 1 SOLID SAWN MEAN M.O.R. (psi)	C.V. (%)
3 .25 X 4.50 INTERIOR D.FIR	VERTICAL	7070	19.8	5500	18
	HORIZONTAL	7702	16.2	5500	18
3.25 X 4.50 V.G.I.F	VERTICAL	7014	18.1	5500	18
	HORIZONTAL	7160	22.2	5500	18
3.25 X 4.50 COASTAL D.FIR	VERTICAL	7896	14.4	5500	18
	HORIZONTAL	8161	25.1	5500	18
3.25 X 4.50 SPRUCE	VERTICAL	5709	12.5	5500	18
	HORIZONTAL	5340	15.9	5500	18
3.25 X 4.50 PINE	VERTICAL	6472	17.4	5500	18
	HORIZONTAL	6362	22.6	5500	18
5.125 X 5.25 INTERIOR FIR	VERTICAL	7669	12.3	5500	18
	HORIZONTAL	7684	11.7	5500	18
5.125 X 5.25 COASTAL FIR	VERTICAL	5646	16.6	5500	18
	HORIZONTAL	5309	16.9	5500	18
5.125 X 5.25 SPRUCE	VERTICAL	5435	15.2	5500	18
	HORIZONTAL	5515	14.7	5500	18
5.125 X 5.25 PINE	VERTICAL	5807	10.2	5500	18
	HORIZONTAL	5405	13.8	5500	18

TABLE 12. SUMMARY TABLE: COMPARISON OF MEAN M.O.R. VALUES

SAMPLE DESCRIPTION	ORIENTATION OF LAMINATIONS	MEAN (psi)	STANDARD DEVIATION (psi) (1)	STANDARD DEVIATION OF DIFFERENCE IN MEANS (psi) (1)	t-STATIS-TIC (1)(2)
3.25 X 4.50 INTERIOR D.FIR	VERTICAL HORIZONTAL	7070 7702	1402 1244	419	1.51
3.25 X 4.50 V.G.I.F	VERTICAL HORIZONTAL	7014 7160	1272 1592	455	0.32
3.25 X 4.50 COASTAL D.FIR	VERTICAL HORIZONTAL	7896 8161	1137 2049	524	0.50
3.25 X 4.50 SPRUCE	VERTICAL HORIZONTAL	5709 5340	715 851	248	1.49
3.25 X 4.50 PINE	VERTICAL HORIZONTAL	6472 6362	1127 1439	408	0.27
5.125 X5.25 INTERIOR D.FIR	VERTICAL HORIZONTAL	7668 7684	945 898	291	0.05
5.125 X5.25 COASTAL D.FIR	VERTICAL HORIZONTAL	5646 5309	936 899	290	1.16
5.125 X5.25 SPRUCE	VERTICAL HORIZONTAL	5434 5515	825 809	258	0.31
5.125 X5.25 PINE	VERTICAL HORIZONTAL	5807 5405	595 746	213	1.89

1. See reference (5)
2. t- statistic required to reject hypothesis that MEAN (vertical) equals MEAN (horizontal) at the 5% level is 2.025.

6.0 CONCLUSIONS

1. In general, crossarms manufactured from Interior D.Fir exhibited the highest mean M.O.R. when graded in accordance with the present manufacturing standard.

2. The mean M.O.R. of the various laminated crossarms tested ranged from 148% to 97% of the value accepted for Class 1 solid sawn crossarms.

7.0 RECOMMENDATIONS

An evaluation of the grade combination used for Spruce and Pine Crossarms should be considered with the goal of increasing strength while remaining practical to manufacture. It is believed that the potential to do this does exist.

A survey should be taken to establish a representative average density for 2 X 6 coastal fir crossarm stock to allow a decision to be made with regards to the need and nature of any additional testing on this product.

Based on the data provided by this report it is recommended that further testing be done, with an increased emphasis on Spruce and Pine crossarms, in order to refine the manufacturing standards to fully meet the needs of the purchasers.

8.0 COMMERCIAL SIGNIFICANCE

As a part of this research, Western Archrib conducted a survey of several utilities in Canada. Results of this survey indicate that there exists a very significant market for Crossarms. In addition to that solid sawn products such as spar arms, substation timbers, and poles are purchased by utilities annually, in extremely large quantities.

Utilities are currently searching for alternate products and sources of supply for these items. There was no objection to a glued-laminated product provided it would meet both technical and commercial considerations.

Information as to the current market value of solid sawn Douglas Fir crossarms confirms that a glued laminated arm manufactured with Douglas Fir will be competitive while one manufactured with Spruce/Lodgepole pine would have a significant pricing advantage.

While further work is required research conducted to date has been positive and indicates strong market potential.

9.0

REFERENCES

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3. American Society for Testing Materials. Standard methods of static tests of timbers in structural sizes. ASTM D-198-84

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5. G.W. Snedecor and W.G. Cochran. Statistical Methods. Sixth Edition, 1967.