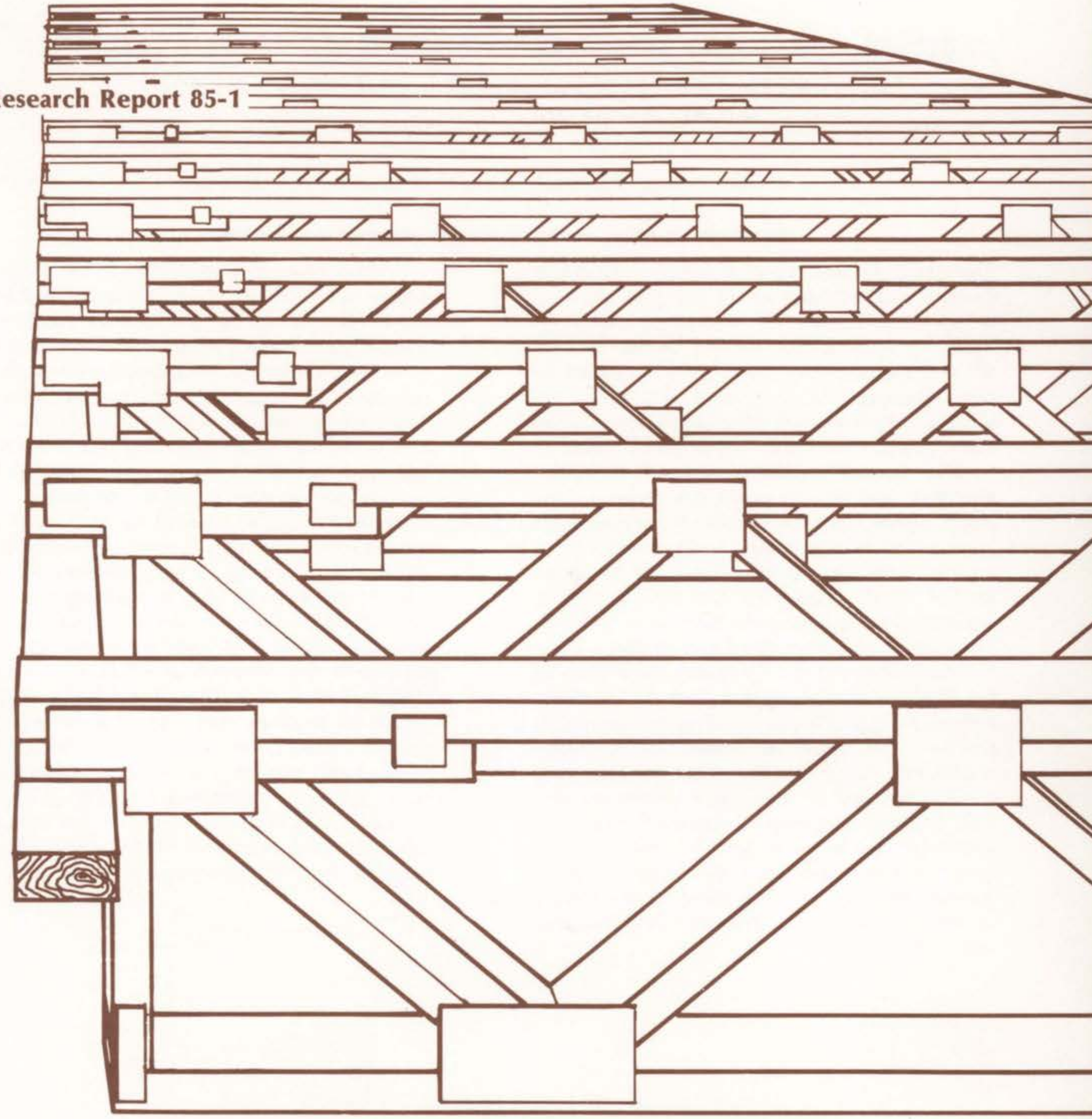
TEST RESULTS FROM AN INVESTIGATION OF PARALLEL-CHORD, TOP-CHORD-BEARING WOOD TRUSSES

Research Report 85-1



Small Homes Council-Building Research Council
University of Illinois at Urbana-Champaign

SMALL HOMES COUNCIL-BUILDING RESEARCH COUNCIL

The Small Homes Council-Building Research Council was established by the University of Illinois as an agency for research, publication, education, and public service in the area of housing and building. Its program is keyed to take advantage of the many University resources — its laboratories and specialists — in the many subjects related to housing and building.

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Many of the Council's studies have been in the areas of simplifying construction methods and adapting large-scale building techniques to the needs of the small builder. Of particular importance has been the work in roof-truss construction and the wall-panel framing system. One of the major research concerns has been with how much space families need in their homes and how that space should be arranged. Special attention has been given to the design of kitchens, and to energy conservation and solar utilization.

Unless research findings reach the hands of people who can use them, research is of little value. For this reason, publications are an important part of the Council's program. A complete list of Council publications is available upon request to the Council at One East Saint Mary's Road, Champaign, IL 61820. This activity is a non-profit but self-supporting one, which is necessary because a major proportion of the publications are distributed out of state.

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ABSTRACT

This report describes the results of 73 tests of top-chord-bearing, parallel-chord, metal-plate-connected wood trusses using various wood species, truss-plate sizes, and two different lumber orientations. The test units were separated into two phases, with Phase I including various replications as a pilot study for planning Phase II. Forty-six trusses were tested in Phase I. After an evaluation of the performances of these units, 27 trusses were designed for Phase II using other lumber species, more precise deflection measurement, and an upgraded plating design.

The main objectives of the study were to provide information on deflection, shear strength, and bearing characteristics of these truss designs. An additional objective was to determine the effect of varying the gap between the inside edges of the bearing and the first vertical or diagonal web-members. The trusses were designed to put maximum stress on the heel joint.

The tests showed that there are important additional deflection and force components resulting from the rotation of each end joint at the reactions. New design methodology and modeling are needed to reliably predict the performance of top-chord-bearing wood trusses.

INTRODUCTION

Full scale tests of top-chord-bearing, parallel-chord, metal-plate-connected wood trusses were designed to test the performance of various wood species, truss-plate sizes, and lumber orientations. Two lumber orientations were tested.

The tests were conducted in two phases. Some of the tests in Phase I were used as a pilot study for planning Phase II. Forty-six trusses were tested in Phase I. After an evaluation of the performances of these units, 27 trusses were designed for Phase II, using other lumber species, more precise deflection measurement, and an up-graded plating design.

The tests provided information on deflection, shear strength, and bearing characteristics of the truss designs. An additional objective was to determine the effect of varying the gap between the inside edges of the bearing and the first vertical or diagonal web-members. The trusses were designed to put maximum stress on the heel joint.

The testing program was sponsored in part by the Lumbermate Company of St. Louis, Missouri and the Small Homes Council-Building Research Council of the University of Illinois. The trusses were designed by the Lumbermate Company and fabricated by Okaw Buildings, Inc., Chesterville, Illinois. Fabrication was supervised by J. M. Denny and D. H. Percival.

TRUSS DESIGNS

Four basic truss designs were developed for Phase I and three types for Phase II. (See Appendix C.) Both 2×4 and 2×6 chord lumber was used in each phase. In several designs, the 2×4's were oriented flatwise (designated 4×2) and the rest oriented edgewise. In all cases, the 2×6's were oriented edgewise.

Design Loads

The allowable design values for the Modulus of Elasticity and the Modulus of Rupture of the lumber dictated the design loads. The design values for the plates were also carefully calculated. All plates, excluding the heel plates at the ends of the trusses, were designed to be compatible with the lumber design values. The objective of the test was to induce failure in the heel joint. Large loads were applied to the trusses to induce large reactions. The same kinds of reactions could have been created by using longer spans.

In previous truss-testing experiments, the heel joint proved to be the critical spot for failure. In Phase II experiments, the lumber and joints were carefully balanced to test which loads induced failure at the heel joint. The E-values of each piece of lumber were checked to assure design accuracy. The design loads used in these tests were as follows:

2×4 on edge, 20′ span = 250 lbs. per linear foot (plf)

4×2 flat, 20′ span = 250 plf

2×6 on edge, 20′ span = 400 plf

These design loads include both the dead and live loads. The loads were applied to the top chords to facilitate testing. Previous testing experience and analysis of trusses demonstrated no significant difference in deflection between placing all of the dead load and the live load on the top chord and applying the bottom-chord dead load separately. Therefore, it should be noted that the dead and live loads were applied as a combined load, giving deflection results for the total load.

For most tests performed to meet code requirements or other criteria, the dead load is applied prior to setting "0" as the reference, or starting, point for measuring deflection. In Phase

I, only one or two trusses were tested for several different designs, but for the majority of the designs, including the trusses for Phase II, three replications of each design were tested.

Lumber

Phase I top and bottom chord lumber for the 2×4 and 4×2 trusses was Southern pine, grade-stamped #1 DN, KD, and the web material was #2, KD. The KD notation indicates kiln-dried and DN indicates dense.

In Phase II, all of the 2×4 and 4×2 chord lumber, as well as the web material, was grade-stamped S.P.F., MSR-2100f, 1.8 E, S-Dry. (S.P.F. is the Canadian designation for a species combination of spruce, pine, and fir. MSR is the designation for Machine-Stress-Rated lumber, and the numbers indicate the material had a stress rating of 2100 psi in bending and an average modulus of elasticity of 1.8×10^6. S-Dry indicates surfacing at or below 19% moisture content.

The 2×6 chord and first diagonal web lumber for Phase I was Southern pine, grade-stamped #1 KD. The 2×4 web material was #2 KD Southern Pine. For Phase II, the 2×6's were Douglas fir lumber as a grade mixture of Select Structural and Dense Select Structural. The lumber was also stamped S-Dry. The first diagonal web members in the 2×6 trusses were also of this mixed grade and the remaining web members were Douglas fir 2×4's, grade stamped Select Structural, S-Dry.

The Douglas fir and S.P.F. lumber for Phase II trusses was purchased through special arrangement because it was not readily available through local supply sources. The Southern pine lumber was purchased from stock at the truss fabricator. For Phase I, the trusses were manufactured and tested and then dismantled for running modulus of elasticity (E) tests on the lumber. For Phase II, both S.P.F. and Douglas fir lumber were tested for "E" prior to fabrication. (These tests were run on a portable "E" tester. The data is included in Appendix B.) Moisture content of the lumber was recorded, as an average from several points on the truss, at the time the truss was tested.

Connector Plates

The metal connector plates were Lumbermate plates of various sizes and gauges as specified in the Truss Engineering Sheets. Four representative design sheets are included in Appendix C.

TEST PROCEDURES

The tests were conducted at the hydraulic testing facility located at the Small Homes Council-Building Research Council, University of Illinois. After fabrication and transportation, the trusses were stacked on the test floor for at least seven days prior to testing. The units were tested singly in a horizontal position between roller bearings and allowed to move freely against the reactions, as shown in Figure 2. Compression load-cells, as shown in Figure 3, were installed at the reactions of the first truss of each type to develop load curves for establishing gauge readings for the hydraulic pumping unit.

After the load curves were established, the load-cells were replaced with double 2×4's at the reaction points, giving a minimum bearing area of 5.25 square inches at each reaction. The loads were applied through bracketed hydraulic cylinders, spaced two feet apart, exerting point-loads at one-foot intervals along the top chord, as shown in Figure 4. A 2×2, two feet long, was placed under the load shoes over the top chord splice plate to prevent buckling by the concentrated load points of the load shoes. Roller hold-down brackets were positioned along the chords to prevent lateral buckling during the tests. These brackets simulate the sheathing, purlins, or let-in panels used in actual construction.

For Phase I, the investigative phase, dial gauges were used to measure deflection at only four locations. However, for Phase II, deflection was measured at thirteen locations by use of a taut-line and scale-mirror arrangement. This set-up was designed to provide deflection data for both the top and bottom chords at each joint and each mid-panel point, as shown in Figure 2. The center-line deflections are shown in Appendix B, Tables 1, 2, and 3. The other deflection data are not discussed in this report but were recorded for future analysis. (It should be noted that when using dial gauges for measuring deflection, provision must be made to measure crushing at the contact points of the reactions. This is very difficult due to rotation of the top-chord bearing projection and the nature of the reaction supports. Therefore, the taut-line, mirror arrangement was used for all the trusses in Phase II. This method eliminates the crushing influence and gives deflection for the truss without reference to a stationary base.)

The loads were applied in 50 plf (pounds per linear foot) increments at five-minute intervals. Due to the design of the hydraulic system, an equalization period of approximately 30 seconds was necessary prior to starting the five-minute hold period. This allowed each cylinder to reach an equalized pressure over the span of the truss. It should also be noted that the failure loads were recorded in even numbers: 500 plf, 450 plf, etc. If a failure occurred during application of the next increment, such as between 450 plf and 500 plf, 450 plf was considered the failure load. This was done because all of the cylinders had not yet reached equal loading during the 30-second time period prior to starting the 5-minute hold for each increment. If the truss then carried the load into the 5-minute hold, that particular load was used as the failure.

Failures occurred between 2 and 5 minutes after the time period had started. Deflection readings were recorded at the end of the five-minute test period. This required approximately another minute. The test continued at these load increments and on this time schedule until failure occurred. (See truss drawings and photographs for the failure locations.)

TEST RESULTS

The test results in Appendix B are listed for all 73 trusses in Tables 1, 2, and 3. Table 1 includes trusses for Phase I, types I-XXI; Table 2 includes trusses for Phase II, types XXII-XXVI; Table 3 includes trusses for the second part of Phase II, types XXVII-XXX. The data is presented in the tables by type, truss number, orientation of the lumber (whether 2×4 or 4×2), and failure loads in plf. Each reaction load is described in terms of pounds, plate type at the heel, centerline deflection at full design load, and a description of the failure and its location. The data for Phase II are presented in the same manner with the exception of the lumber orientation. All of the lumber was oriented on edge except for type XXX, which was oriented flat (4×2).

The configuration of each truss type is included in Appendix A, with a description and location of failure at the recorded loads. In addition, several photographs are shown as representative of the various types of joint or lumber failures recorded in the study. (See Figures 5, 6, and 7.)

CONCLUSION

The test results of these parallel, top-chord-bearing trusses indicate several conditions that are important to their strength and performance. The tests showed that there are important additional deflection and force components resulting from the rotation of each end joint at the reactions. Further deflection occurs as the reaction force is concentrated on the inside edge of the bearing surface, causing the top chord to crush. These highly concentrated forces in the top chord end joints cause the connector plates to fail by peeling, localized buckling, tearing or combinations of these.

The results of these tests indicate that new design methodology and modeling are needed to reliably predict the performance of top-chord-bearing wood trusses.

REFERENCE LIST

Design Specification for Metal-Plate Connected Parallel Chord Wood Trusses, PCT-80, Truss Plate Institute, 180. TPI-583 D'Onofrio Drive, Suite 200, Madison, WI 53719.

Grading Rules, Southern Pine Inspection Bureau, 1977 Edition, SPIB, Box 846, Pensacola, FL 32594.

National Design Specification for Wood Construction (NDS), 1982. National Forest Products Association, 1619 Massachusetts Ave. N.W., Washington, D.C. 20036.

"Portable E-Tester for Selecting Structural Component Lumber," *Forest Products Journal*, Vol. 31, No. 2., 1981. FPRS, 2801 Marshall Ct., Madison, WI 53705.

Standard Grading Rules for Canadian Lumber, latest revision, National Lumber Grades Authority, 1055 W. Hastings Street, Vancouver, B.C., Canada, V6E2HI.

Western Lumber Grading Rules, 1981. Western Wood Products Association, 1500 Yeon Bldg., Portland, OR 97204.

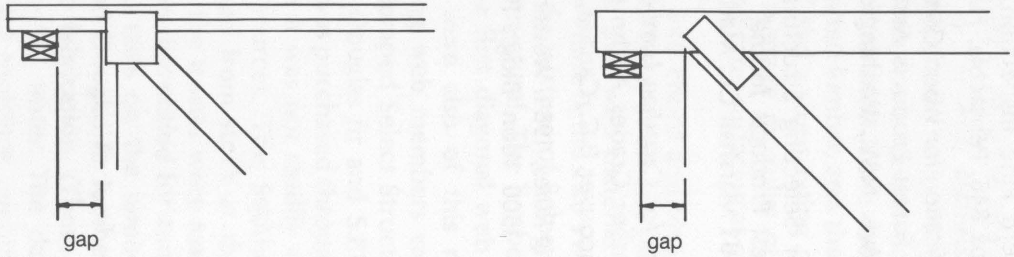


Figure 1. The gap in the space between the inner edge of the reaction and the first vertical or diagonal web.

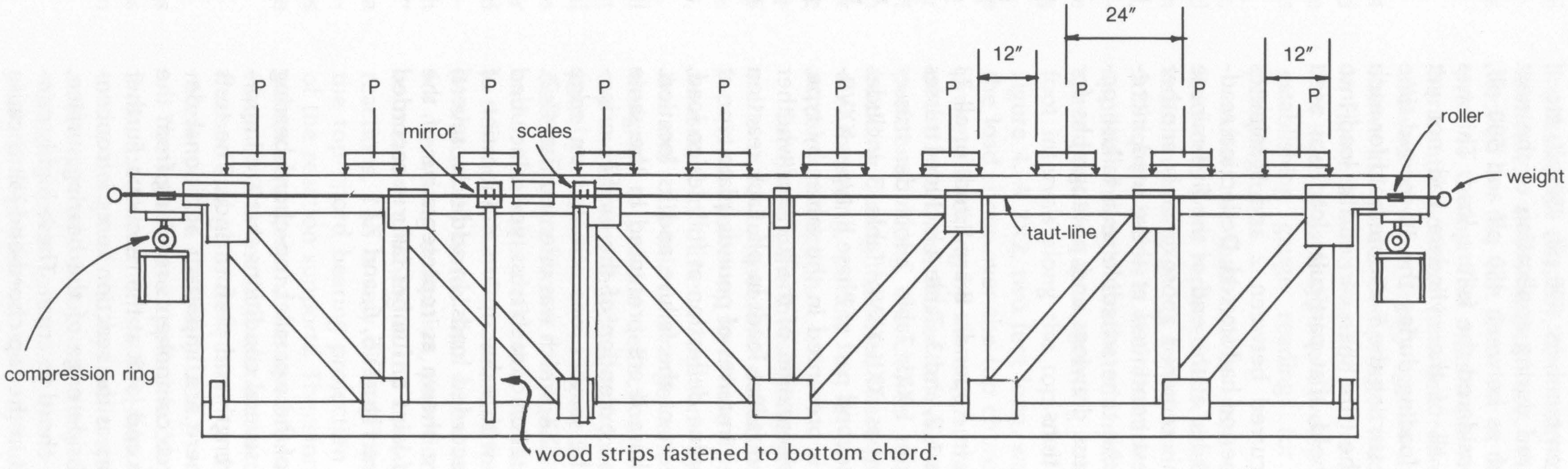


Figure 2. General set-up for tests.

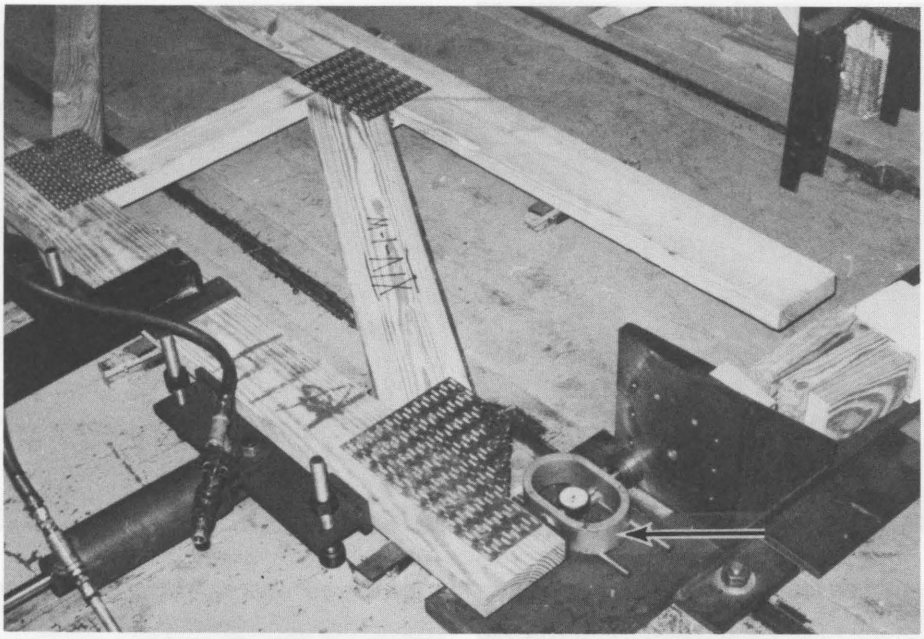


Figure 3. Compression Rings for Calculating Loads

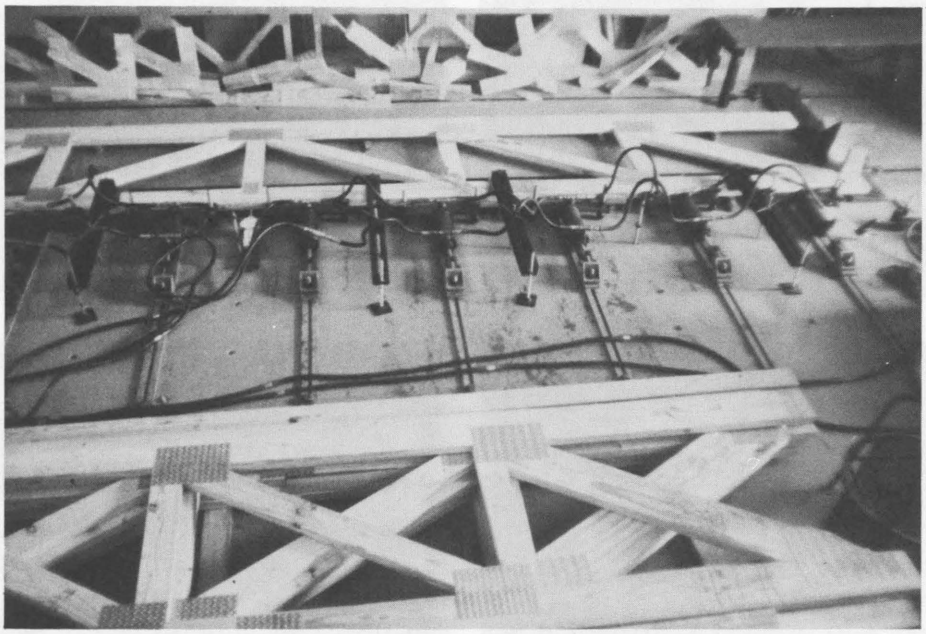


Figure 4. Truss Under Loading

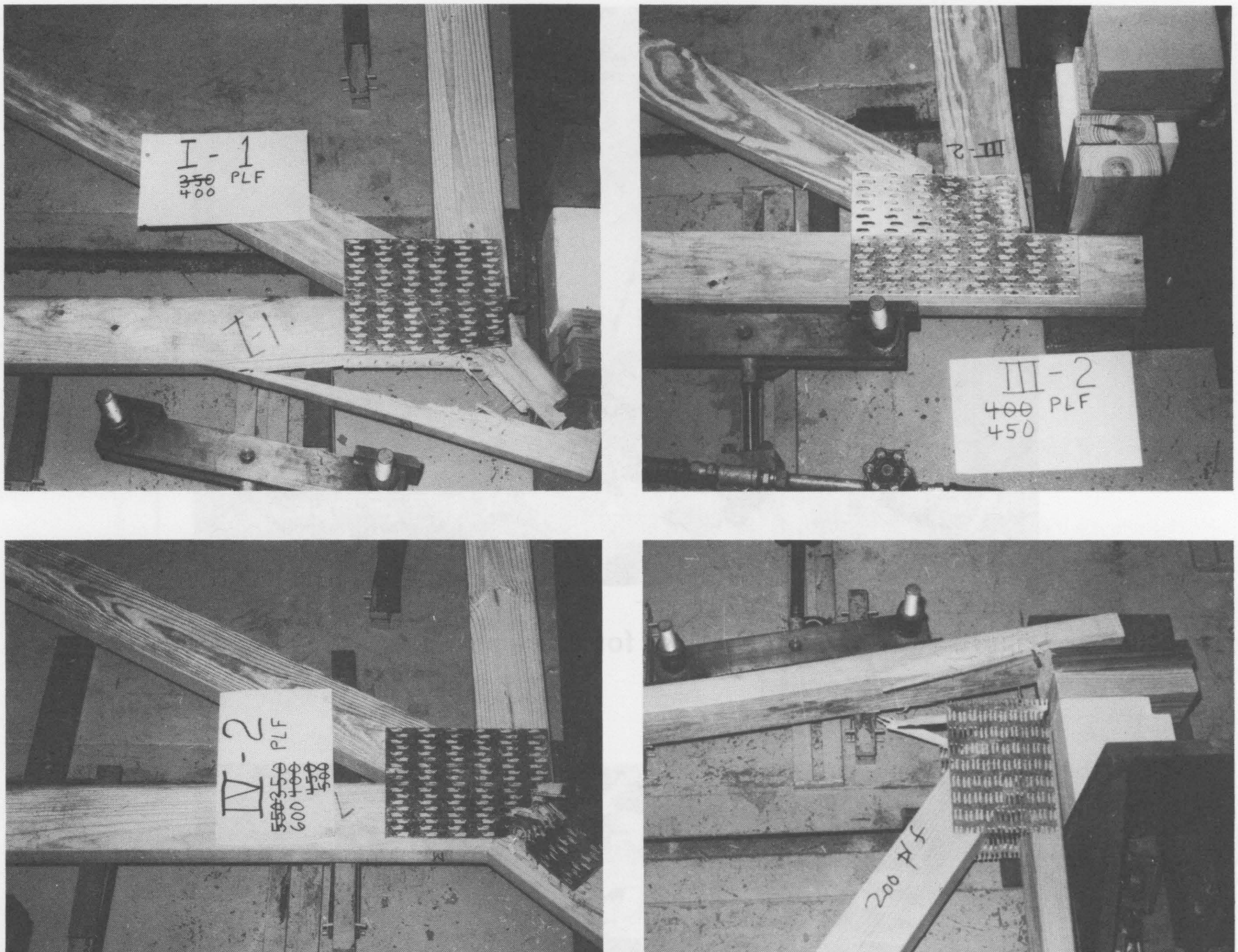


Figure 5. Representative Failure Types

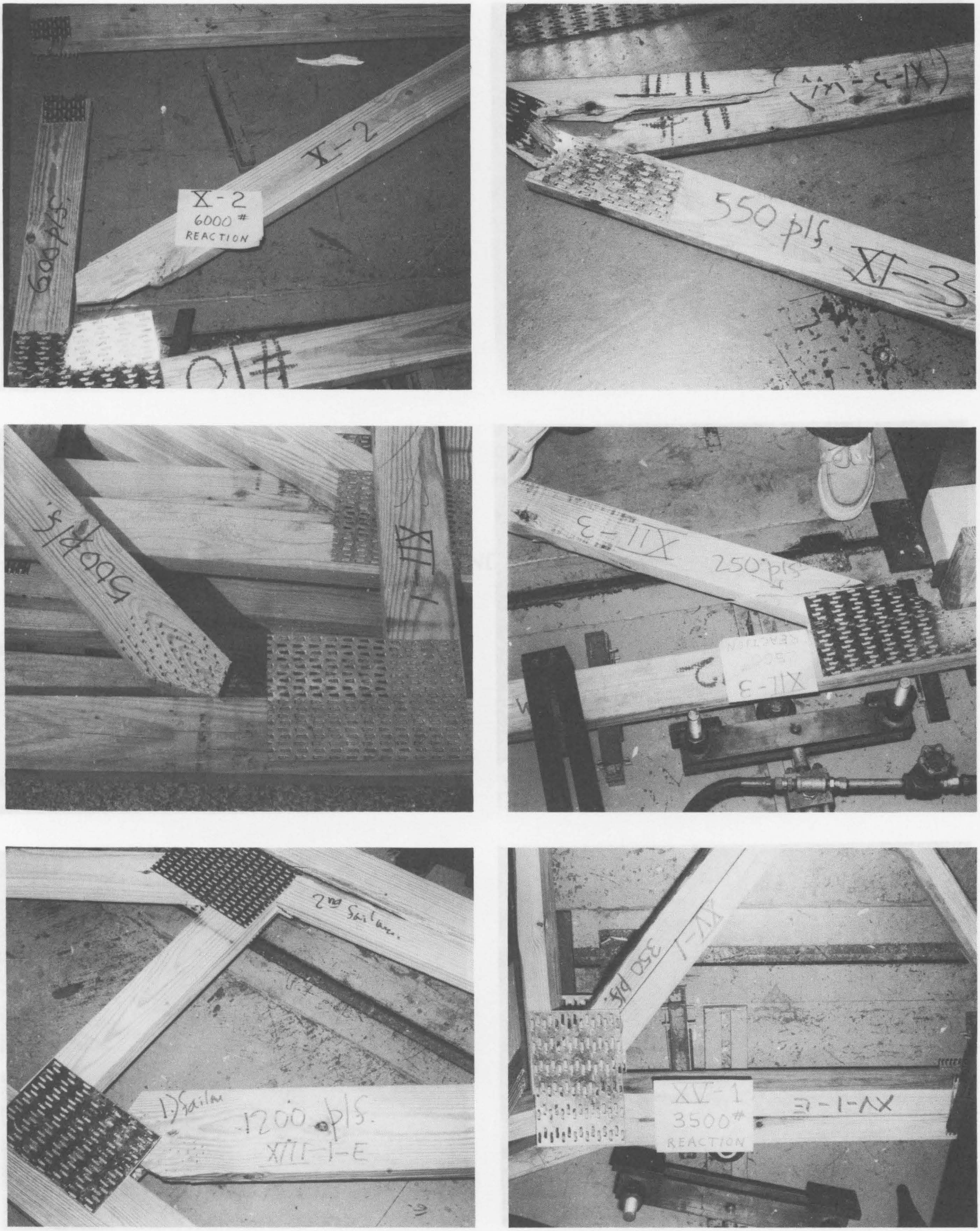


Figure 6. Representative Failure Types

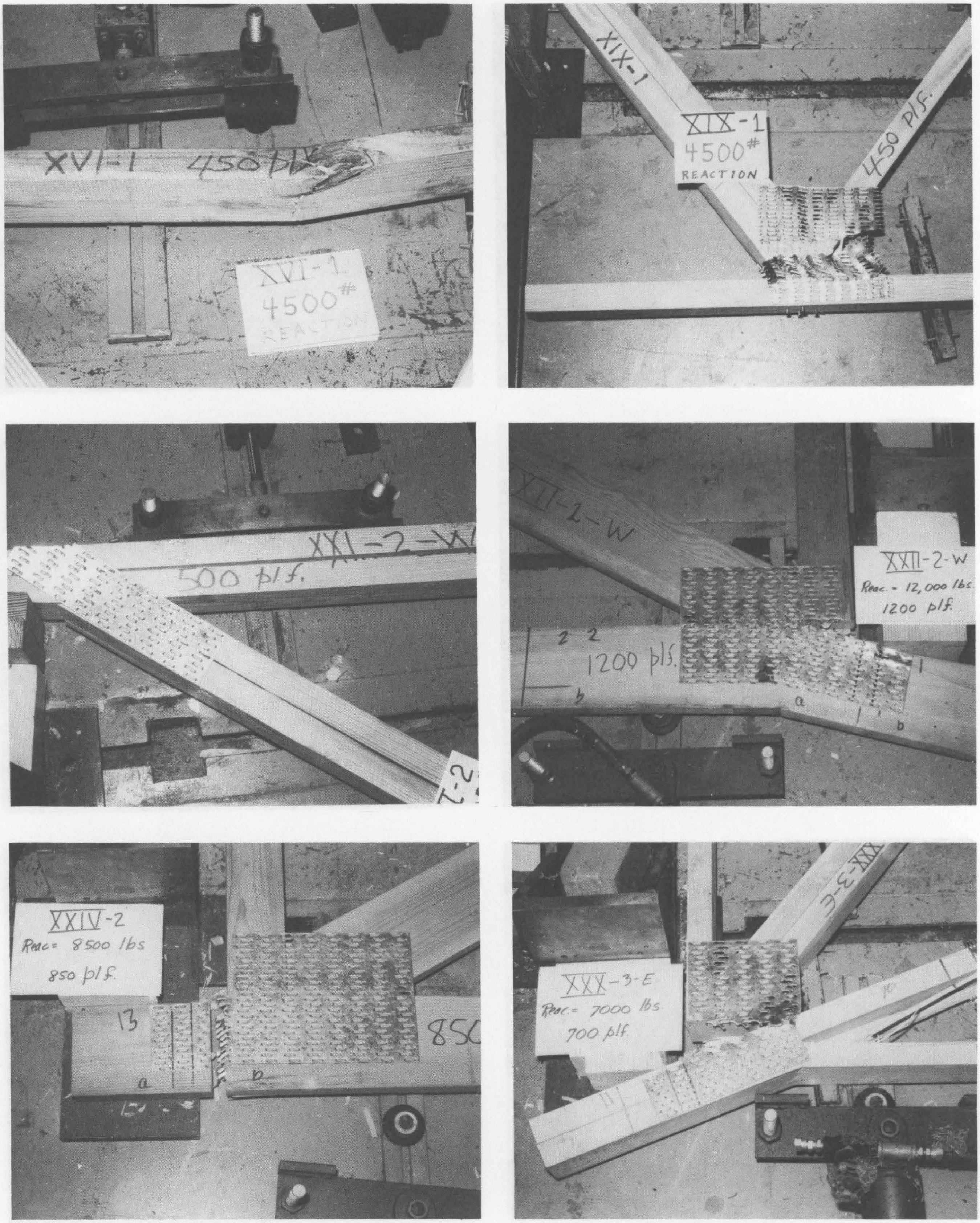
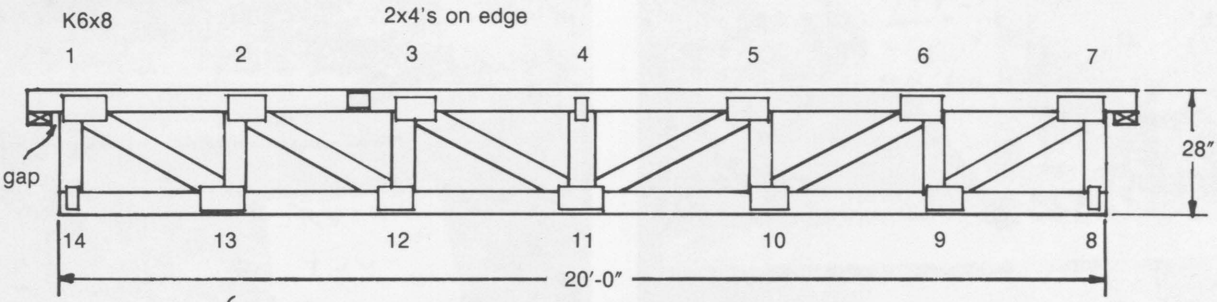


Figure 7. Representative Failure Types

APPENDIX A

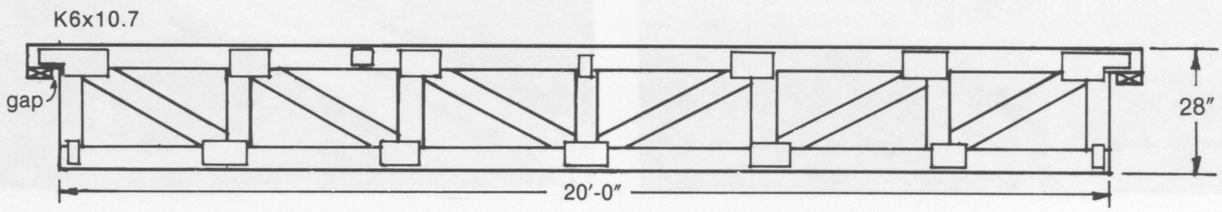
design load = 250 plf. 2½x design load = 625plf.
2x4, SYP, #1 Dense K.D. chords
#2 K.D. webs
15% adjustment



I – ½″ gap (VIII)
- 1 = 400 plf. — initial failure started as horizontal shear in top chord @ jt. 1.
- 2 = 450 plf. — initial failure started as horizontal shear in t.c. @ jt. 7.
- 3 = 450 plf. — initial failure started as horizontal shear in t.c. @ jt. 7.

II — 1½″ gap
- 1 = 350 plf. — initial failure started as horizontal shear in t.c. @ jt. 1.
- 2 = 350 plf. — initial failure started as horizontal shear in t.c. @ jt. 1.

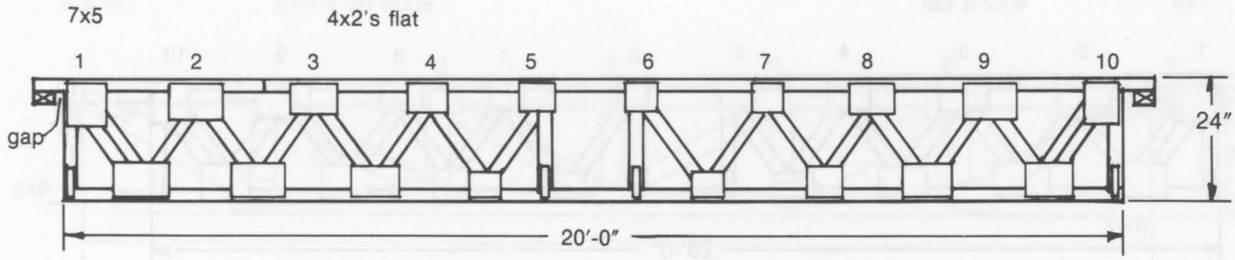
design load = 250 plf. 2½x design load = 625plf.
2x4, SYP, #1 Dense K.D. chords
#2 K.D. webs
15% adjustment



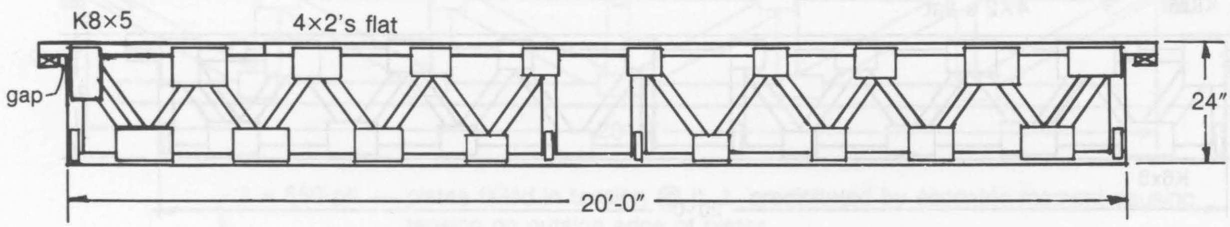
III – 1½″ gap
- 1 = 500 plf. — plate and t.c. lumber failure due to bending @ jt. 7.
- 2 = 450 plf. — plate peel and withdrawal from tension web @ jt. 1.

IV – ½″ gap
- 1 = 550 plf. — plate failure @ t.c. splice due to point load from cylinders
- 2 = 600 plf. — horizontal shear failure in t.c. and tension failure in plate due to bending @ jt. 1.

design load = 250 plf. 2½x design load = 625plf.
4x2, SYP, #1 Dense K.D. chords
#2 K.D. webs
15% adjustment

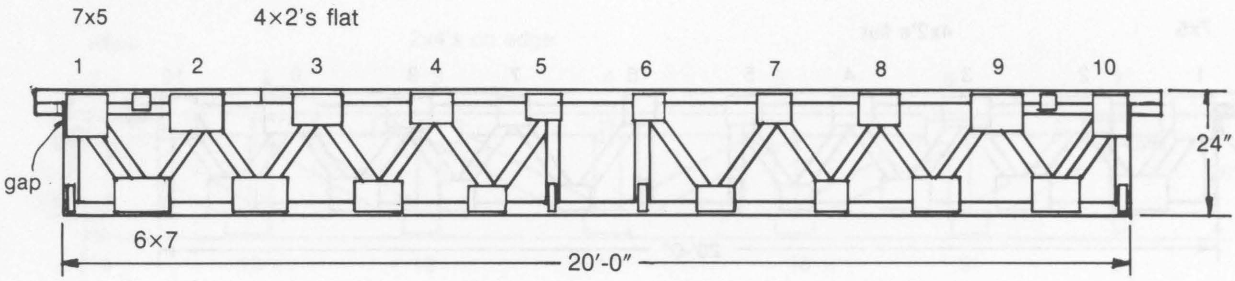


V - ½″ gap { 1 = 200 plf. — plate peel and withdrawal from t.c. @ jt. 10.
2 = 150 plf. — plate peel and withdrawal from t.c. @ jt.1.

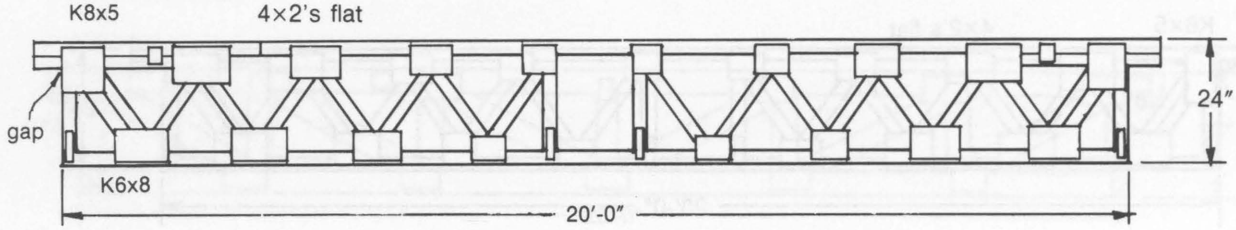


XVII - ½″ gap { 1 = 200 plf. — plate peel and withdrawal from t.c. @ jt. 1. teeth tore wood from t.c.
2 = 200 plf. — plate peel and withdrawal from t.c. @ jt. 10. teeth tore wood from t.c.

design load = 250 plf. 2½x design load = 625plf.
4x2, SYP, #1 Dense K.D. chords
#2 K.D. webs
15% adjustment

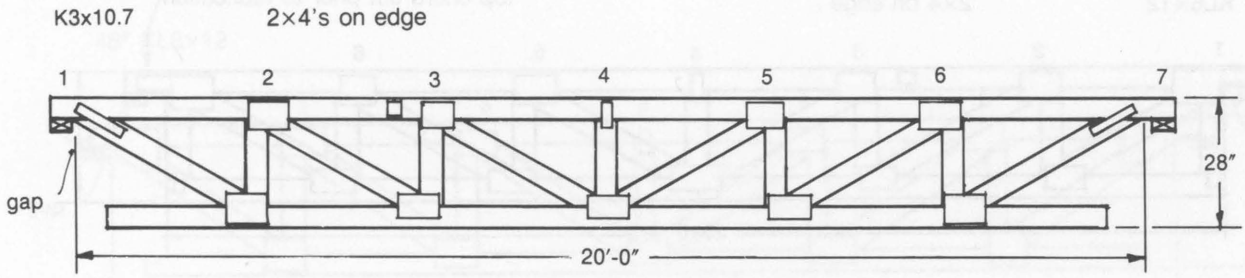


VI - 1″ gap { 1 = 350 plf. — plate peel and withdrawal from t.c. @ jt. 1. teeth tore wood from lower t.c.
2 = 310 plf. — plate peel and withdrawal from t.c. @ jt. 1. teeth tore wood from lower t.c.

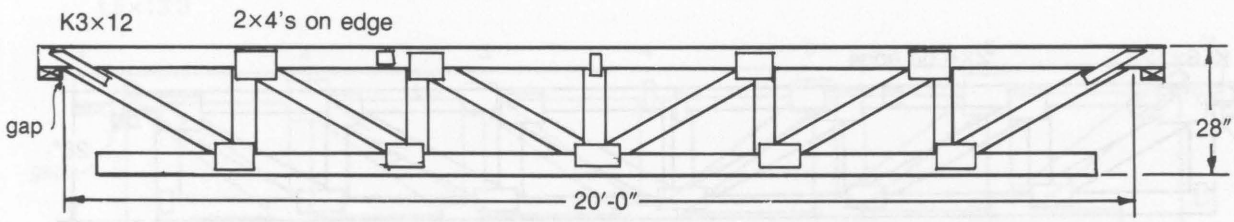


XV - 1″ gap { 1 = 350 plf. — plate peel and withdrawal from t.c. @ jt. 10.
2 = 350 plf. — plate peel and withdrawal from t.c. @ jt. 10.
3 = 350 plf. — plate peel and withdrawal from t.c. @ jt. 1. teeth tore wood from lower t.c.

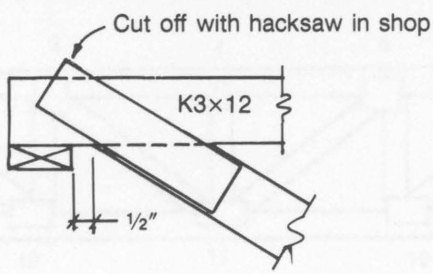
design load = 250 plf. 2½x design load = 625plf
2x4, SYP, #1 Dense K.D. chords
#2 K.D. webs
15% adjustment



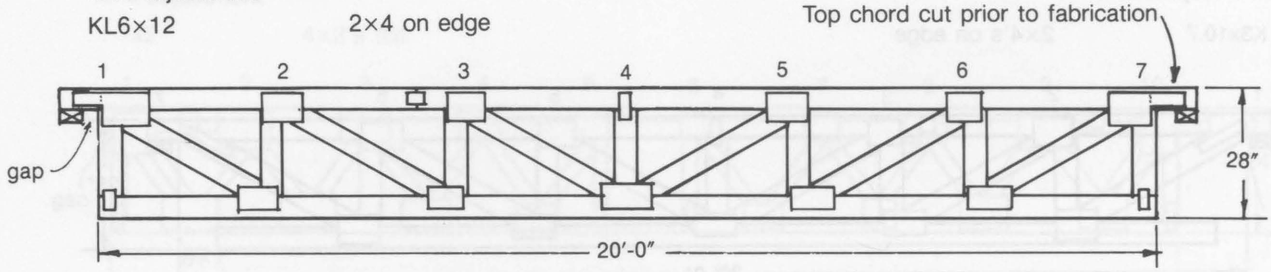
VII - ½" gap
- 1 = 400 plf. — t.c. failed in horizontal shear @ jt. 1.
- 2 = 500 plf. — plates failed in shear @ jt. 7. tooth withdrawal began on top chord @ 450 plf.



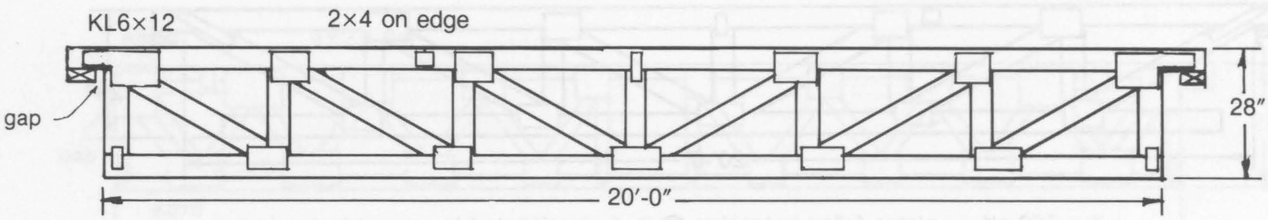
XI - ½" gap
- 1 = 550 plf. — plates failed in tension @ jt. 1. precipitated by eccentric moment causing tension on outside edge of plates.
- 2 = 500 plf. — plates failed in tension @ jt. 7. precipitated by eccentric moment causing tension on outside edge of plates.
- 3 = 550 plf. — plates failed in tension @ jt. 1. precipitated by eccentric moment causing tension on outside edge of plates.



design load = 250 plf. 2½x design load = 625plf.
2x4, SYP, #1 Dense K.D. chords
#2 K.D. webs
15% adjustment



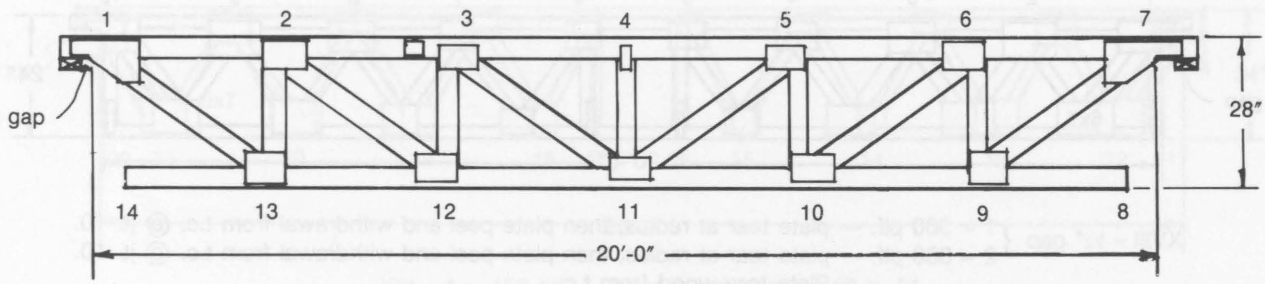
IX – ½″ gap = 475 plf. — vertical shear of plates @ jt. 1.



X – ½″ gap
- 1 = 420 plf. — tension failure in web @ jt. 7.
- 2 = 600 plf. — wood sheared in tension web @ jt. 7.
- 3 = 600 plf. — tension failure in web @ jt. 7.

design load = 250 plf.   2½x design load = 625plf.
2x4, SYP, #1 Dense K.D. chords
#2 K.D. webs
15% adjustment

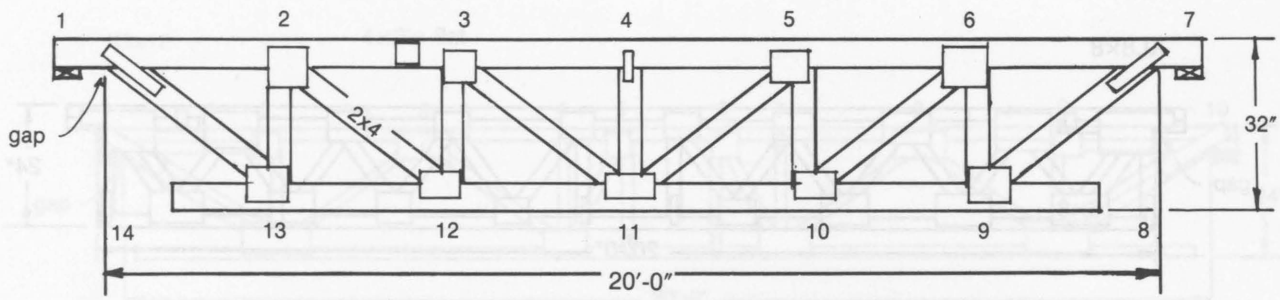
45° KL6×12



XII – ½″ gap
1 = 500 plf. — tooth withdrawal from diagonal tension web @ jt. 13.
2 = 600 plf. — tooth withdrawal from diagonal tension web @ jt. 7.
3 = 250 plf. — tension web failure at severe slope of grain @ jt. 1.

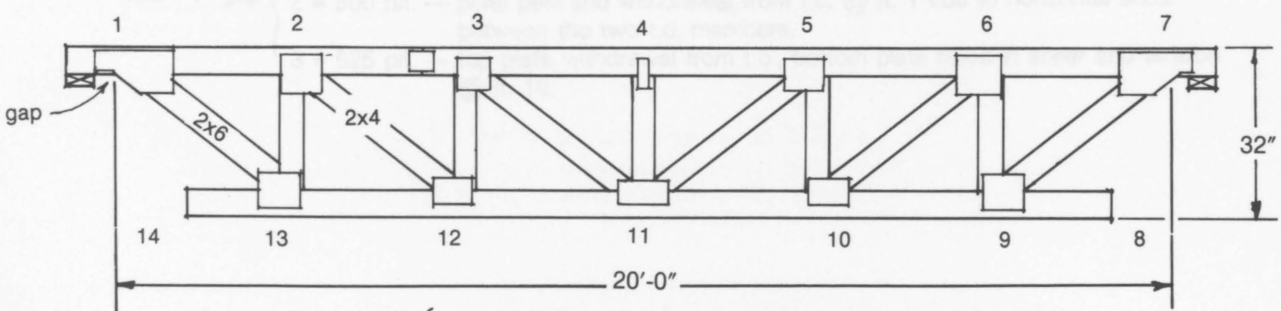
design load = 400 plf.   2½x design load = 1000plf.
2x6, SYP, #1K.D. chords
#1 K.D. heel webs
#2 K.D. 2×4 webs
15% adjustment

L5×13.3



XIII – ½″ gap
1 = 1200 plf. — tooth withdrawal from diagonal web @ jt. 9.
2 = 800 plf. — tooth withdrawal from diagonal web @ jt. 13
3 = 1050 plf. — tooth withdrawal from diagonal web @ jt. 13.

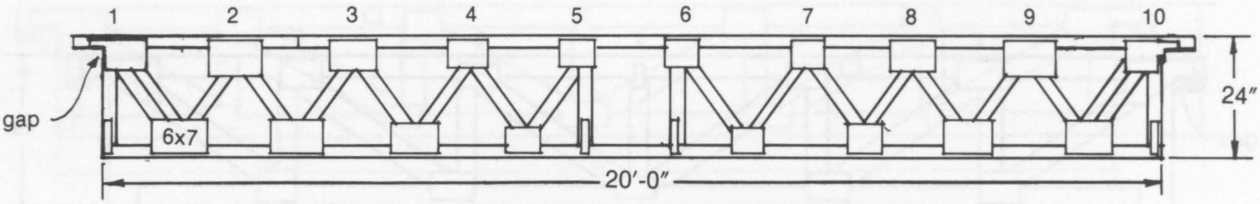
45° KL 8×12



XIV – ½″ gap
1 = 1050 plf. — tension web failure under plate @ jt. 9.
2 = 1200 plf. — plate failed in shear @ jt. 1.
3 = 1100 plf. — plate and t.c. shear failure @ jt. 1.

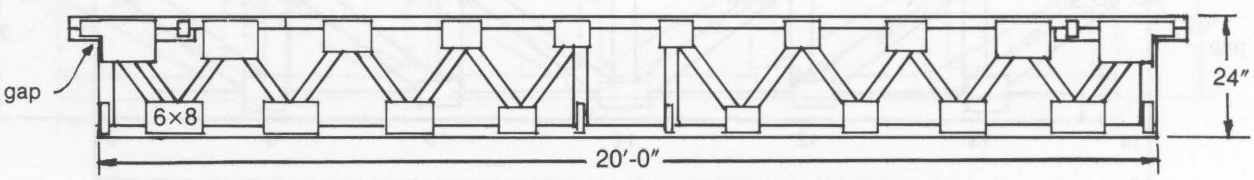
design load = 250 plf.   2½x design load = 625plf.
4x2, SYP, #1 Dense K.D. chords
#2 K.D. webs
15% adjustment

KL6×8



XVIII – ½″ gap
1 = 300 plf. — plate tear at radius, then plate peel and withdrawal from t.c. @ jt. 10.
2 = 350 plf. — plate tear at radius, then plate peel and withdrawal from t.c. @ jt. 10. Plate tore wood from t.c.

KL8×8

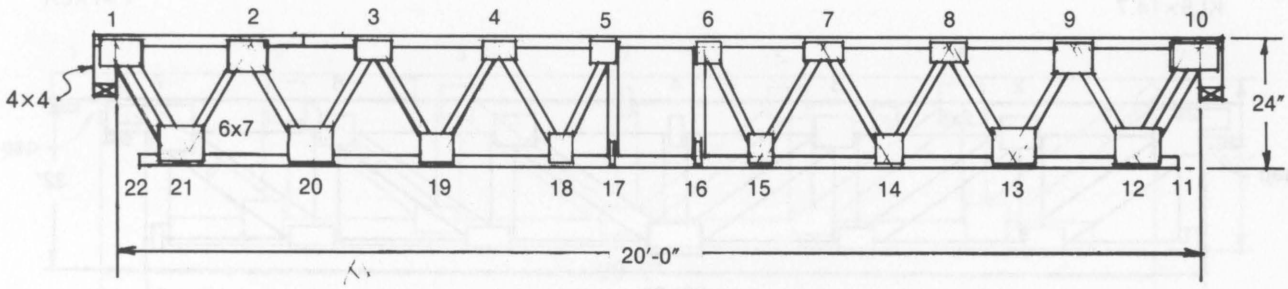


XVI – 1″ gap
1 = 450 plf. — t.c. failed in bending at large knot between jts. 7 and 8.
2 = 500 plf. — plates failed in shear and tension @ jt. 10 precipitated by eccentric moment causing tension at radius of plates.
3 = 500 plf. — t.c. failed in bending between jt. 3 and 4.

design load = 250 plf. 2½x design load = 625plf.
4x2, SYP, #1 Dense K.D. chords
#2 K.D. webs
15% adjustment

K5×8

4×2's flat

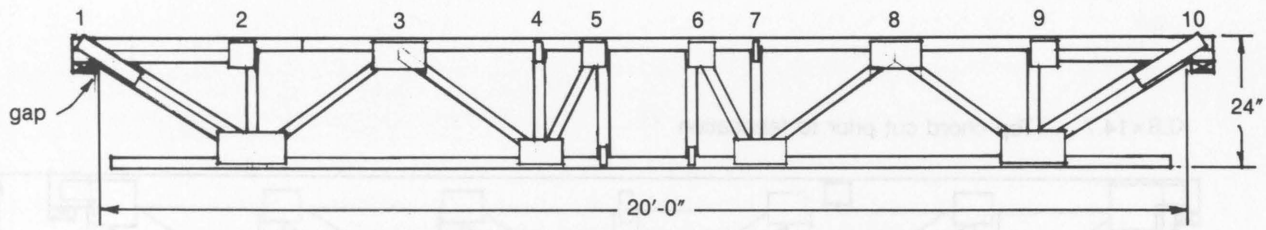


XIX - 1 = 450 plf. — plate failed in shear @ jt. 21.

XX - 1 = 450 plf. — plate peel and withdrawal due to shear @ jt. 21.
(this truss had k5×7 heel plates)

K3x12

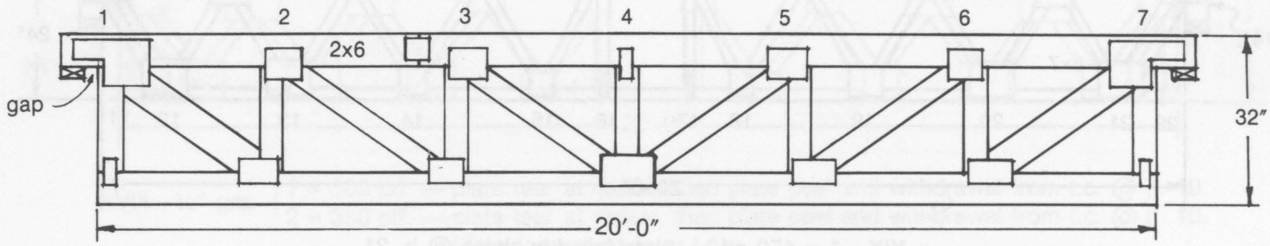
4×2's flat



XXI - 1″ gap
- 1 = 500 plf. — plate peel and withdrawal from t.c. @ jt. 1 due to horizontal shear between the two t.c. members.
- 2 = 500 plf. — plate peel and withdrawal from t.c. @ jt. 1 due to horizontal shear between the two t.c. members.
- 3 = 525 plf. — top plate withdrawal from t.c., bottom plate failed in shear and tension @ jt. 10.

design load = 400 plf.   2½x design load = 1000plf.
2x6, D. fir, mixed Select Structural and
Dense Select Structural chords, first webs
Select Structural 2x4 webs
15% adjustment

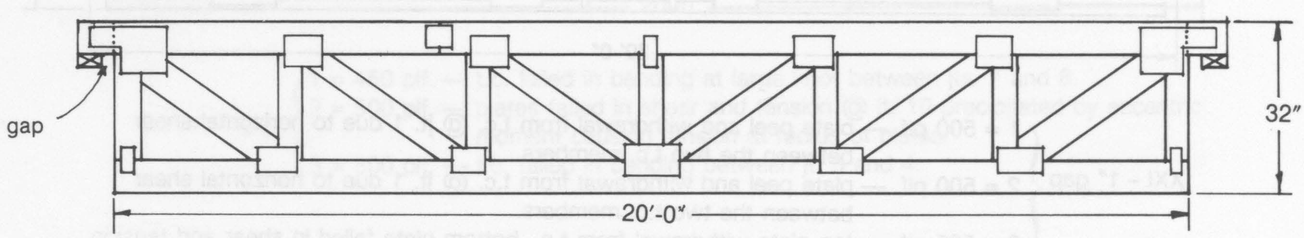
KL8×14.7



XXII - 1″ gap
- 1 = 1100 plf. — plate and t.c. failure in tension due to bending @ jt. 1.
- 2 = 1200 plf. — plate and t.c. failure in tension due to bending @ jt. 1.
- 3 = 950 plf. — plate and t.c. failure in tension due to bending @ jt. 7.

XXII - 2½″ gap
- 1 = 900 plf. — plate and t.c. failure in tension due to bending @ jt. 1.
- 2 = 950 plf. — plate and t.c. failure in tension due to bending @ jt. 1. Chord split vertically at reing shake in lumber.
- 3 = 900 plf. — plate and t.c. failure in tension due to bending @ jt. 1.

KL8×14.7   Top chord cut prior to fabrication

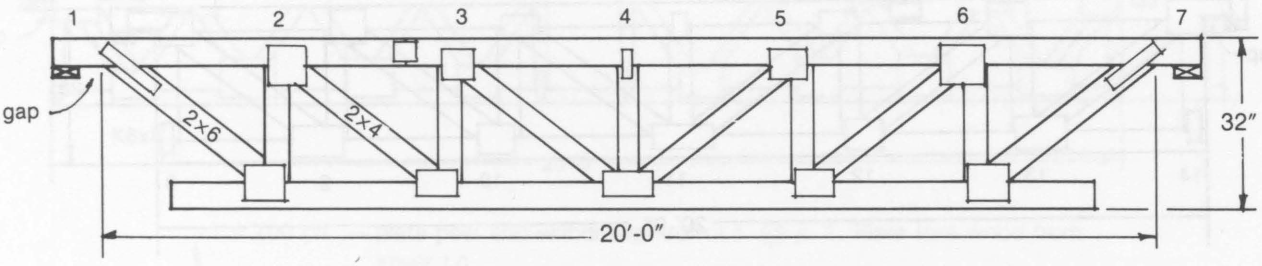


XXIV - 1″ gap
- 1 = 700 plf. — vertical shear of plates @ jt. 1.
- 2 = 850 plf. — vertical shear of plates @ jt. 7.
- 3 = 850 plf. — vertical shear of plates @ jt. 7.

design load = 400 plf.   2½ × design load = 1000 plf.
2×6, D. fir, mixed Select Structural and
Dense Select Structural chords, first webs,
Select Structural 2×4 webs.

15% adjustment

K5×14.7

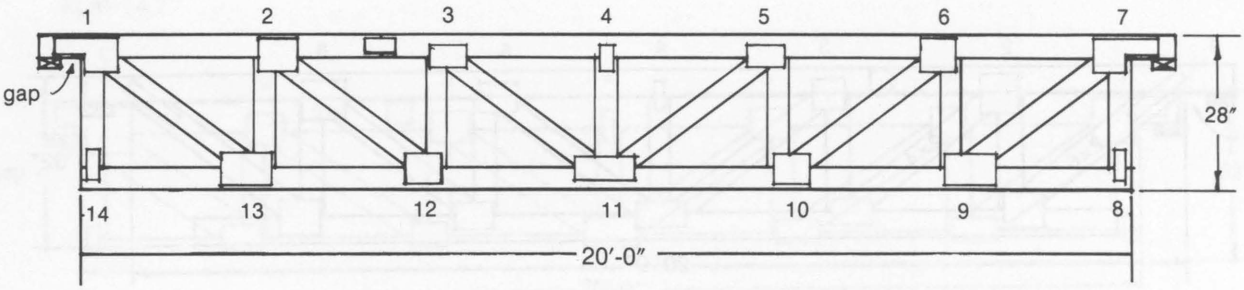


XXV - 1″ gap
- 1 = 1250 plf. — plates failed in tension @ jt. 1, precipitated by eccentric moment causing tension on outside edge of plates.
- 2 = 1200 plf. — plates failed in tension @ jt. 7, precipitated by eccentric moment causing tension on outside edge of plates.
- 3 = 1200 plf. — plates failed in tension @ jt. 7, precipitated by eccentric moment causing tension on outside edge of plates.

XXVI - 2½″ gap
- 1 = 1000 plf. — plates failed in tension @ jt. 7, precipitated by eccentric moment causing tension on outside edge of plates.
- 2 = 1000 plf. — plate peel and withdrawal @ jt. 7, and web tension failure.
- 3 = 1000 plf. — plates failed in tension @ jt. 1, precipitated by eccentric moment causing tension on outside edge of plates.

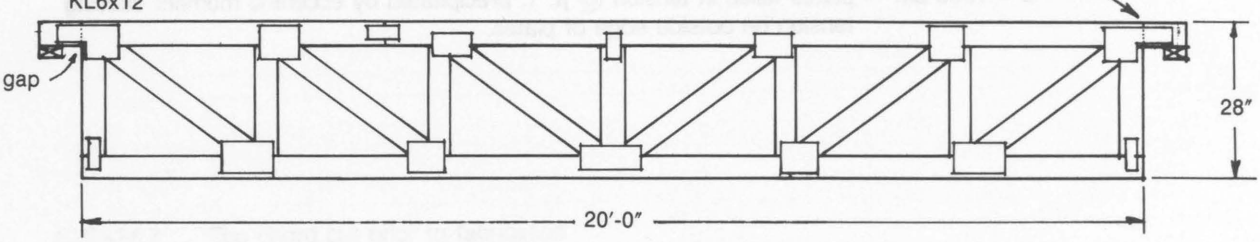
design load = 250 plf.   2½x design load = 625plf.
2x4, S.P.F., MSR—2100f, 1.8E
15% adjustment

KL6x12



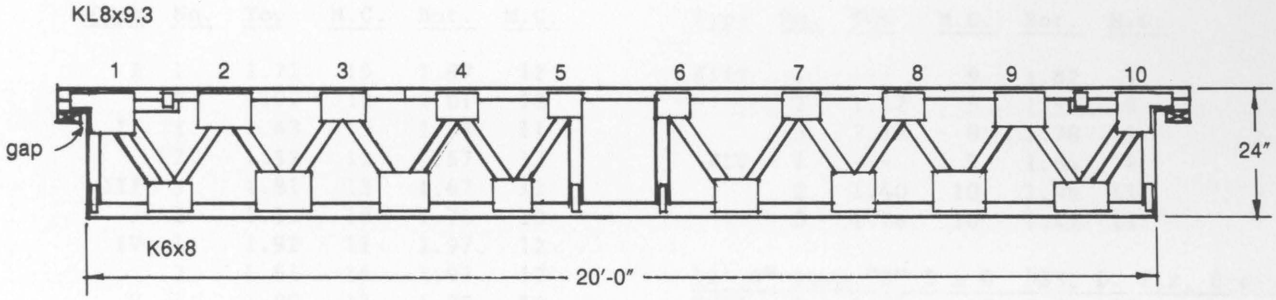
XXVII - ½″ gap
- 1 = 850 plf. — plate peel and withdrawal from diagonal tension web @ jt. 13.
- 2 = 750 plf. — plate and t.c. failure in tension due to bending @ jt. 7.
- 3 = 800 plf. — plate peel and withdrawal from diagonal tension web @ jt. 12.

KL6x12



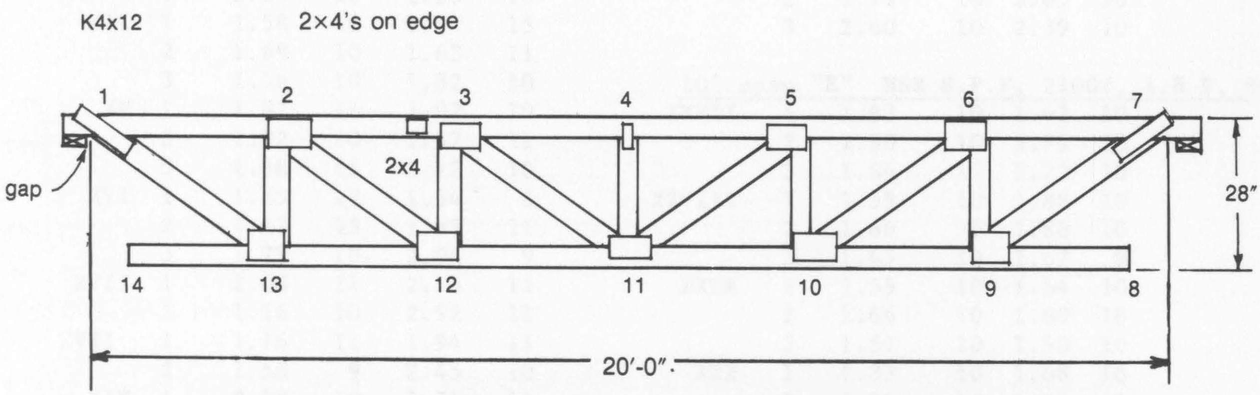
XXVIII - ½″ gap
- 1 = 600 plf. — top plate peeled and back plate sheared vertically @ jt. 7.
- 2 = 600 plf. — plate peel and withdrawal from t.c. @ jt. 7.
- 3 = 550 plf. — vertical shear of plates @ jt. 7.

design load = 250 plf. 2½x design load = 625plf.
4x2, S.P.F., MSR—2100f, 1.8E
15% adjustment

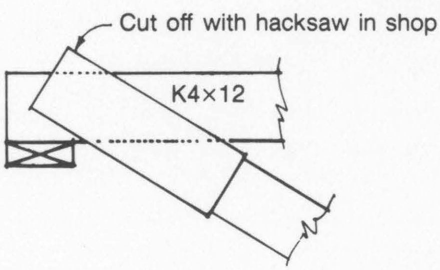


XXX - 1" gap
- 1 = 700 plf. — plate peel and withdrawal from t.c. @ jt. 1. Plate tore wood from lower t.c.
- 2 = 650 plf. — plate peel and withdrawal from t.c. @ jt. 10. Plate tore wood from lower t.c.
- 3 = 700 plf. — horizontal shear of plates @ jt. 10. Precipitated by eccentric moment causing tension at radius of plates.

design load= 250 plf 2½×design load= 625plf
2×4 S/P.F. MSR, 2100f, 1.8E
15% adjustment



XXIX - ½" gap
- 1 = 750 plf. — plate peel and withdrawal from diagonal tension web @ jt. 13.
- 2 = 650 plf. — plate peel and withdrawal from diagonal tension web @ jt. 9.
- 3 = 500 plf. — t.c. failure in tension due to bending at knot location @ jt. 7.



APPENDIX B

"E" DATA AND MOISTURE CONTENT OF LUMBER (@ TIME OF TRUSS TESTS)

10' span "E" #1 DN, KD, SYP

Type	No.	Top	M.C.	Bot.	M.C.
I	1	1.72	15	1.87	12
	2	1.97	12	2.01	12
II	1	1.43	13	1.33	11
	2	1.52	12	1.67	11
III	1	1.81	13	1.67	11
	2	1.52	13	1.73	10
IV	1	1.92	11	1.97	12
	2	1.61	16	1.97	12
V	1	1.90	11	1.85	12
	2	1,87	13	1.72	12
VI	1	1.30	12	1.67	13
	2	1.40	12	1.75	12
VII	1	1.33	16	2.04	11
	2	1.70	14	1.90	13
VII	1	1.82	9	1.79	11
IX	1	2.25	9	2.38	14
X	1	0.98	9	1.77	13
	2	1.58	9	1.77	10
	3	1.70	10	1.39	12
XI	1	1.55	9	1.98	12
	2	1.82	10	1.43	9
	3	2.01	10	1.33	10
XII	1	1.58	10	1.57	15
	2	1.69	10	1.63	11
	3	1.56	10	1.82	10
XV	1	1.81	11	1.97	10
	2	1.92	10	1.57	11
	3	1.68	11	2.12	10
XVI	1	1.85	12	1.64	8
	2	1.67	13	1.87	11
	3	1.79	13	2.04	9
XVII	1	2.08	11	2.16	11
	2	1.16	10	2.52	11
XVII	1	1.76	11	1.94	11
	2	1.58	9	2.45	10
XIX	1	2.38	10	1.71	11
XX	1	2.01	10	1.80	11
XXI	1	1.58	17	1.49	18
	2	1.80	17	1.37	14
	3	2.17	14	2.76	20

12'-6" span "E" 2 x 6 #1 KD, SYP

Type	No.	Top	M.C.	Bot.	M.C.
XIII	1	---	9	1.82	9
	2	1.62	9	1.99	9
	3	2.17	9	1.78	9
XIV	1	---	9	1.84	9
	2	1.40	10	1.46	11
	3	1.76	10	1.47	11

12' 6" span "E" 2 x 6 DSS, D. fir, S-dry

Type	No.	Top	M.C.	Bot.	M.C.
XXII	1	1.61	10	2.34	10
	2	1.54	10	2.67	10
	3	1.84	10	2.06	10
XXIII	1	1.76	10	2.10	10
	2	1.88	10	2.97	10
	3	1.78	10	1.93	10
XXIV	1	2.12	10	2.03	10
	2	1.80	10	2.15	10
	3	1.98	10	2.23	10
XXV	1	2.63	10	1.97	10
	2	1.92	10	2.29	10
	3	2.21	10	2.15	10
XXVI	1	2.01	10	2.01	10
	2	2.11	10	2.63	10
	3	2.60	10	2.39	10

10' span "E" MSR S.P.F, 2100f, 1.8 E, S-dry

Type	No.	Top	M.C.	Bot.	M.C.
XXVII	1	1.83	10	1.63	10
	2	2.50	10	1.71	10
	3	1.64	10	1.73	10
XXVIII	1	1.99	10	1.88	10
	2	1.68	9	1.88	10
	3	1.45	10	1.67	9
XXIX	1	1.55	10	1.54	10
	2	1.66	10	1.80	10
	3	1.57	10	1.50	10
XXX	1	1.83	10	1.68	10
	2	1.56	10	1.66	10
	3	1.82	10	1.85	10

TABLE 1

Summary of Test Results - Phase I
Lumbermate T.C.B. - PCT.

Clear Span: 20'-0" **Depth:** 24" (4x2)
28" (2x4)
36" (2x6)

Lumber
Chords: SYP, No. 1, Dn, KD
Webs: SYP, No. 2, KD
SYP, No. 1, KD (1st diagonal webs)
Webs, No. 2 KD, SYP (2x4)

Design Loads: 2x4, 4x2 = 250 plf.
2x6 = 400 plf.

				Failure Loads				
Truss Type	No.	Lumber Orientation	Extension Gap (in.)	plf.	Reaction lbs.	Heel Plates	℄ Deflection @ full design load (in.)	Failure Type, Location (Joint locations are shown on truss drawings)
I	1	2x4	1/2"	400	4000	K6x8	.75	horizontal shear in t.c. @ Jt. 1
	2	2x4	1/2"	450	4500	K6x8	.59	horizontal shear in t.c. @ Jt. 7
II	1	2x4	1 1/2"	350	3500	K6x8	.83	horizontal shear in t.c. @ Jt. 1
	2	2x4	1 1/2"	350	3500	K6x8	.74	horizontal shear in t.c. @ Jt. 1
III	1	2x4	2"	500	5000	KL6x10.7	.75	plate and t.c. failure @ Jt. 7
	2	2x4	2"	450	4500	KL6x10.7	.72	plate peel from tension web @ Jt. 1
IV	1	2x4	1/2"	550	5500	KL6x10.7	.61	plate failure @ t.c. splice due to point load of cylinder.
	2	2x4	1/2"	600	6000	KL6x10.7	.64	plate failure and shear in t.c. @ Jt. 1.
V	1	4x2	1/2"	100	2000	K7x5	--(1)	plate peel from t.c. @ Jt. 10
	2	4x2	1/2"	150	1500	K7x5	--(1)	plate peel from t.c. @ Jt. 1
VI	1	Dbl. 4x2	1"	350	3500	K7x5	.90	plate peel from t.c. @ Jt. 1. Teeth tore wood from lower t.c.
	2	Dbl. 4x2	1"	310	3100	K7x5	.90	plate peel from t.c. @ Jt. 1. Teeth tore wood from lower t.c.
VII	1	2x4	1"	400	4000	K3x10.7	.86	horizontal shear in t.c. @ Jt. 1.
	2	2x4	1"	500	5000	K3x10.7	.64	plates failed in shear @ Jt. 7 (started peeling @ 450 plf.)
VIII (same type as I)	1	2x4	1/2"	450	4500	K6x8	.64	horizontal shear in t.c. @ Jt. 7
IX	1	2x4	1/2"	475	4750	KL6x12	.64	vertical shear of plates @ Jt. 1
X	1	2x4	1/2"	420	4200	KL6x12	.79	tension failure in web @ Jt. 7
	2	2x4	1/2"	600	6000	KL6x12	.68	wood sheared in tension web @ Jt. 7
	3	2x4	1/2"	600	6000	KL6x12	.75	tension failure in web @ Jt. 7
XI	1	2x4	1/2"	550	5500	K3x12	.74	plates failed in tension @ Jt. 1
	2	2x4	1/2"	500	5000	K3x12	.83	plates failed in tension @ Jt. 7
	3	2x4	1/2"	550	5500	K3x12	.72	plates failed in tension @ Jt. 1
XII	1	2x4	1/2"	500	5000	KL6x12-45°	.81	tooth withdrawal from tension web @ Jt. 12
	2	2x4	1/2"	600	6000	KL6x12-45°	.72	tooth withdrawal from tension web @ Jt. 7
	3	2x4	1/2"	250	2500	KL6x12-45°	.74	tension web failure @ severe slope of grain @ Jt. 1
XIII	1	2x6	1/2"	1200	12000	K5x13.3	.57	tooth withdrawal from diagonal web @ Jt. 8
	2	2x6	1/2"	800	8000	K5x13.3	.73	tooth withdrawal from diagonal web @ Jt. 12
	3	2x6	1/2"	1050	10500	K5x13.3	.61	tooth withdrawal from diagonal web @ Jt. 12
XIV	1	2x6	1/2"	1050	10500	KL8x12-45°	.52	tension web failure under plate @ Jt. 8
	2	2x6	1/2"	1200	12000	KL8x12-45°	.83	plate failed in shear @ Jt. 1
	3	2x6	1/2"	1100	11000	KL8x12-45°	.65	plate and t.c. shear failure @ Jt. 1
XV	1	Dbl. 4x2	1"	350	3500	K8x5	.99	plate peel from t.c. @ Jt. 10
	2	Dbl. 4x2	1"	350	3500	K8x5	.93	plate peel from t.c. @ Jt. 10
	3	Dbl. 4x2	1"	350	3500	K8x5	1.04	plate peel from t.c. @ Jt. 1, teeth tore wood from lower t.c.
XVI	1	Dbl. 4x2	1"	450	4500	KL8x8	.86	t.c. failed in bending @ large knot between Jt. 7 & Jt. 8
	2	Dbl. 4x2	1"	500	5000	KL8x8	.74	plates failed in shear and tension @ Jt. 10
	3	Dbl. 4x2	1"	500	5000	KL8x8	.81	t.c. failed in bending between Jt. 3 & Jt. 4
XVII	1	4x2	1/2"	200	2000	K8x5	--(1)	plate peel from t.c. @ Jt. 1. Teeth tore wood from t.c.
	2	4x2	1/2"	200	2000	K8x5	--(1)	plate peel from t.c. @ Jt. 10. Teeth tore wood from t.c.
XVIII	1	4x2	1/2"	300	3000	KL6x8	--(1)	(scabed on plywood @ Jt. 19 @ 250 plf. plate peel) plate tear @ radius then peel from t.c. @ Jt. 10
	2	4x2	1/2"	350	3500	KL6x8	.83	plate tear @ radius, then peel from t.c. @ Jt. 10
XIX	1	4x2	---	450	4500	K5x8	.72	plate failed in shear @ Jt. 20
XX	1	4x2	---	450	4500	K5x7	.76	plate peel and withdrawal due to shear @ Jt. 20
XXI	1	dbl. 4x2	1"	500	5000	K3x12	.65	plate peel from t.c. @ Jt. 1, due to horizontal shear of both t.c.'s.
	2	4x2	1"	500	5000	K3x12	.66	plate peel from t.c. @ Jt. 1, due to horizontal shear of both t.c.'s.
	3	4x2	1"	525	5250	K3x12	.78	top plate withdrawal from t.c., bottom plate-shear & tension @ Jt.10

(1) = Failure occurred prior to reaching design load.

TABLE 2

SUMMARY OF TEST RESULTS-PHASE II (2x6)
LUMBERMATE, TCB-PCT

Clear span: 20'-0", Depth: 32", Design Load: 400 plf., 2 1/2 DL = 1000 plf.

Lumber: chords - 2x6, D.fir, Sel. Struc. Dense, S-Dry; Heel webs: 2x6, D. fir, Sel. St. Dn, S-Dry
Webs - 2x4, D. fir, Sel. Struc., S-Dry

TRUSS		FAILURE LOADS					
TYPE	NO.	EXTENSION GAP (IN.)	PLF.	REACTION	HEEL PLATES	℄ DEFLECTION @ FULL DESIGN LOAD (IN.)	FAILURE TYPE, LOCATION (JOINT LOCATIONS ARE SHOWN ON TRUSS DRAWINGS)
XXII	1	1"	1100	11000	KL8x14.7	.41	plate and t.c. failure in tension due to bending @ Jt. 1
	2	1"	1200	12000	KL8x14.7	.42	plate and t.c. failure in tension due to bending @ Jt. 1
	3	1"	950	9500	KL8x14.7	.37	plate and t.c. failure in tension due to bending @ Jt. 1
XXIII	1	2 1/2"	900	9000	KL8x14.7	.43	plate and t.c. failure in tension due to bending @ Jt. 1
	2	2 1/2"	950	9500	KL8x14.7	.44	plate and t.c. failure in tension due to bending @ Jt. 1, chord split vertically @ ring shake in lumber.
	3	2 1/2"	900	9000	KL8x14.7	.45	plate and t.c. failure in tension due to bending @ Jt. 1
XXIV	1	1"	700	7000	KL8x14.7	.42	vertical shear of plates @ Jt. 1 } Top chords cut @ heel prior to fabrication
	2	1"	850	8500	KL8x14.7	.38	vertical shear of plates @ Jt. 7
	3	1"	850	8500	KL8x14.7	.41	vertical shear of plates @ Jt. 7
XXV	1	1"	1250	12500	K5x14.7	.40	Jt. 1 } Plates failed in tension, precipitated by eccentric moment causing tension on outside edge of plates.
	2	1"	1200	12000	K5x14.7	.38	Jt. 7
	3	1"	1200	12000	K5x14.7	.32	Jt. 7
XXVI	1	2 1/2"	1000	10000	K5x14.7	.42	plates failed in tension @ Jt.7, precipitated by eccentric moment causing tension on outside edge of plates.
	2	2 1/2"	1000	10000	K5x14.7	.41	plate peel and withdrawal @ Jt. 7, and web tension failure.
	3	2 1/2"	1000	10000	K5x14.7	.42	plates failed in tension @ Jt. 1, precipitated by eccentric moment causing tension on outside edge of plates.(plates cut off in shop)

TABLE 3

SUMMARY OF TEST RESULTS - PHASE II - (4x2, 2x4)
LUMBERMATE, TCB - PCT

Clear span: 20' 0", Depth: 28" - 2x4 Design load: 250 plf. 2 1/2 x D.L. = plf.
24" - 4x2
Lumber: chord & webs - S.P.F., MSR - 2100f - 1.8E, S-Dry

TRUSS		FAILURE LOADS					
TYPE	NO.	EXTENSION GAP (IN.)	PLF.	REACTION	HEEL PLATES	℄ DEFLECTION @FULL DESIGN LOAD (IN.)	FAILURE TYPE, LOCATION (JOINT LOCATIONS ARE SHOWN ON TRUSS DRAWINGS)
XXVII	1	1/2"	850	8500	KL6x12	.55	plate peel and withdrawal from diagonal tension web @ Jt. 13
	2	1/2"	750	7500	KL6x12	.60	plate peel and t.c. failure in tension due to bending @ Jt. 7
	3	1/2"	800	8000	KL6x12	.56	plate peel and withdrawal from diagonal tension web @ Jt. 12
XXVIII	1	1/2"	600	6000	KL6x12	.60	top plate peeled & back plate sheared vertically @ Jt. 7
	2	1/2"	600	6000	KL6x12	.60	plate peel and withdrawal from t.c. @ Jt. 7
	3	1/2"	550	5500	KL6x12	.63	vertical shear of plates @ Jt. 7 (For this group, all top chords cut @ heel prior to fabrication)
XXIX	1	1/2"	750	7500	K4x12	.60	plate peel & withdrawal from diagonal tension web @
	2	1/2"	650	6500	K4x12	.63	plate peel & withdrawal from diagonal tension web @ Jt.9
	3	1/2"	500	5000	K4x12	.63	t.c. failure in tension due to bending @ knot location @ Jt. 7
XXX	1	1"	700	7000	KL8x9.3	.60	plate peel and withdrawal from t.c. @ Jt. 1. Plates tore wood from lower t.c.
	2	1"	650	6500	KL8x9.3	.65	plate peel and withdrawal from t.c. @ Jt. 10. Plates tore wood from lower t.c.
	3	1"	700	7000	KL8X9.3	.59	horizontal shear of plates @ Jt. 10, precipitated by eccentric moment causing tension at radius of plates.

APPENDIX C

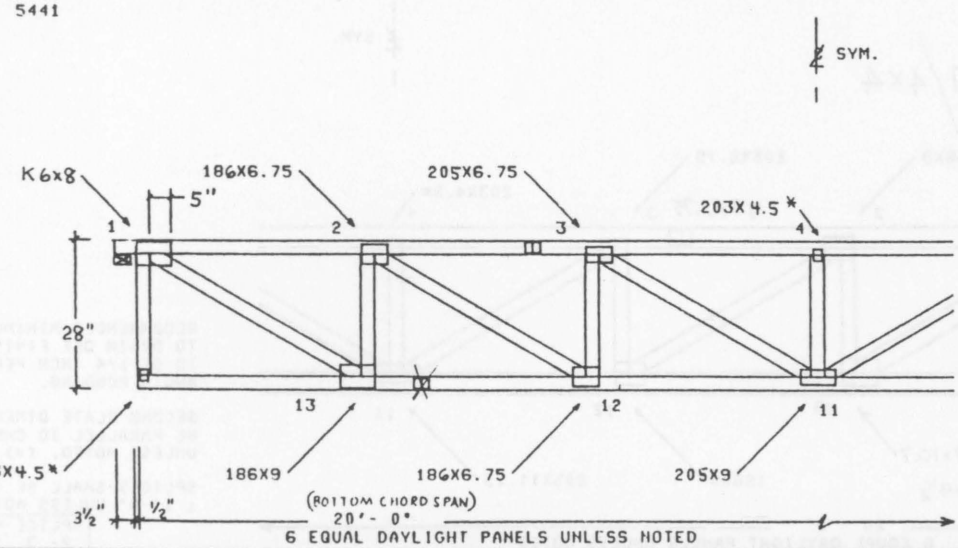
TEST #8 20'- 0" SPAN 28.00 OAH ENGR MD CHK FEB 2, 1983
FLAT,HOWE WEBS,ALL DIAGONALS IN TENSION CODE TPI 78

TOP CHORD LIVE LOAD	250.0 PLF	TOP CHORD	2X4	SOU PINE #1 DN KD 15
TOP CHORD DEAD LOAD	.0 PLF	BOT CHORD	2X4	SOU PINE #1 DN KD 15
BOT CHORD DEAD LOAD	.0 PLF	WEBS	2X4	SOU PINE #2 KD 15
TOTAL UNIFORM LOAD	250.0 PLF	1-13	2X4	SOU PINE #1 KD 15
LOAD DURATION ADJUSTMENT	15%			

REACTION AT 14 - 2500 MIN BRG- 3.50 IN

MEMBER	FORCE	MEMBER	FORCE	MEMBER	FORCE
1- 2	-3401	1-14	0	1-13	3988
2- 3	-5441	2-13	-2083	2-12	2393
3- 4	-6121	3-12	-1250	3-11	798
14-13	0	4-11	-833		
13-12	3401				
12-11	5441				

LM PLATE SERIES:
680 20GA 200 PSI NET
680 18GA 240 PSI NET
680 16GA 195 PSI NET



6 EQUAL DAYLIGHT PANELS UNLESS NOTED

RECOMMENDED MINIMUM SLOPE TO DRAIN OFF FINISHED ROOF TO BE 1/4 INCH PER FOOT TO AVOID PONDING.

SECOND PLATE DIMENSION TO BE PARALLEL TO CHORDS UNLESS NOTED.

SPLICES SHALL BE 1/4 PANEL ± 1'-0" UNLESS NOTED.

SPLICE PLATES	
2- 3	183X6.75
13-12	K3 X9.3

LUMBERMATE COMPANY
SAINT LOUIS, MISSOURI

THIS DESIGN SUGGESTION IS INTENDED FOR USE BY THE BUILDING ARCHITECT AND ENGINEER IN PREPARATION OF THEIR FINAL DESIGNS. NO RESPONSIBILITY IS ASSUMED FOR THE ERECTION,BRACING, AND ASSEMBLY TO THE COMPLETE STRUCTURE. DESIGN BASED ON CRITERIA ESTABLISHED BY THE TRUSS PLATE INSTITUTE AND "NDS" BY THE NATIONAL FOREST PRODUCTS ASSOCIATION. CUT MEMBERS TO BEAR. LATERALLY SUPPORT CHORDS. LUMBERMATE TRUSS PLATES OF GALVANIZED STEEL ARE INDICATED BY GAGE AND SIZE. PRESS PLATES SECURELY ON BOTH SIDES OF JOINTS. CENTER PLATES ON JOINTS UNLESS NOTED.

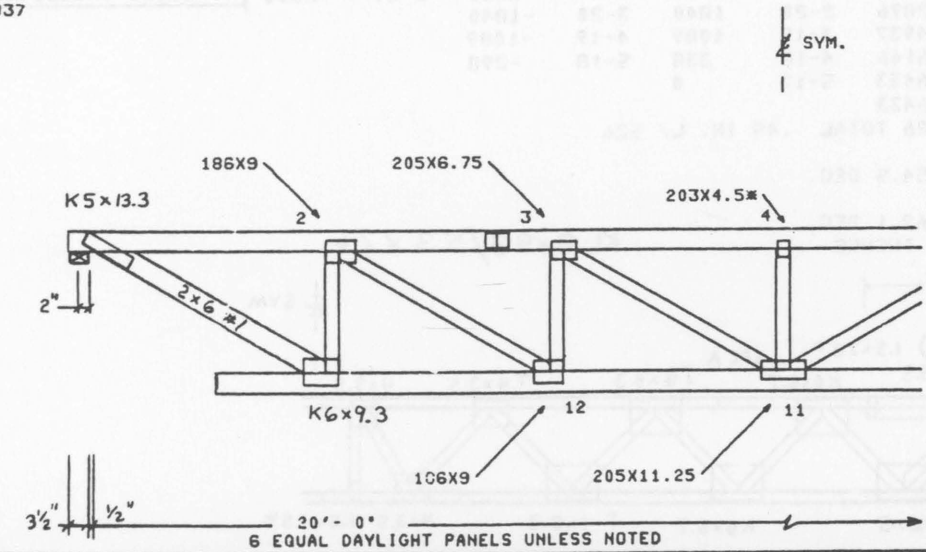
TEST 13 20'- 0" SPAN 32.00 OAH ENGR CHK APR 14, 1983
A-01 FLAT,HOWE WEBS,ALL DIAGONALS IN TENSION CODE TPI 78

TOP CHORD LIVE LOAD	400.0 PLF	TOP CHORD	2X6	SOU PINE #1 KD 15
TOP CHORD DEAD LOAD	.0 PLF	BOT CHORD	2X6	SOU PINE #1 KD 15
BOT CHORD DEAD LOAD	.0 PLF	WEBS	2X4	SOU PINE #2 KD 15
TOTAL UNIFORM LOAD	400.0 PLF		2x6	SOU PINE #1 KD 15
LOAD DURATION ADJUSTMENT	15%			

REACTION AT 14 - 3997 MIN BRG- 4.72 IN

MEMBER	FORCE	MEMBER	FORCE	MEMBER	FORCE
1- 2	-5023			1-13	6027
2- 3	-8037	2-13	-3331	2-12	3616
3- 4	-9042	3-12	-1998	3-11	1205
14-13	0	4-11	-1332		
13-12	5023				
12-11	8037				

LM PLATE SERIES:
680 20GA 200 PSI NET
680 18GA 240 PSI NET
680 16GA 195 PSI NET



6 EQUAL DAYLIGHT PANELS UNLESS NOTED

RECOMMENDED MINIMUM SLOPE TO DRAIN OFF FINISHED ROOF TO BE 1/4 INCH PER FOOT TO AVOID PONDING.

SECOND PLATE DIMENSION TO BE PARALLEL TO CHORDS UNLESS NOTED. (*)

SPLICES SHALL BE 1/4 PANEL ± 1'-0" UNLESS NOTED.

SPLICE PLATES	
2- 3	185X6.75

LUMBERMATE COMPANY
SAINT LOUIS, MISSOURI

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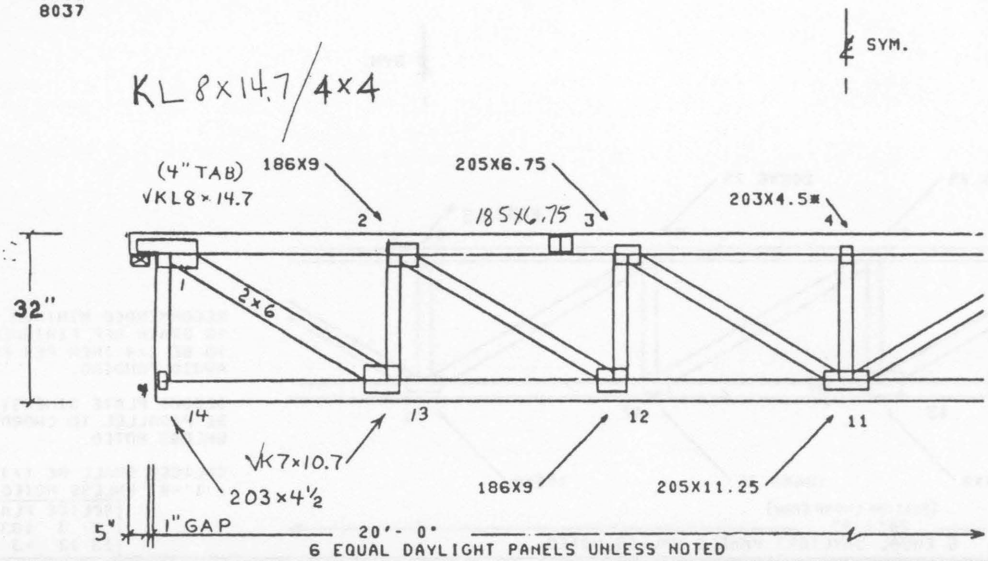
TEST 22 20'- 0" SPAN 32.00 OAH ENGR CHK AUG 24, 1983
A-01 FLAT,HOWE WEBS,ALL DIAGONALS IN TENSION CODE TPI 78

TOP CHORD LIVE LOAD	400.0 PLF	TOP CHORD 2X6	DOUG FIR SEL STR
TOP CHORD DEAD LOAD	.0 PLF	BOT CHORD 2X6	DOUG FIR SEL STR
BOT CHORD DEAD LOAD	.0 PLF	WEBS 2X4	DOUG FIR SEL STR
TOTAL UNIFORM LOAD	400.0 PLF	END DIAG 2X6	DOUG FIR SEL STR
LOAD DURATION ADJUSTMENT	15%		

REACTION AT 14 = 3997 MIN BRG= 4.72 IN

MEMBER	FORCE	MEMBER	FORCE	MEMBER	FORCE
1- 2	-5023	1-14	0	1-13	6027
2- 3	-8037	2-13	-3331	2-12	3616
3- 4	-9042	3-12	-1998	3-11	1205
14-13	0	4-11	-1332		
13-12	5023				
12-11	8037				

LM PLATE SERIES:
680 20GA 200 PSI NET
680 18GA 240 PSI NET
680 16GA 195 PSI NET



RECOMMENDED MINIMUM SLOPE TO DRAIN OFF FINISHED ROOF TO BE 1/4 INCH PER FOOT TO AVOID PONDING.

SECOND PLATE DIMENSION TO BE PARALLEL TO CHORDS UNLESS NOTED. (*)

SPLICES SHALL BE 1/4 PANEL ± 1'-0" UNLESS NOTED.

SPLICE PLATES	
2- 3	185X6.75

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TEST 30 LOW JOIST 20'- 0'' SPAN 24'' O.A.H. AUG 24, 1983
DES. BY: JMD CHK. BY: CODE TPI 78

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SAINT LOUIS MISSOURI

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DESIGN BASED ON CRITERIA ESTABLISHED BY THE TRUSS PLATE INSTITUTE AND "NDS" BY THE NATIONAL FOREST PRODUCTS ASSOCIATION

CUT MEMBERS TO BEAR. LATERALLY SUPPORT CHORDS

LUMBERMATE TRUSS PLATES OF GALVANIZED STEEL ARE INDICATED BY GAGE AND SIZE. PRESS PLATES SECURELY ON BOTH SIDES OF JOINTS. CENTER PLATES ON JOINTS UNLESS NOTED

LOW JOIST PLATE SIZE SECOND DIMENSION IS PARALLEL TO CHORD UNLESS NOTED BY *

TOP CHORD LIVE LOAD	250.0 PLF	TOP CHORD 4X2	SPR P.F. MSR 2100F-1.8E
TOP CHORD DEAD LOAD	.0 PLF	BOT CHORD 4X2	SPR P.F. MSR 2100F-1.8E
BOT CHORD DEAD LOAD	.0 PLF	WEBS 4X2	SPR P.F. MSR 2100F-1.8E
TOTAL UNIFORM LOAD	250.0 PLF		
LOAD DURATION ADJUSTMENT	0%		

REACTION= 2500# MIN. BRG= 3.50 IN PLATES: SERIES T 20GA 230 GROSS

MEMBER	FORCE	MEMBER	FORCE	MEMBER	FORCE	MEMBER	FORCE	MEMBER	FORCE
1- 2	-1448	22-21	0	1-22	0	1-21	2610	2-21	-2610
2- 3	-3917	21-20	2096	2-20	1840	3-20	-1840		
3- 4	-5542	20-19	4937	3-19	1089	4-19	-1089		
4- 5	-6333	19-18	6146	4-18	338	5-18	-298		
5- 6	-6433	18-17	6433	5-17	0				
		17-16	6433						

DEFL-LIVE .45 IN. L/ 526 TOTAL .45 IN. L/ 526
STD PANEL DIM= 30.00 IN.
14 STD WEBS= 25.81 IN. 54.5 DEG.
SPC PANEL DIM= 8.06 IN.
2 SPC WEBS= 32.47 IN. 69.1 DEG.
CHASE DAYLITE DIM= 8.00 INCHES