Destructive Testing of Stressed Skin Panels

Forestry Department
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DISCLAIMER

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Summary

A stressed skin panel is an engineered, pre-built component consisting of a frame of dimensional lumber, to which top and bottom flanges of plywood or other panel material are structurally glued. Stressed skin panels may be used as floor, wall or roof components in buildings—they allow, for example, for much ,larger spans than regular flat plywood or OSB in traditional floor and roof construction.

Twenty-four full scale stressed skin panels were designed, constructed and tested: six with flanges of Douglas fir plywood, six with flanges of Alberta spruce and twelve with flanges of oriented strandboard. The panels were short-term tested to destruction to verify that established engineering design theories hold for stressed skin panels made with OSB and spruce plywood flange. Half of the panels were short-term tested to destruction after sustained loading for 1000 days with a uniform distributed load equivalent of 2 kN/m^2 (~40 lbs/ft^2).

From this study, it can be concluded that the current structural design theory for Douglas fir plywood faced stressed skin panels also works for panels with flanges of Alberta spruce plywood and oriented strandboard. The average ultimate short-term flexural strength of panels with flanges of oriented strandboard and spruce plywood was 85% of that of panels with flanges of Douglas fir plywood, where panels were of identical design. Duration of load for 1000 days with 2 kN/m^2 for 1000 days appears to do no significant damage to the short-term stiffness and strength of stressed skin panels faced with OSB or plywood.

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1. OBJECTIVES

According to the contractual agreement with the client;

"The objective of this project is to determine the residual bending properties of stress-skin-panels after 1000 days load duration. The work under this project includes the following:

a) static bending test to failure of each stress-skin-panel,

b) from each test the following properties shall be determined;

- modulus of rupture,
- modulus of elasticity,
- stress at proportional limit, and
- work to maximum load. and

c) the bending results shall be related to the time dependent behaviour of the stress-skin-panels.

2. INTRODUCTION

2.1 Background

Stressed skin wood panels often consist of a frame or web, constructed of solid lumber, to which top and bottom skins, of plywood or other panel materials, are structurally glued. A schematic diagram of a stressed skin panel is shown in Figure 1. There are stressed skin panels without bottom skins or with flanges in place of the bottom skin, but those particular designs are not considered in this study.

The use of oriented strandboard (OSB) has become increasingly acceptable for structural purposes. However, its application in stressed skin panels (SSPs) has not been fully developed due to the lack of experimental data on the short- and long-term behaviour of SSPs with OSB skin.

For purposes of design calculation, it can be assumed that the stressed skin panel will behave like a composite beam. In calculating section properties for the stressed skin panel, the designer must take into account the fact that not all materials will have similar moduli of elasticity. These may be reconciled by the use of a transformed section which is a section of uniform modulus of elasticity.

Both the Council of Forest Industries of B.C. (COFI - 1976) and the American Plywood Association (APA - 1987) have published standard guidelines for engineering design of SSPs with plywood. However, there are no provisions for

SSPs with OSB.

OSB has a perpendicular core layer sandwiched between two outer layers which have a "parallel-to-grain" orientation, but the contribution of the middle ply to the stiffness of the stressed skin panel is assumed negligible.

The long-term stiffness of stressed skin panels is not addressed in current design codes. From the experiments conducted by the authors (1988), Alberta Research Council (1987 and 1988), and Kliger (1986), the results indicated time-dependent deflections were between 50 to 70% of the elastic deflections under normal service loading.

2.2 Design of Stress Skin Panel

To ensure maximum stiffness of stressed skin panels, flanges must be rigidly glued to the web. Then the whole panel assembly will behave as a composite unit, with direct transfer of forces between flanges and web; the flanges taking most of the bending stress and the web shear stresses.

Where flanges are made of plywood, joints should be "scarfed" or "tongued-and-grooved" glued, and supplemented with splice plates. Panels of oriented strandboard can be made to be the exact length of the stringers so that no joints are required.

For purposes of design calculation, it can be assumed that stressed skin panels will behave like a composite beam. General flexural formulations can be applied to design the cross-section. In calculating section properties for stressed skin panels, the designer must take into account the fact that not all material will have a similar moduli of elasticity. These may be reconciled by the use of a transformed section, which is a section of uniform modulus of elasticity. Sections should be designed in such a way that each material is not stressed beyond the safety limits stipulated in the appropriate design codes. For bending, deflection and rolling shear, the panel is "normalized" to the material of the flanges; for horizontal shear, to a material with the properties of the web.

Stressed skin panels are designed by the "trial and error" method. A trial section is assumed and then checked for its ability to do the job intended; if the section does not meet the design criteria, it is modified and the process repeated. The design criteria include deflection, bending stress on the bottom flange, bending stress on the top flange, bending stress on the tension splices, rolling shear and horizontal shear. In-plane buckling and shear lag are beyond the scope of this study.

Owing to the structural efficiency possible with stressed skin panels, whereby relatively shallow panels prove adequate for strength, the design is likely to be controlled by the allowable deflection. The first aspect of the assumed section to be checked, therefore, will be deflection. Moment will be checked next, and shear last—since it is least likely to govern.

It is normal for calculations to indicate that the bottom flange, which will be under tension, may be thinner than the top flange. This is due to the fact that the top, or compression, flange carries the imposed load.

2.3 Scope of Study

The scope was to conduct short-term tests to destruction according to ASTM E72-80 of full sized stress skin panels faced with OSB and plywood (D. fir and CSP).

Tests were to be carried out on 12 panels that had just been manufactured in addition to short-term testing to destruction of 12 panels after 1000 days of prior sustained loading; the objective being to see if the sustained loading had any damaging effect to short-term stiffness and strength.

3. METHODS AND MATERIALS

3.1 Design Assumptions

Normally, stressed skin panels are designed to carry a uniformly distributed live load, which in this case would be 1.9 kPa (40 p.s.f.). However, because the testing set up calls for third point loading, the panel design was modified so that it would sustain a minimum of 4350 N of line loads (this is equivalent to a uniformly distributed load of 2.0 kPa) as shown in Figure 6.

The ratio between the live load deflection and the beam span is limited to (length/360).

The deflection criteria govern the design for SSPs shown in Figures 2 and 3, regardless of the material used for the flange. It was, therefore, not necessary to modify the design to accommodate bending moment or shear stresses.

A sample set of design calculations for a stressed skin panel using oriented strandboard as flange material is given in Appendix A.

3.2 Materials

Twenty-four stressed skin panels were fabricated for the short- and long-term experiments (12 specimens each). Each stressed skin panel had overall dimensions of 165 mm thick x 1220 mm wide x 4880 mm long. Table 1 gives the skin thicknesses for stressed skin panels tested.

Table 1. Short- and long-term test specimens.

Flange Material	Quantity	Top Flange(mm)	Bottom Flange(mm)
OSB	6 + 6	15.5 thick	9.5 thick
D. fir	3 + 3	15.5 thick	9.5 thick
Spruce	3 + 3	15.5 thick	9.5 thick

The OSB flanges were manufactured according to the plan dimensions given above. However, plywood flanges had to be spliced together because the plywood only came in 2440 mm lengths.

The webs of all the stressed skin panels were made of 38 mm wide x 140 mm spruce-pine-fir, No. 2 or better, sawn lumber, spaced at 394 mm o.c.. The webs were bonded to the flange (skin) with resorcinol resin. Nails were used to maintain the pressure on the resin while the resin was cured under ambient conditions.

3.3 Fabrication of Stressed Skin Panels

Twenty-four (24) stressed skin panels were constructed at Western Archrib from materials purchased at lumber yards in Edmonton. The webs of all twenty-four panels were identical in terms of material and design. Only the flanges differed—six of the stressed skin panels had flanges of Douglas fir, which originated in British Columbia; six had flanges of Alberta spruce plywood, and twelve had flanges of OSB, which is also an Alberta product.

The stressed skin panels were assembled according to the standards of the American Plywood Association and the construction diagrams in Figure 2 and Figure 3 with the following dimensions:

* overall length: 4880 mm
* overall width: 1220 mm
* top flange thickness: 15.5 mm
* bottom flange thickness: 9.5 mm
* web constructed from 38 mm x 140 mm (2" x 6") lumber

The plywood joints were tongued and grooved, glued and supported with splice plates. The oriented strandboards were manufactured specifically to match the overall dimensions of the stressed skin panels; therefore, no jointing in the flange was required.

All pieces of lumber and all panels were machine stress rated to determine moduli of elasticity. These values were used to calculate the overall stiffness of the panels as set out in Table 2.

Table 2. Modulus of elasticity data.

Flange Material	Modulus of Elasticity, MPa			EI Calculated N-mm²/1220 mm
	Top Flange	Bottom Flange	Web	
Douglas fir Plywood	16582	15126	11665	155×10^9
Spruce Plywood	16371	13401	11665	128×10^9
Oriented Strandboard	9486	9754	11665	1414×10^9

Any pieces of lumber with a moisture content over 15% were rejected.

Resorcinol resin adhesive was used to glue the flanges to the webs. As there was not a press large enough to handle the stressed skin panels, the flanges were nailed tightly to the webs to allow sufficient time for a solid bond to form.

Blocking was provided at the points where concentrated loads were to be applied.

3.4 Test Methods

Testing for the short-term was conducted according to ASTM E72-80: "Standard Methods of Conducting Strength Tests of Panels for Building Construction". The load test set up is shown in Figure 4. This is a third point loading arrangement using an air bag. The pressure created inside the air bag was transformed into two line loads that were superimposed onto the test panel. Each panel was subjected to a loading rate of 4410 N per minute. Deflection was measured and plotted against total load.

A photograph of the Stressed Skin Panel Tester is shown in Figure 5.

All panels were tested to failure. Points of failure were noted and photographs taken where fractures occurred.

Upon completion of each test, moisture samples were taken from webs and flanges.

Indoor temperature and relative humidity were monitored throughout testing.

Testing for the long-term was also conducted according to ASTM E 72-80. The test set-up is shown in Figure 4. The third point loading arrangement uses four water-filled drums. The weight of the drums is transformed into two line loads across the test panel. The load was applied quickly to reduce the effects of the rate of loading on the time-deflection curve. Deflection was measured and plotted against elapsed time.

Indoor temperature and relative humidity were monitored through the testing.

Moisture samples taken from the same material as the individual elements of the stressed skin panels are being weighed weekly to determine moisture content of the elements at any given week. The temperature, humidity and moisture content measurements will provide a basis for a relation between the deflection and the stiffness of the stressed skin panels.

4. RESULTS AND DISCUSSION

4.1 Flexural Behaviour of Stress Skin Panels

Short-term Flexural Behaviour

The average results from the bending tests are shown in Figure 4. All three flange types (OSB, D.fir and spruce) of stressed skin panels tested had mid-span deflections less than SPAN/360 based on an equivalent uniformly distributed load of 2 kN/m^2 which was used in the long-term flexural tests.

The experimental short-term flexural stiffness of the stressed skin panels (SSPs) are compared with the predicted values in Table 3. The predicted stressed skin panel stiffness values are calculated based on conventional design theory used for plywood (COFI 1976, APA 1987). The theory appears to apply a little better to OSB stressed skin panels than to plywood SSP.

It is interesting to note that short-term flexural stiffness performance of SSPs after 1000 days sustained loading had slightly higher stiffness due to lower moisture content of the face material at the time of the testing (see Table 4). These results also indicate that the sustained loading did no significant short term flexural stiffness damage. Test results for the individual SSPs tested can be found in Appendix B.

Table 3. Comparison between the calculated SSP flexural stiffness and that obtained from the experiments.

Flange Material	Number of Samples	Short Term Flexural Stiffness, EI ($kN.m^2/1220$ mm)		
		Predicted	Actual Average* No Sustained Load	Actual Average** after Sustained Load
Oriented Strandboard	6 + 6	1,414	1,320	1,413
Douglas-fir Plywood	3 + 3	1,552	1,765	1,772
Spruce Plywood	3 + 3	1,289	1,560	1,613

* Moisture Content 7 - 8%
** Moisture Content 6%

The failure of the stressed skin panels was typically initiated by tensile splitting in the bottom flange. The fracture would then move upward, through the web-flange interface, toward the neutral axis of the cross section. Many fracture lines, intersected knots, and small cracks were found in the materials. The failure of OSB stressed skin panels was not as sudden as the plywood faced stressed skin panels. The results obtained indicate no significant effects of sustained loading on the short-term flexural strength.

Table 4. Ultimate maximum moments obtained in short-term flexure testing of stressed skin panels prior to and after sustained loading.

Flange Material	Number of Samples	Short Term Ultimate Maximum Moment N.m/1220 mm	
		Actual Average* No Sustained Load	Actual Average** After Sustained Load***
OSB	6 + 6	41,160 N.m	42,010 N.m
D. fir Plywood	3 + 3	50,540 N.m	48,546 N.m
CSP Plywood	3 + 3	46,155 N.m	42,527 N.m

* Moisture Content 7 - 8 % at test
** Moisture Content 6% at test
*** 1000 days of sustained loading with a constant moment 6,544 N.m prior to short term test

Long-term Flexural Behaviour

The long-term flexural deflection behaviour creep of stressed skin panels during 1000 days sustained loading is tabulated in Table 4. Fractional deflection, FD(t), is defined as the ratio of total deflection and the one-minute deflection. It can be seen that the fractional deflection of the stressed skin panels reached "2" by the end of the 1000-day experiments for OSB, slightly higher than similar panels faced with plywood.

After unloading, some creep recovery (visco-elastic) took place during the 50 days of creep recovery. The data obtained showed that approximately ⅔ of the time-dependent-flexure under sustained loading was non-recoverable (viscous). However, the short term stiffness and strength (reported in Tables 3. and 4.) did not appear to have changed significantly due to 1000 days of sustained loading at the 13 - 16% of maximum short time level.

Table 5. Fractional deflection of stressed skin panels sustained loaded for 1000 days plus 50 days of creep recovery following unloading.

Type of SSP (165x1220x4880 mm)	OSB Flanges	CSP Plywood Flanges	D.fir Plywood Flanges
Sustained Moment* (N.m/1220 mm)	6544	6554	6570
Full Span Deflection 1 minute after uploading	10.08 mm	8.42 mm	8.92 mm
Elapsed time from uploading	Fractional Deflection		
1 minute	1.00	1.00	1.00
10 minutes	1.02	1.01	1.01
10^2 minutes	1.06	1.03	-
10^3 minutes	1.10	1.09	1.04
10^4 minutes	1.16	1.18	1.11
10^5 minutes	1.39	1.41	1.31
10^6 minutes	1.90	1.66	1.60
1000 days = T	2.04	1.72	1.66
Unloading	Unloading	Unloading	Unloading
T + 1 minute	0.91	0.61	0.57
T + 10 minutes	0.89	0.61	0.57
T + 10^2 minutes	0.87	0.58	0.53
T + 2 · 10^3 minutes	0.83	0.52	0.51
T + 10^4 minutes	0.74	0.48	0.45
T + 50 days	0.62	0.39	0.36

* The stress level was approximately 13 - 16% of ultimate short term maximum

4.2 Mechanical Strength of the SSP Skin Material

Samples (300 x 1200 mm) taken from undamaged areas of the stress skin panels were flexure and tension tested. The summary of the data in Table 6. shows clearly the layering nature of the OSB and plywood skin.

Table 6. Short-term flexure and tension properties of the SSP skin panels.

Panel Material (Parallel)	Panel Thickness	Flexure MOE	Tension MOE	ULT. Tension Strength	Density	Moisture Content
	mm	MPa	MPa	MPa	kg/m^3	%
OSB	9.88	8154	5645	13.4	676	5
	16.13	7823	5567	12.7	665	5
CSP Plywood	9.80	10010	7035	14.8	504	6
	15.33	8507	8267	13.4	428	6
Douglas fir Plywood	9.83	12.348	7405	20.5	587	6
	15.23	9020	10737	13.5	454	6

4.2 Nature of Failure

The failure of a panel during the short-term testing is progressive. It usually begins with tensile fracture across the bottom flange. The web members then begin to fail from the bottom and fracture longitudinally. Shear failure along the bottom interface (which is material failure rather than glue failure) is also evident. All top flanges remain intact. Many fracture lines, in both flanges and webs, intersect knots and initial cracks found in the material.

Failure of the plywood flanges is characterized by a very sudden and dramatic collapse. Two of the stressed skin panels sheathed with plywood exhibited failure at tensile splice points.

The nature of failure in short-term destructive testing did not appear significantly different whether or not they had been exposed to sustained loading for 1000 days with a 2 kN/M^2 UDL.

4.3 Comparison of Actual Results to Design Calculations

The comparison in Table 3 indicates that the stressed skin panels made with flanges or oriented strandboard performed slightly less well than expected, whereas the stressed skin panels made with flanges of plywood performed better than expected.

It should be noted that, in design, it was assumed that the core section of the OSB makes no contribution to the stiffness of the stressed skin panel.

5. CONCLUSIONS

The use of oriented strandboard has become increasingly acceptable for structural purposes. However, its application in the stressed skin panels has not been fully developed due to lack of data on stressed skin panels made with oriented strandboard. This study on Alberta produced panels is expected to increase the market demand for structural applications of OSB.

- Conventional design of stressed skin panels made with flanges of Alberta OSB was found adequate. Experimental short-term tests of elastic flexural stiffness of OSB flanged stressed skin panels agrees fairly well with the conventional designed theory. As for plywood, the layered structure of OSB must be considered.

- A design for sustained loading flexure behaviour of SSPs with OSB can be based on a calculated short-term elastic deflection multiplied with the fractional creep factor valid for the time span considered.

- The ultimate short-term stiffness and strength of stressed skin panels that has been sustained loaded (at 13-16% of ultimate) for 1000 days appears not affected when tested according to ASTM E72-80 fifty days after unloading.

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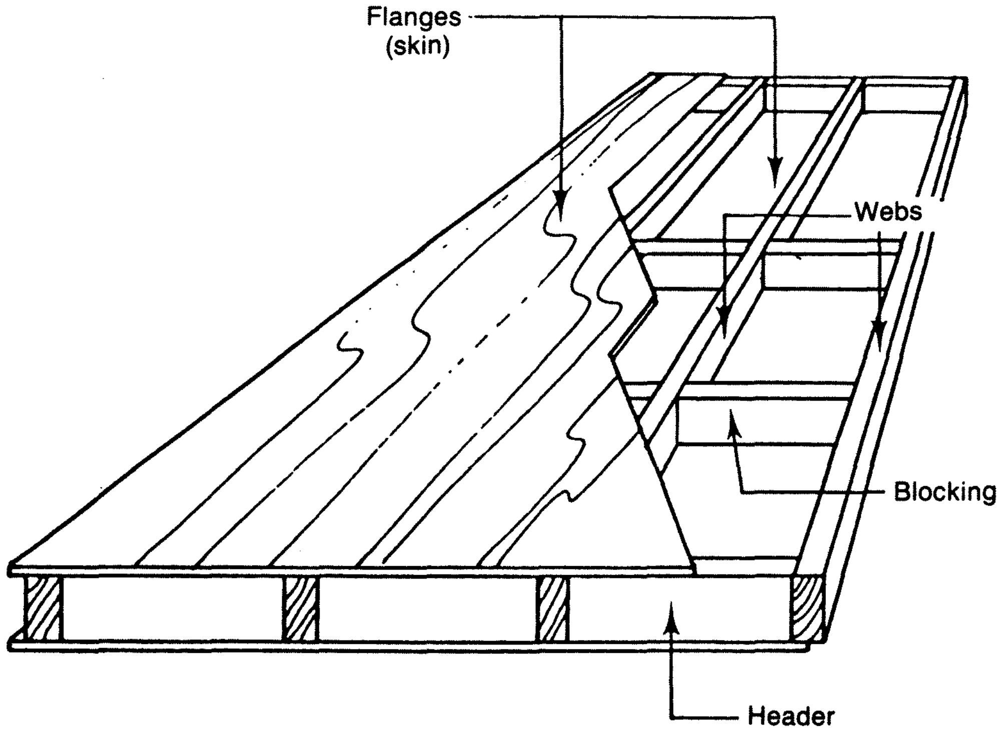
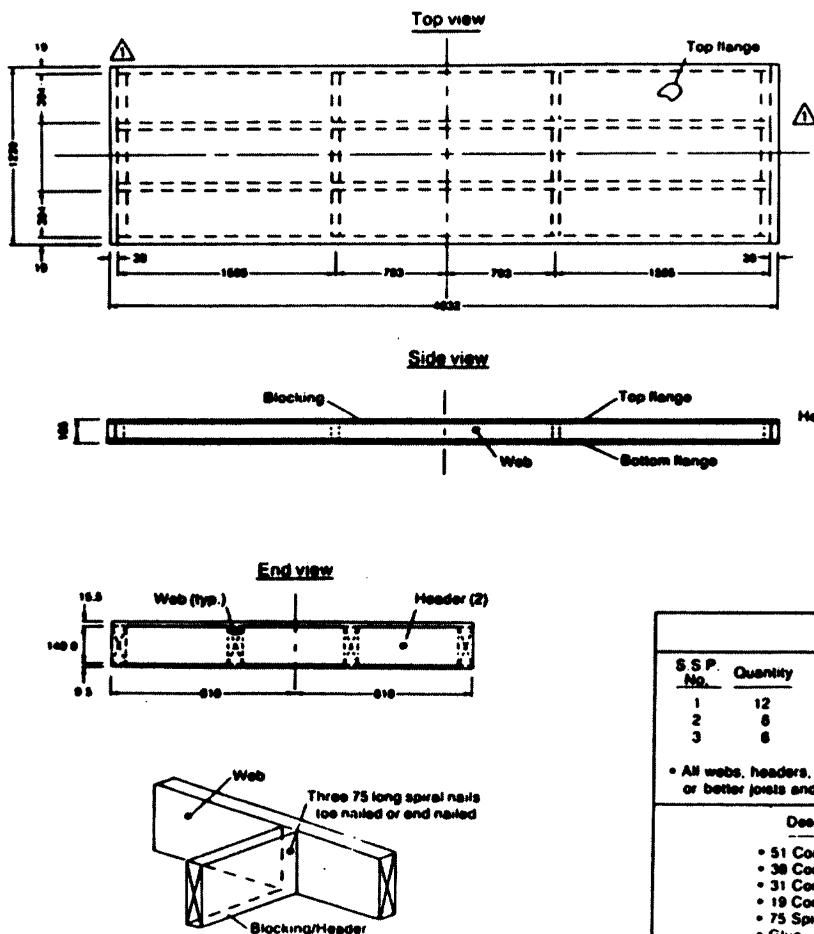
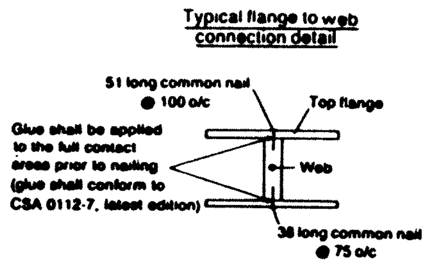


Figure 1. Schematic diagram of stressed skin panel.





General notes

1. All stressed skin panels shall be assembled and manufactured in accordance with the drawings and written instruction from the engineer
2. Flanges and webs shall be the specified size and grade
3. The moisture content for each component shall be between 7 and 16 percent with a variation of not more then 5 percent between components, at time of gluing.
4. Prior to gluing, the gluing surfaces shall be free of dust, oil or any deterious substances which may cause defect in the bonding of parts.
5. The gluing surfaces shall not be sanded flat such that the variation is less then 1.0 mm
6. The usage of glue shall be in accordance with the exact instruction supplied by the glue manufacturer Any deviation shall be subjected to the engineers written approval. The fabricater shall use positive mechanical means to ensure the proper bonding of materials (suggested contact pressure. 700 kPa to 1000 kPa)
7. Care shall be taken in the storage and handling of all parts (especially the wood panels for the flanges) so that permanent deformation does not result due to bending or other means
8. All dimensions are in mm or noted otherwise

Schedule of materials

S.S.P. No.	Quantity	Top flange	Bottom flange
1	12	OSB 15.5 thick	OSB 9.5 thick
2	6	D. fir ply. 15.5 thick	D fir ply 9 5 thick
3	6	Spruce ply. 15.5 thick	Spruce ply 9 5 thick

• All webs, headers, and blocking shall be 38 x 140 (2" x 6") SPF grade no. 2 or better joists and planks.

Description	Quantity
• 51 Common nail	4800
• 38 Common nail	6150
• 31 Common nail	610
• 19 Common nail	1210
• 75 Spiral nail	1820
• Glue	50 m² surface area

Stressed skin panel (S.S.P.) construction drawing - general

Revisions ⚠1 Reduce from six to three nails
Change header configuration

Alberta Research Council
Approved by: L B.
Drawn by A A — Date drawn 86 07 08
Designed by. P W
Date issued July 14 1986
Scale N.T.S

Figure 2. Stressed skin panel construction drawing: general.

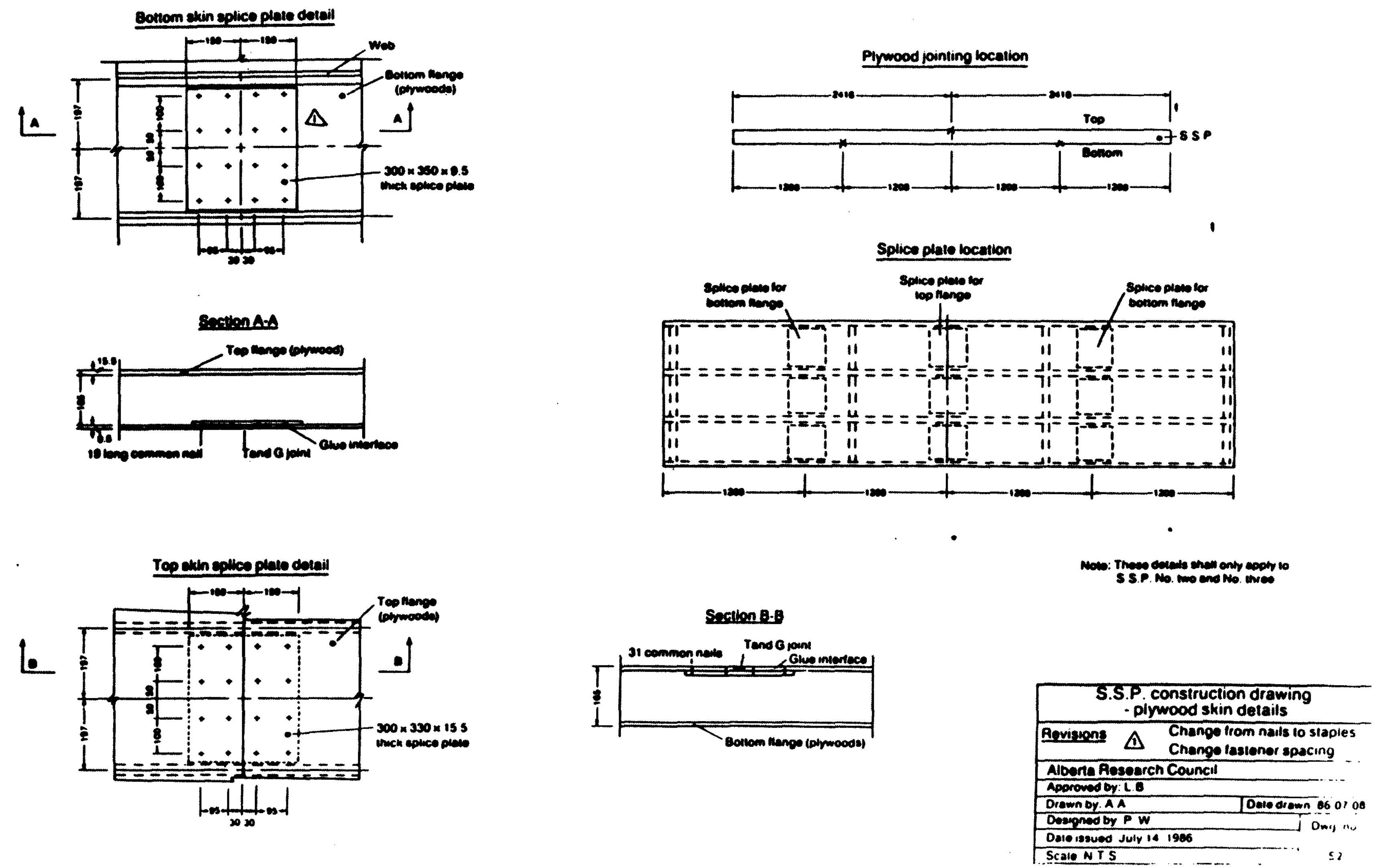


Figure 3. Stressed skin panel construction drawing: plywood flange details.

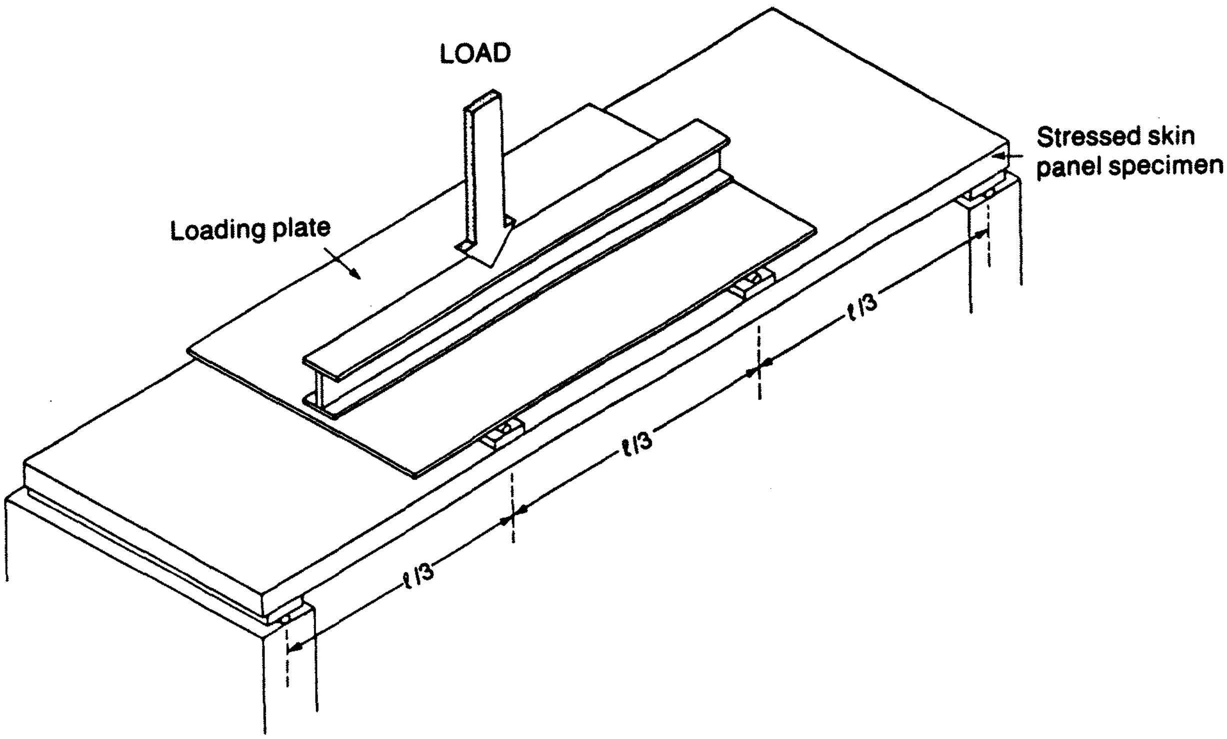


Figure 4 Load test arrangement for short-term and long-term testing of stressed skin panels.

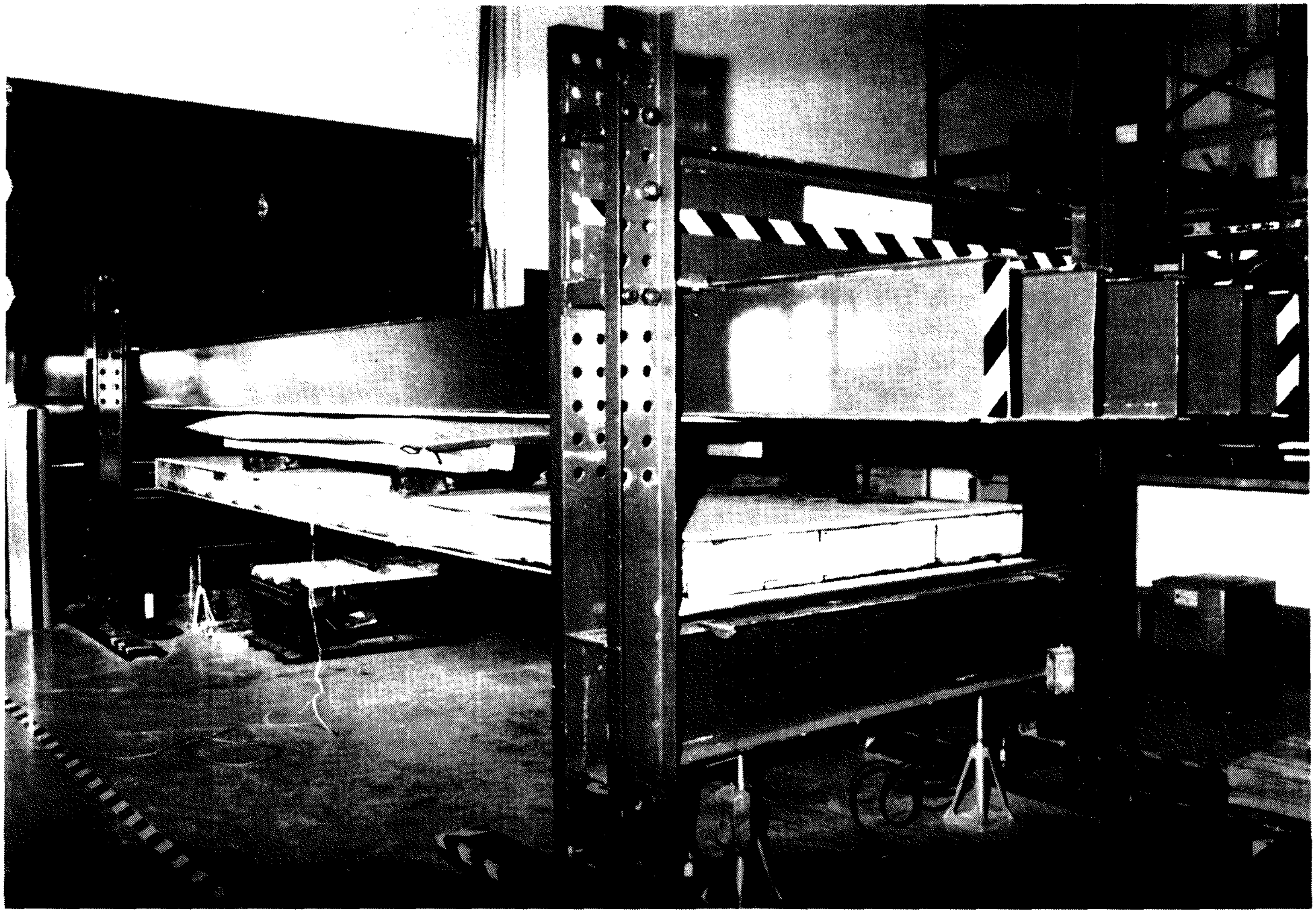
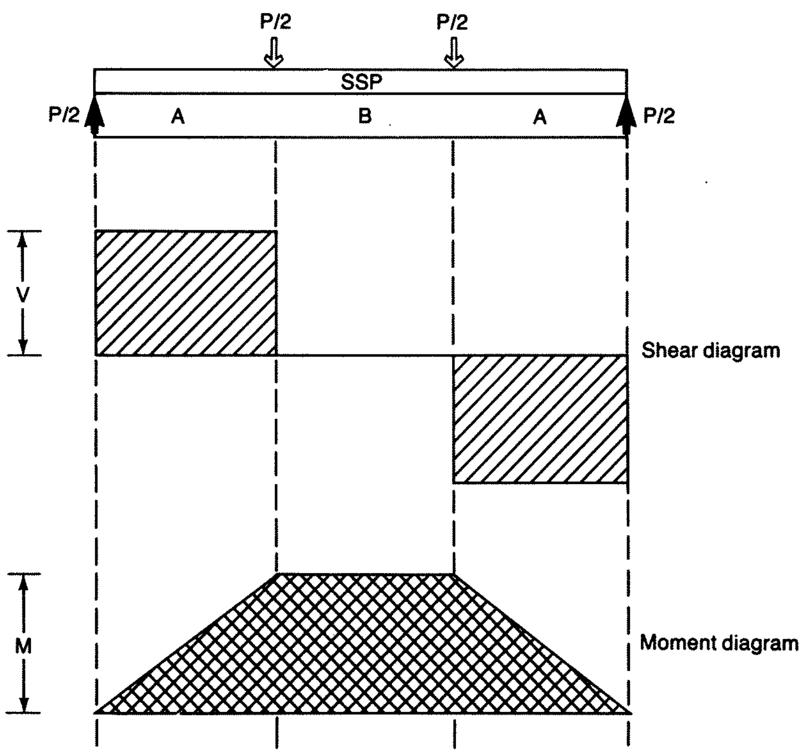


Figure 5. Stressed skin panel tester.



Type of test	Source of load	Span Lengths (mm) A	B
Short-term	Air bag pressure	1585	1585
Long-term	Drums with water	1585	1585
Boltzmann's	Concrete blocks	785	790

Figure 6. Test set-up used for stressed skin panels.

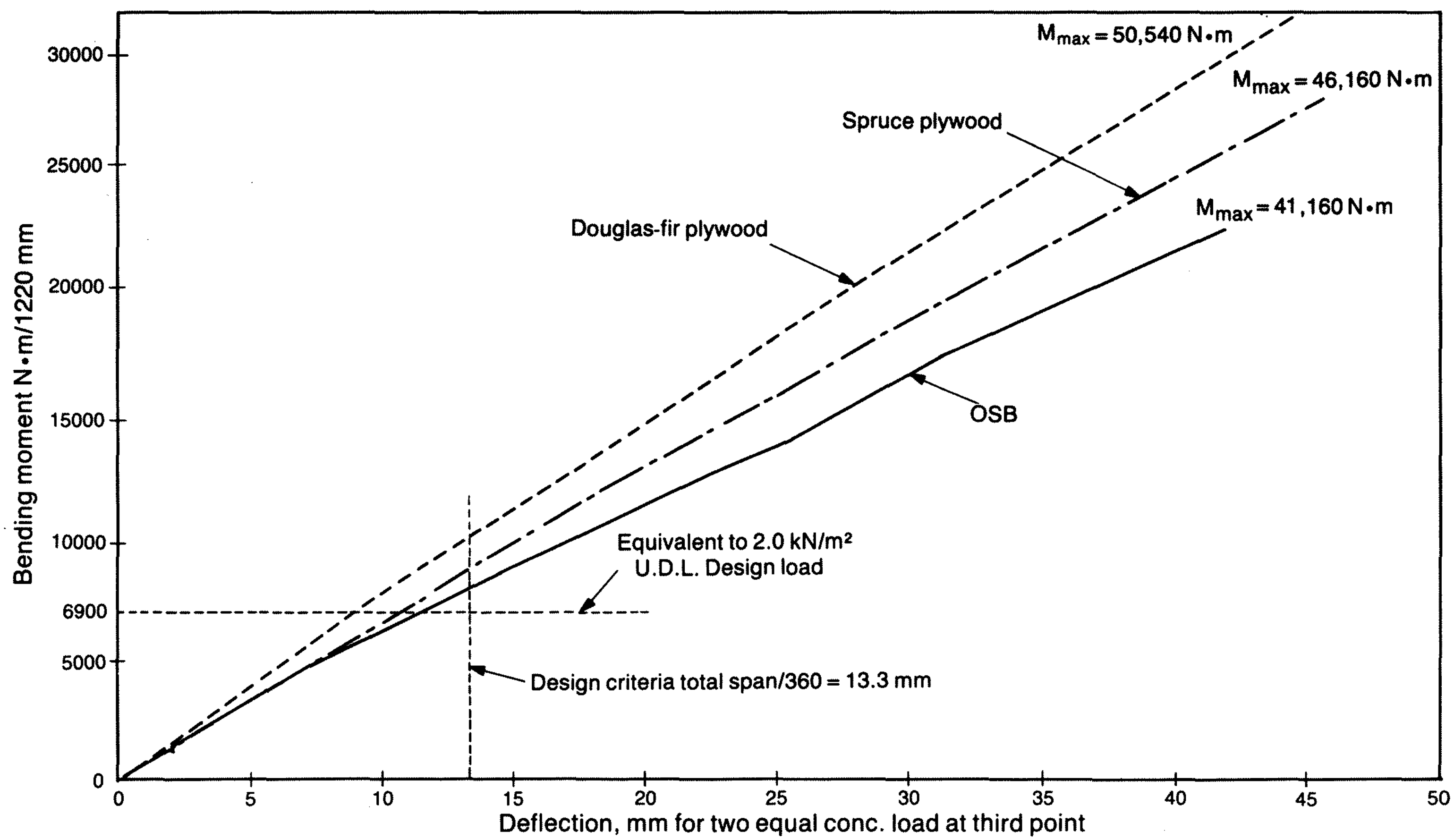


Figure 7. Experimental short-term deflection curves for stressed skin panels made with flanges of different materials. The dimensions of the panels were 165 x 1220 x 4880 mm.

Appendix A

Sample Design for Stressed Skin Panels
with Skins of Oriented Strandboard

Appendix A

Sample Design for Stressed Skin Panels with Skins of Oriented Strandboard

Area (Gross) $A = b \cdot t$

Composite Flexural Stiffness $EI = \Sigma E \cdot (I + A \cdot d^2)$

Effective Area $A_e = A \cdot SR$

Effective Moment of Inertia $I_e = I \cdot [1 - (1 - SR)^3]$

Fractional Deflection Function $FD(t) = \dfrac{EI_t}{EI_{elastic}}$

Moment of Inertia (Gross) $I = \dfrac{b \cdot t^3}{12}$

Neutral Axis location $N.A. = \dfrac{\Sigma E \cdot A \cdot y}{\Sigma E \cdot A}$

where

b = width

d = distance rom neutral axis

SR = shelling ration

t = thickness

E = modulus of elasticity

Example:

Determine the 400000-minute fractional deflection of the OSB Stressed Skin Panel using either:

1. the Young's modulus in bending, or
2. in uni-axial (tension/compression) assuming a shelling ratio of 0.5.

Data: SSP - top skin = 15.5 mm (nominal) OSB

bottom skin = 9.5 (nominal) OSB

webs = 38 X 140 mm S-P-F Lumber

width = 1220 mm

top skin - t = 16.12 mm

E_b = 8483 MPa (based on I_{gross})

E_c = 5610 MPa (based on A_{gross})

b = 1220 mm

lumber web - t = 140 mm

E = 12138 MPa (same for uni-axial)

b = 38 mm

bottom skin - t = 9.67 mm

E_b = 8535 MPa (based on I_{gross})

E_t = 4330 MPa (based on A_{gross})

b = 1220 mm

Calculations based on E in bending

$$[\ 1 - (\ 1 - SR)^3\ ] = 0.875\ (\ SR = 0.5)$$

top skin:

$$E_e = \frac{8483\ MPa}{0.875} = 9695\ MPa$$

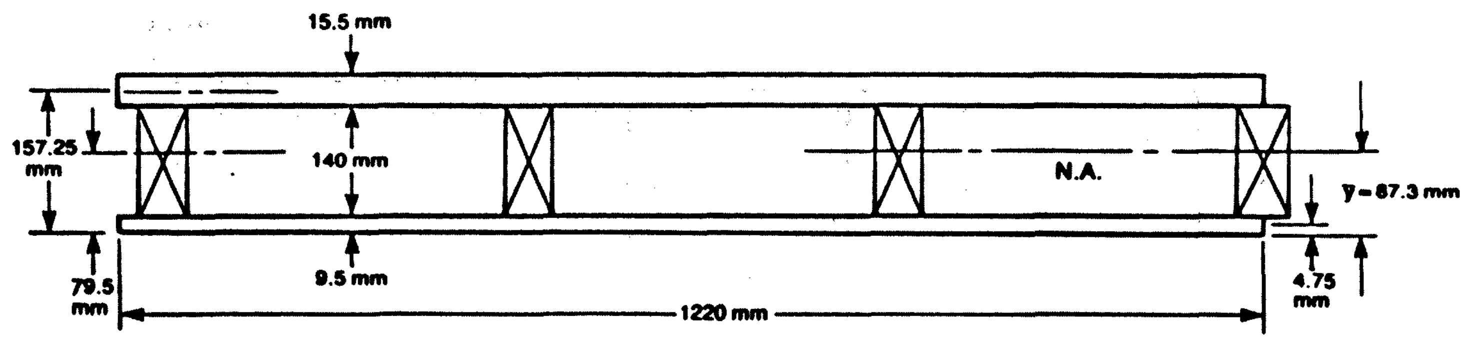
A_e = 9833 mm2 (16.12 x 1220):2 = 9833 mm²

I_e = 372633 mm^4

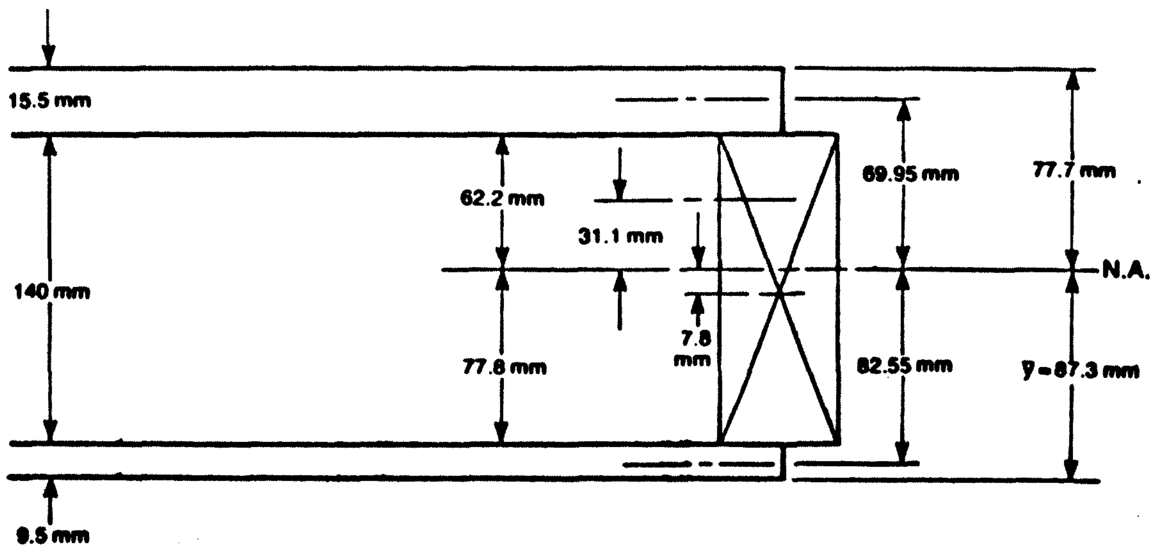
FD(400000) = 2.31 (flexural creep)

lumber web:

E = 12138 MPa



Location of Neutral Axis



Distances from Neutral Axis to Midpoints and Outer Surfaces of Each Element

$$A = 38 \cdot 140 \cdot 4 = 21280 \text{ mm}^2$$

$$I = \frac{4 \cdot 38 \cdot 140^3}{12} = 347.6 \times 10^5 \text{ mm}^4$$

FD(400000) = 1.71 (flexural creep)

bottom skin:

$$E_e = \frac{8535 \text{ MPa}}{0.875} = 9754 \text{ MPa}$$

$$A_e = 5899 \text{ mm}^2$$

$$I_e = 80439 \text{ mm}^4$$

FD(400000) = 2.23 (flexural creep)

Neutral Axis Location

E	A	E · A	y	E · A · y
9695	9833	95.3 E6	157.73	150.4 E8
12138	21280	258.3 E6	79.67	205.8 E8
9754	5899	57.5 E6	4.84	2.78 E8
		Σ = 411.2 E6		Σ = 359.0 E8

N.A. = 87.3 mm

Flexural Stiffness

E	I	A	d	E (I=A d^2)
9695	372633	9833	70.42	476.36 E9
12138	347.6 E5	21280	7.64	436.99 E9
9754	80439	5899	82.47	392.08 E9

$EI_{elastic}$ = 1305.4-E9 Nmm^2

Neutral Axis Location @ 400000 minutes

Input values are identical to above except that the moduli values are reduced as follows:

$$E_{400000} = \frac{E_{elastic}}{FD(400000)}$$

$\therefore$ N.A. = 85.6 mm

Flexural Stiffness @ 400000 minutes

E_t	I	A	d	E (I=A d^2)
4197	372633	9833	72.13	216.28 E9
7098	347.6 E5	21280	5.93	252.04 E9
4374	80439	5899	80.76	168.65 E9

EI_{400000} = 637.0 E9 N-mm^2

Fractional Deflection of SSP @ 400000 minutes

$$FD\ (400000) = \frac{EIe}{EI_{400000}} = \frac{1305.4\ E9}{637.0\ E9}$$

$$= \underline{2.05}$$

compare above to the experimental result:

$$\text{difference} = \frac{2.05 - 1.71}{1.71} \cdot 100 = 19.8\ \%$$

Calculations based on uni-axial E

top skin:

E_c = 5610 MPa

A = 19666 mm^2

I = 425867 mm^4

lumber web:

E = 12138 MPa

A = 21280 mm^2

I = 347.6 E5 mm^4

bottom skin:

E_t = 4330 MPa

A = 11797 mm^2

$$I = 91930 \text{ mm}^4$$

Neutral Axis Location

E	A	E · A	y	E · A · y
5610	19666	110.3 E6	157.73	173.0 E8
12138	21280	258.3 E6	79.67	205.8 E8
4330	11797	51.1 E6	4.84	2.47 E8
		Σ = 419.7 E6		Σ = 382.3 E8

Flexural Stiffness

E	I	A	d	$E\ (I+A\ d^2)$
5610	425867	19666	66.64	492.34 E9
12138	347.6 E5	21280	11.42	455.60 E9
4330	91930	11797	86.26	380.48 E9

$$EI_{elastic} = 1328.4 \text{ E9 N-mm}^2$$

Neutral Axis Location @ 400000 minutes

Input values are identical to above except that the moduli values are reduced as follows:

$$E_{400000} = \frac{E_{elastic}}{FD(400000)}$$

$\therefore$ N.A. = 88.8 mm

Flexural Stiffness @ 400000 minutes

E_t	I	A	d	$E\ (I+A\ d^2)$
2429	425867	19666	68.96	228.21 E9
7098	347.6 E5	21280	9.1	259.24 E9
1942	91930	11797	83.93	161.56 E9

$$EI_{400000} = 649.0 \text{ E9 N-mm}^2$$

<u>Fractional Deflection of SSP @ 400000 minutes</u>

$$FD(400000) = \frac{1328.4\ E9}{649.0\ E9}$$

$$= \underline{2.05}$$

compare above to the experimental result:

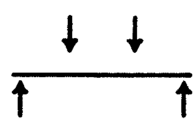
$$\text{difference} = \frac{2.05 - 1.71}{1.71} \cdot 100 = 19.8\ \%$$

Now having calculated the fractional behaviour of the SSP from the material component behaviour (or by direct experiment) the actual deflection of any SSP can be calculated.

Centerline Deflection:

$$\Delta(t) = \frac{P}{\sum_{i=1}^{n} \frac{K_i}{FD_i(t)}}$$

where P = Two equal conc. loads symetrically placed



n = number of components

$$\Delta_{mm} = \frac{Pa(3L^2-4a^2)}{24EI}$$

K_i = spring constant of the web, top or bottom skin

$$\frac{24\ E\ I_t}{a\ (3L^2-4a^2)}$$

I_t = transformed moment of inertia

L = span of beam

a = moment arm

$FD_i(t)$ = material's fractional deflection function for sustained loading

Appendix B

Destructive Flexure Tests of SSPs
After 1000 days of Loading

Destructive Testing of Stress Skin Panels.
Summary

Client : A.R.C.
Test Date : January, 1990
Proj. Ref.: 40605100

Test Material: D-Fir - SSP
Dimensions: 165 mm x 1220 mm x 4832 mm
Conditioning: Uncontrolled Environment
Moment arm: 1586 mm

Sample No.	Test Weight (kg)	Load Apparatus (kg)	Deflection @ 17.79 kN LVDT (mm)	Deflection @ 17.79 kN Dial Gauges (mm)	Deflection @ 17.79 kN Curve Jig (mm)	Slope of Load-Defl. curves. N/mm	Defl. @ 44.48 kN (mm)	Manometer @ 17.79 kN (mm)	Time to Failure (min)	Failure Load (kN)	Max. Moment (N-m)	EI (kN-sq.mm) (x1000000)	M.C. (%)
D-Fir - 14	134	189	20.60	20.13	0.044	872.9	61.925	609.6	14:43	58.405	46301	1669	6
D-Fir - 15	137	189	16.88	19.01	0.036	973.9	82.550	546.1	14:43	64.366	51026	1862	6
D-Fir - 22	137	189	18.24	18.38	0.030	933.1	57.150	596.9	13:17	60.941	48311	1784	6
Avg.	136.0	189.0	18.57	19.17	0.037	926.6	67.208	584.2	14.34	61.237	48546	1772	6.0
C.V. %	1.04	0.00	8.28	3.78	16.54	5.48	16.40	4.70	4.75	3.99	4.88	5.48	0.00

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Appendix C

Tension Test Data of Skin
from SSPs Loaded 1000 days

Stress Skin Panels
(1' x 4' SSP samples)

Client : A.R.C.
Test Date : January - February, 1990
Proj. Ref.: 40605100

Test Material : O.S.B.
Nom. Thickness : 3/8 "
Conditioning : Uncontrolled Environment

Panel #		Thickness (mm)	MSR-MOE (MPa)	Tension Tester Peak Load (kN)	Tension Tester Strength (MPa)	Tension Tester MOE (MPa)	Density (kg/m^3)	M.C. (%)
OSB-7	# 1	9.54	7870	38.255	13.9	6627	675	5
	# 2	9.86	8940	43.237	15.2	7832	686	5
	# 3	9.78	8150	39.055	13.9	4645	666	5
	# 4	9.80	8420	32.027	11.4	5629	682	5
OSB-8	# 1	9.88	8110	33.984	11.9	7816	678	5
	# 2	10.30	7840	28.291	9.5	4998	668	5
	# 3	9.88	8580	39.233	13.8	5211	688	5
	# 4	9.66	8240	35.185	12.7	4441	669	5
OSB-9	# 1	10.10	8030	46.929	16.1	6951	675	4
	# 2	9.96	7870	37.498	13.1	4561	674	5
	# 3	10.32	7800	43.192	14.5	3742	673	5
	# 4	10.46	8400	40.657	13.5	4614	668	5
OSB-10	# 1	9.90	8930	41.635	14.6	4589	676	5
	# 2	10.28	7930	40.123	13.6	4419	669	5
	# 3	9.38	9300	37.187	13.8	7485	705	5
	# 4	9.72	7980	34.340	12.3	4414	675	5
OSB-11	# 1	9.76	8360	34.251	12.2	6594	679	5
	# 2	9.74	8090	40.479	14.4	6607	680	5
	# 3	10.18	7980	40.479	13.8	4214	668	5
	# 4	10.32	7800	41.769	14.1	5756	669	5
OSB-12	# 1	9.58	7270	33.184	12.0	6718	663	5
	# 2	9.54	7420	34.385	12.5	3520	663	5
	# 3	9.54	8270	38.299	13.9	7359	685	5
	# 4	9.56	8110	43.459	15.8	6732	697	5
Avg.		9.88	8154	38.214	13.4	5645	676	5
St.Dev		0.30	460	4.351	1.5	1356	10	0
C.V. %		3.07	5.65	11.39	10.88	24.02	1.53	4.25

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Stress Skin Panels
(1' x 4' SSP samples)

Client : A.R.C.
Test Date : January - February, 1990
Proj. Ref.: 40605100

Test Material : OSB - CSP - DFIR
Nom. Thickness : 5/8 "
Conditioning : Uncontrolled Environment

Panel #	Thickness	MSR-MOE	Tension Tester			Density	M.C.
			Peak Load	Strength	MOE		
	(mm)	(MPa)	(kN)	(MPa)	(MPa)	(kg/m^3)	(%)
OSB - 8 # 3	16.04	7980	59.072	12.8	7003	673	5
OSB -10 # 3	16.20	7620	59.072	12.7	4237	658	4
OSB -12 # 3	16.16	7870	59.250	12.7	5462	663	5
Avg.	16.13	7823	59.131	12.7	5567	665	5
St.Dev	0.08	184	0.103	0.1	1386	8	0
C.V. %	0.52	2.36	0.17	0.51	24.90	1.15	3.34
CSP -16 # 3	15.38	9000	59.072	13.3	8034	418	6
CSP -17 # 3	15.00	7680	59.161	13.7	6865	428	6
CSP -18 # 3	15.60	8840	59.117	13.2	9901	438	6
Avg.	15.33	8507	59.117	13.4	8267	428	6
St.Dev	0.30	720	0.045	0.3	1531	10	0
C.V. %	1.98	8.47	0.08	2.01	18.52	2.34	5.97
DFIR-14 # 3	15.48	9070	59.206	13.3	4989	462	6
DFIR-15 # 3	15.14	9830	59.206	13.6	13602	459	5
DFIR-22 # 3	15.12	8160	59.517	13.7	13620	442	6
Avg.	15.25	9020	59.310	13.5	10737	454	6
St.Dev	0.20	836	0.180	0.2	4978	11	0
C.V. %	1.33	9.27	0.30	1.51	46.36	2.37	7.86

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