Limit States Design with Hyspan and Hybeam: LVL for New Zealand Construction

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Introduction

Laminated Veneer Lumber (LVL) beams and wood I joists are now available in New Zealand. Carter Holt Harvey Engineered Wood Products manufactures Hyspan LVL and Hybeam wood I beams.

Hyspan is Laminated Veneer Lumber (LVL) made by gluing stress graded radiata pine veneer together in a continuous lengthwise process, to produce long lengths of wood (up to 12 m standard, longer by special arrangement). Thicknesses 45 or 63 mm will be available in New Zealand, in widths 170 to 600 mm. (see Table 1)

Hybeam is a range of I beams with Hyspan LVL flanges factory glued to a plywood web to form beams of depth 246 mm, 300 mm and 360 mm. These beams are also available in lengths to 12 m.

Hyspan

Hyspan is manufactured to AS/NZS 4357: Structural laminated veneer lumber. The characteristic stresses (MPa) for Hyspan are in Table 2. Laminating the thin veneers reduces the inherent variability of wood, and provides a more stable, higher strength, uniform engineering material. The tension strength in particular is much higher than for sawn timber. This means the long lengths of Hyspan are particularly suited to use in box beams, portals (Figure 1) or fabricated I beams (such as Hybeam).

Hyspan can carry higher loads for the same section area, and enables longer spans than with conventional sawn timber. For example, in the design of the Te Rapa school (Figure 2) the architect wanted sloping ceilings over the classrooms. The load imposed by a heavy tile roof induced excessive deflections in standard 300 x 50 timber rafters. These deflections were controlled by using higher stiffness Hyspan LVL rafters and beams in lengths from 3.3 metres to over 8 metres, in sizes 240 x 45 to 400 x 63. Some of the primary structural beams were paired to form 400 x 126 on site. Section properties and design capacities for a number of Hyspan members are in Table 1.

Table 1: Section properties of Hyspan beams

Depth D mm	Thickness B mm	Mass kg/m	Ixx 10^6 mm^4	Zxx 10^3 mm^3	J 10^6 mm^4	EI 10^9 Nmm^2	$\phi f_b Z$ kNm
170	45	4.7	18.4	217	4.3	243	8.2
170	63	6.6	25.8	303	10.9	340	11.5
200	45	5.6	30.0	300	5.2	396	11.3
200	63	7.8	42.0	420	13.4	554	15.9
240	45	6.7	51.8	432	6.4	684	16.3
240	63	9.4	72.6	605	16.7	958	22.9
300	45	8.4	101.3	675	8.3	1337	25.5
300	63	11.7	141.8	945	21.7	1871	35.7
360	45	10.0	175.0	972	10.1	2309	36.7
360	63	14.1	244.9	1361	26.7	3233	51.4
400	45	11.2	240.0	1200	11.3	3168	45.4
400	63	15.6	336.0	1680	30.0	4435	63.5
450	63	17.6	478.4	2126	34.2	6315	80.4
500	63	19.5	656.3	2625	38.4	8663	99.2
600	63	23.4	1134.0	3780	46.7	14969	142.9

Available sizes and Section properties for Hyspan

Table 1 gives section sizes and properties for a range of standard Hyspan sections. Depths that are even divisors into the standard maximum billet width of 1200 are the most economical. Lengths from 4.8 m up to 12 m are stocked in thicknesses 45 and 63 mm. Longer lengths are available on request. For details of supply and confirmation of standard sizes, designers should consult the manufacturers.

Structural design to NZS 3603:1993 - The Building Code of New Zealand

Hyspan is made to a New Zealand standard, with stresses in Table 2 determined in accordance with AS/NZS 4063 and so design complies with the provisions of the Building Code of New Zealand through clause C2.3 in NZS 3603. However because of its low variability, some of the factors in NZS 3603 and AS 1720 do not apply. In summary, the design basis for Hyspan LVL is as follows.

Characteristic stresses

For limit states design to the New Zealand Timber Structures Code NZS 3603 characteristic stresses are in Table 2.

Table 2: Characteristic stresses (MPa) for Hyspan

f_b	f_t	f_c	f_s	fp	E	G
42	27	34	4.5	12	13200	650

Strength modification factors

The strength modification factors are:

1. Strength reduction factor ϕ
   The strength reduction factor $\phi = 0.9$
   This recognises the low variability of Hyspan and the high precision of LVL manufacturing.

2. Duration of load
   Duration of load factors k_1 for strength and k_2 for stiffness should be as for solid timber in Tables 2.4 and 2.5 in NZS 3603.
   LVL is a solid veneer product and in material respects has similar load duration properties to timber. It is manufactured in the dry condition so will behave like kiln dried solid sawn lumber.

3. Load sharing
   Because Hyspan LVL is much less variable than sawn lumber, the load sharing relationships in NZS 3603 do not hold. Hence, $k_4 = k_5 = k_6 = 1.0$.

4. Moisture condition
   For use in dry conditions, no modification is required. Where Hyspan is subject to humid conditions such that the average moisture content would exceed 16% over a 12 month period, the modification factor k_{14} in Table 2 should be used. However, under these conditions, should the moisture content exceed 20% Hyspan may be subject to a decay hazard. Carter Holt Harvey recommends treatment to H3 level with LOSP for this hazard.

Table 4: Moisture content adjustment factor k_{14}

Property	Equilibrium moisture content (EMC)		
	< 16%	16% to 25%	> 25%
Bending and compression	1.0	1.53 - 0.033 EMC	0.7
Tension and shear	1.0	1.35 - 0.022 EMC	0.8
Modulus of elasticity	1.0	1.35 - 0.022 EMC	0.8

5. Sloping or curved edges

Hyspan LVL is made from parallel laminated veneer. It is very strong along the grain, but stress perpendicular to the grain should be avoided just as in solid timber. Wide sections must be handled carefully. When a design includes cut sloped or curved edges, the grain orientation factor k_{15} for strength is:

Table 3: Grain orientation factor k_{15} and k_{16} for cut edges

Angle of cut edge (degrees)	0	3	5	10	15	20	30	45
Edge in tension	1.0	0.92	0.80	0.50	0.31	0.21	0.11	0.06
Edge in compression	1.0	0.97	0.93	0.79	0.65	0.55	0.42	0.32

For stiffness k_{16} has the same value as k_{15} for tension, but the angle is assessed as the average of the two cut edges.

6. Size effect
Characteristic stresses for Hyspan in bending and tension should be multiplied by the size factor k_{24} as given for glued laminated timber in clause 8.7.7 of NZS 3603 except that for beams less than 300 mm deep, k_{24} = 1.0

Design of joints with Hyspan

For the design of nailed, screwed and bolted joints, Hyspan should be considered as having the properties of a J4 joint group. For proprietary fasteners such as nail plates, consult nailplate manufacturers for appropriate characteristic stresses.

Nail spacings and end distances should be as given in NZS 3603 except that for nail spacing along the grain, use a spacing of no less than $15d_a$. Where holes are not pre-drilled.

Hybeam

Hybeam, is an all wood I beam with a number of advantages over sawn timber joists.

- optimised to conserve wood resources
- available in long lengths for long or multiple span floor and floor-ceiling systems.
- uniform height with no shrinkage
- light weight, stable, straight
- no need to lap or splice over bearers. Flooring sheets can be placed in a continuous line.
- reduction in floor squeaking
- can be cut to any length with ordinary woodworking tools
- Service holes can be cut in the 9 mm plywood web to fix plumbing, and ducting firmly in position within the depth of the floor.

The structural properties of Hybeam are in Table 5. Designers can use these data for sizing the standard HJ246, HJ300, HJ360 for joist, rafter and purlin applications. Spans for Hybeam for standard house construction are in Table 6,and suggested spans for purlins in portal frame buildings in Table 7. Further information for the use of Hybeam is available from Carter Holt Harvey Engineered Wood Products.

Table 5: Section properties of Hybeam

Hybeam section code	Hybeam depth mm	Mass kg/m	EI_x Nmm^2 10^9	EI_y Nmm^2 10^9	GJ Nmm^2 10^6	GA_w N 10^6	A_f mm^2	D_l mm	ϕV_n kN	ϕM_n kNm
HJ 246	246	3.6	596	14.7	1170	1.11	1944	211	7.5	10.0
HJ 300	300	4.4	1111	21.5	1644	1.38	2350	262	9.7	15.0
HJ 360	360	5.1	1877	25.0	2526	1.65	2727	316	12.1	20.9

The design equations for serviceability and strength of Hybeam are:

Deflection
There is a significant shear component in the deflection of I section beams.

For a uniformly distributed load w over a span of L metres:

$$\delta = k_2 \left(5wL^4/384\, EI_x \; + \; wL^2 / 8GA_w\right) \qquad \text{(mm)}$$

Bending strength

$\phi M_n = 24.3\, k_1 A_f D_1$ (Nmm) (applies for k_8 in range 0.79 to 1.0)

$\phi M_n = 30.6\, k_1\, k_8\, A_f D_1$ (Nmm) (for k_8 in < 0.79)

Shear Strength

$\phi V_n = 43.7\, k_1(D_1 - 40)$ (N) (allows for a 40 mm diameter web hole).

Symbols

Ei_x	Stiffness bending about the x axis
Ei_y	Stiffness for bending about the y axis
GJ	Torsional rigidity
GA_w	Shear stiffness for shear in bending about x axis
A_f	Flange area
D_1	Effective distance between flange area centroids
ϕV_n	Design strength in shear, for bending about x axis (k factors 1.0)
ϕM_n	Design strength in bending about x axis (k factors 1.0)

Table 6: Recommended maximum spans for Hybeam joists in houses.

	Single span		Continuous span	
Joist spacing	**450**	**600**	**450**	**600**
HJ 246	4.7	4.4	5.4	5.0
HJ 300	5.5	5.0	5.9	5.4
HJ 360	6.3	5.8	6.7	6.1

Table 7: Maximum recommended spans (m) for purlins for light commercial buildings

Wind zone		**Low**		**Med**		**High**	
Wind speed		32 m/s		37 m/s		45 m/s	
Purlin spacing		0.9	1.2	0.9	1.2	0.9	1.2
For general roof area:		**Nett wind suction co-efficient = -0.7**					
HJ 246	Full span	8.7	7.7	7.9	7.1	6.8	6.0
HJ 300	Full span	10.7	9.7	9.4	8.1	7.4	6.5
HJ 360	Full span	12.8	11.1	10.7	9.2	8.4	7.3
For high suction zones		**Nett wind suction co-efficient = -1.5**					
HJ 246	Full span	6.6	5.7	5.6	4.9	4.6	4.0
	With blocking at mid span	6.7	6.0	6.0	5.4	5.2	4.7
HJ 300	Full span	7.1	6.2	6.1	5.3	5.0	4.4
	With blocking at mid span	7.9	7.0	6.9	6.2	5.9	5.3
HJ 360	Full span	8.0	6.9	6.8	6.0	5.5	
	With blocking at mid span	8.8	7.8	7.7	6.8	6.5	5.8

Photograph 1.   . Hyspan used in a box beam portal.

Photograph 2.   . Hyspan roof structure

Photograph 3. . Hybeam I beams as used in a floor structure.

Photograph 4. .Roof structure showing Hyspan portals with Hybeam Purlins.