WORKING LOAD LIMITS

The attached WLL charts are valid *for all "hairpin" type plate anchors* in a length range 250-360mm and were derived from tests of anchors sold by current Australian suppliers.
Tests showed that the anchor type and length made no difference to the concrete strength limit state.

The attached tables provide WLLs for the failure of the concrete surrounding a "hairpin" style anchor (concrete strength limit state). When using the attached tables please note:

1) The factored ultimate load ϕR_u is the predicted failure load of the concrete when it cracks and can no longer support the anchor load, it includes the capacity reduction factor ϕ_c for concrete.
This is defined as follows in Appendix A of AS3850

$$\phi R_u = x/k_s \quad .. \text{A4.6}$$

where

ϕR_u = strength limit state capacity
x = mean value of test data (Paragraph A4.4)
k_s = sampling factor, Table A2 = 1.3 (more than 5 tests)

and

$$WLL = \phi R_u /2.5$$

NB!

i) *The concrete can crack at R_u regardless of whether a hanger bar is fitted or not. If a hanger is not fitted then this is the load that the concrete around the anchor will fail and the anchor will pull out*
ii) *If a hanger is fitted then although the concrete has cracked, the load will be transferred to the hanger. If the hanger is not strong enough it will fail by shearing at the connection point (hole in the anchor) or tensile failure of the bar or pullout from the concrete.*
iii) *If the hanger has been correctly designed (see table below for recommendations) then ultimate failure will occur at 2.5 times the WLL of the hanger bar or the WLL of the anchor, whichever is the lower.*

2) If the design anchor load is less than the values in these tables then the anchor can be used without additional reinforcing without panel cracking. Anchors lifted at right angles to the anchor axis e.g. tilting up from the edge, should be fitted with a "shear bar" over the anchor to 30mm from the bottom face, fully anchored by a cog or hook.

3) The factored ultimate load (ϕR_u) for edge shear (loading toward the edge) is the load at which the panel edge is predicted to crack, *regardless of whether a shear bar is present*. If a shear bar is present it should control the crack and minimize the risk of spalling. We recommend sufficient anchors be installed so that the design anchor load is less than ϕR_u or some spalling may occur

4) Where the design anchor load exceeds the WLL in these tables for axial tension then a hanger bar must be used to fully transfer the anchor load deep into the concrete panel.
5) Hanger bars, being part of the anchor, must include a factor of 2.5 against failure by any mode.
6) Tension limit states are limited by ultimate strength calculated from AS4671 and AS3850.
7) Shear limit states are limited by shear of the hanger where it passes through the hole of the anchor and cannot be calculated. This must be tested to AS3850.
8) Hanger bar pullout limit state is calculated using AS3600 development lengths.
   The following table shows the calculated loads and development lengths according to the requirements of AS4671, AS3850 and AS3600 for a hanger bar with two legs:
9) Assume the hanger bar is centrally placed with 60mm cover either side.
10) Concrete Compressive Strength **= 10MPa** - to ensure that the hanger is always effective, particularly when demoulding. Shorter lengths may be used at higher concrete strengths.

Hanger d_b	Area A_b	$R_u = N_{tf}$ Characteristic Ultimate Tensile Strength 500N AS4671 $R_m/R_u = 1.08$ Total for 2 legs	WLL TENSION AS3850 $\Phi * R_u / 2.5$	WLL SHEAR At anchor hole TESTED AS3850 DF = 2.5	Development AS3600 Clause 13.1.2.1	Hanger Bar Leg Length
Rebar	**Area**	**Tonnes**	**Tonnes**	**Tonnes**	$L_{sy,t}$	**LL**
N16	201	22.2	**7.1**	8.0	**561**	**650**
N20	314	34.6	11.1	**9.0**	**851**	**940**

Note:
- N16 is limited by design standards to 7.1t WLL for tension in the reinforcing bar.
- N20 is limited by tests to 9.0t WLL for shear through the bar at the anchor hole.
- The hanger bar leg length is the total anchored length above and below the concrete crack developed from the foot of the anchor.

Total Hanger Bar Length

The total length of bar required = $2 * LL + 2\pi * d_b$

Rebar d_b	Bend $2\pi * db$	Leg Length $2 * LL$	TOTAL Length
16	100.5	650	**1400**
20	126	940	**2005**

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CONCRETE STRENGTH LIMIT STATE
WLL TABLES FOR AXIAL TENSION AND
"EDGE SHEAR" (loads directed toward an edge)

for varying panel thicknesses and concrete compressive strength.

Note:

1. *These values are for the cracked concrete capacities in the presence of normal shrinkage reinforcing.*
2. *Hanger Reinforcing must be used when loads exceed these values for tension.*
3. *"Shear" Bars – are recommended for all applications where loads are applied toward an edge. The values for "edge shear" are for the unreinforced cracking load.*
4. *The 2.5 factor used to calculate the WLL in these tables may not be necessary for edge shear when rotating from the mould as the panel is supported on one edge during rotation and therefore cannot fall freely. In this case a lower factor of ~1.5 may be viable BUT a "shear bar" must always be used to control the crack.*

Demoulding - f'c = 12MPa

Panel thickness	Ultimate Edge Shear ϕR_u	**WLL Edge Shear**	Ultimate Axial Tension ϕR_u	**WLL Axial Tension**
mm	Factored		Factored	
	Tonnes Force	**Tonnes Force**	Tonnes Force	**Tonnes Force**
100.00	1.57	**0.6**	4.87	**1.9**
120.00	2.11	**0.8**	5.42	**2.2**
150.00	2.92	**1.2**	6.23	**2.5**
170.00	3.47	**1.4**	6.77	**2.7**
175.00	3.60	**1.4**	6.90	**2.8**
180.00	3.74	**1.5**	7.04	**2.8**
190.00	4.01	**1.6**	7.31	**2.9**
200.00	4.28	**1.7**	7.58	**3.0**
220.00	4.82	**1.9**	8.12	**3.2**
250.00	5.63	**2.3**	8.94	**3.6**

Initial Lift f'$_c$ = 15MPa

Panel thickness	Ultimate Edge Shear ϕR_u	WLL Edge Shear	Ultimate Axial Tension ϕR_u	WLL Axial Tension
mm	Factored		Factored	
	Tonnes Force	**Tonnes Force**	Tonnes Force	**Tonnes Force**
100.00	1.76	**0.7**	5.45	**2.2**
120.00	2.36	**0.9**	6.05	**2.4**
150.00	3.27	**1.3**	6.96	**2.8**
170.00	3.88	**1.6**	7.57	**3.0**
175.00	4.03	**1.6**	7.72	**3.1**
180.00	4.18	**1.7**	7.87	**3.1**
190.00	4.48	**1.8**	8.17	**3.3**
200.00	4.78	**1.9**	8.48	**3.4**
220.00	5.39	**2.2**	9.08	**3.6**
250.00	6.30	**2.5**	9.99	**4.0**

Cured - f'$_c$ = 20MPa

Panel thickness	Ultimate Edge Shear ϕR_u	WLL Edge Shear	Ultimate Axial Tension ϕR_u	WLL Axial Tension
mm	Factored		Factored	
	Tonnes Force	**Tonnes Force**	Tonnes Force	**Tonnes Force**
100.00	2.03	**0.8**	6.29	**2.5**
120.00	2.73	**1.1**	6.99	**2.8**
150.00	3.78	**1.5**	8.04	**3.2**
170.00	4.47	**1.8**	8.74	**3.5**
175.00	4.65	**1.9**	8.91	**3.6**
180.00	4.82	**1.9**	9.09	**3.6**
190.00	5.17	**2.1**	9.44	**3.8**
200.00	5.52	**2.2**	9.79	**3.9**
220.00	6.22	**2.5**	10.49	**4.2**
250.00	7.27	**2.9**	11.54	**4.6**

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Cured - f'$_c$ = 25MPa

Panel thickness	Ultimate Edge Shear ϕR_u	WLL Edge Shear	Ultimate Axial Tension ϕR_u	WLL Axial Tension
mm	Factored		Factored	
	Tonnes Force	**Tonnes Force**	Tonnes Force	**Tonnes Force**
100.00	2.27	**0.9**	7.03	**2.8**
120.00	3.05	**1.2**	7.82	**3.1**
150.00	4.22	**1.7**	8.99	**3.6**
170.00	5.00	**2.0**	9.77	**3.9**
175.00	5.20	**2.1**	9.97	**4.0**
180.00	5.39	**2.2**	10.16	**4.1**
190.00	5.78	**2.3**	10.55	**4.2**
200.00	6.18	**2.5**	10.94	**4.4**
220.00	6.96	**2.8**	11.72	**4.7**
250.00	8.13	**3.3**	12.90	**5.2**

Cured - f'$_c$ = 40MPa

Panel thickness	Ultimate Edge Shear ϕR_u	WLL Edge Shear	Ultimate Axial Tension ϕR_u	WLL Axial Tension
mm	Factored		Factored	
	Tonnes Force	**Tonnes Force**	Tonnes Force	**Tonnes Force**
100.00	2.87	**1.1**	8.90	**3.6**
120.00	3.86	**1.5**	9.89	**4.0**
150.00	5.34	**2.1**	11.37	**4.5**
170.00	6.33	**2.5**	12.36	**4.9**
175.00	6.58	**2.6**	12.61	**5.0**
180.00	6.82	**2.7**	12.85	**5.1**
190.00	7.32	**2.9**	13.35	**5.3**
200.00	7.81	**3.1**	13.84	**5.5**
220.00	8.80	**3.5**	14.83	**5.9**
250.00	10.28	**4.1**	16.31	**6.5**