A BRIEF OVERVIEW OF STRUCTURAL STEEL DESIGN, TILT PANEL CONSTRUCTION & RESIDENTIAL SLABS

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Introduction

I have prepared some brief technical notes with regard to:

- Structural steel design;
- Tilt panel construction; and
- Residential slabs.

The intention of these notes is to:

- Provide non-Engineers with some background theory on structural design; and
- Provide checklists to aid structural inspections.

Structural Steel Design

Limit State Design:

- Structural Engineers use *Limit State Design* to analyse a structure. A limit state is a condition of a structure beyond which it can no longer fulfil the relevant design criteria.

- Dead, live, wind and earthquake loads are obtained from *AS 1170-2002-Structural Design Actions*.

- A structure designed by *Limit State Design* is proportioned to sustain all actions likely to occur during its design life, and to remain fit for use, with an appropriate level of reliability or each limit state.

Two Primary Considerations in Structural Design:

Design for Strength:

- Refers to the ability of a structural member to withstand bending and shear forces. Bending moments are often the primary consideration in structural steel members whilst shear is less significant.

Design for Serviceability:

- The most common serviceability criterion is the ability of a section to limit deflection in order to carry out its intended function. Serviceability design is based on the requirement that the service load deflections must not exceed specified values such as span/500 may be used to design against cracking of plaster or masonry.

- It should be noted that a section may have adequate bending capacity to withstand the applied loads but may be poor in terms of serviceability.

- Deflection of steel sections is related to a property called second moment of area about the X-X axis. This property generally increases with section depths and weight. For example, there are 4 different sizes of 200UB steel section varying from 18.2kg/m up to 29.8kg/m. The section weights have huge implications with regard to bending capacity and serviceability.

- During an inspection of erected structural steel it is therefore essential that the correct section weight has been installed. This can often be checked by measuring such things as the flange width and using manufacturer’s tables.

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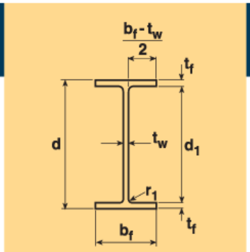
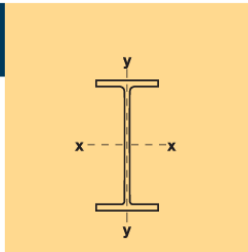




Universal Beams

Table 15 Universal Beams — Dimensions and Properties

Designation	Depth of Section d	Flange Width b_f	Flange Thickness t_f	Web Thickness t_w	Root Radius r_1	Depth Between Flanges d_1	$\frac{d_1}{t_w}$	$\frac{(b_f-t_w)}{2t_f}$	Gross Area of Cross-Section A_g	About x-axis I_x	About x-axis Z_x	About x-axis S_x	About x-axis r_x	About y-axis I_y	About y-axis Z_y	About y-axis S_y	About y-axis r_y	Torsion Constant J	Warping Constant I_w	Designation
kg/m	mm	mm	mm	mm	mm	mm			mm^2	10^6mm^4	10^3mm^3	10^3mm^3	mm	10^6mm^4	10^3mm^3	10^3mm^3	mm	10^3mm^4	10^9mm^6	
610 UB 125	612	229	19.6	11.9	14.0	572	48.1	5.54	16000	986	3230	3680	249	39.3	343	536	49.6	1560	3450	610 UB 125
113	607	228	17.3	11.2	14.0	572	51.1	6.27	14500	875	2880	3290	246	34.3	300	469	48.7	1140	2980	113
101	602	228	14.8	10.6	14.0	572	54.0	7.34	13000	761	2530	2900	242	29.3	257	402	47.5	790	2530	101
530 UB 92.4	533	209	15.6	10.2	14.0	502	49.2	6.37	11800	554	2080	2370	217	23.8	228	355	44.9	775	1590	530 UB 92.4
82.0	528	209	13.2	9.6	14.0	502	52.3	7.55	10500	477	1810	2070	213	20.1	193	301	43.8	526	1330	82.0
460 UB 82.1	460	191	16.0	9.9	11.4	428	43.3	5.66	10500	372	1610	1840	188	18.6	195	303	42.2	701	919	460 UB 82.1
74.6	457	190	14.5	9.1	11.4	428	47.1	6.24	9520	335	1460	1660	188	16.6	175	271	41.8	530	815	74.6
67.1	454	190	12.7	8.5	11.4	428	50.4	7.15	8580	296	1300	1480	186	14.5	153	238	41.2	378	708	67.1
410 UB 59.7	406	178	12.8	7.8	11.4	381	48.8	6.65	7640	216	1060	1200	168	12.1	135	209	39.7	337	467	410 UB 59.7
53.7	403	178	10.9	7.6	11.4	381	50.1	7.82	6890	188	933	1060	165	10.3	115	179	38.6	234	394	53.7
360 UB 56.7	359	172	13.0	8.0	11.4	333	41.6	6.31	7240	161	899	1010	149	11.0	128	198	39.0	338	330	360 UB 56.7
50.7	356	171	11.5	7.3	11.4	333	45.6	7.12	6470	142	798	897	148	9.60	112	173	38.5	241	284	50.7
44.7	352	171	9.7	6.9	11.4	333	48.2	8.46	5720	121	689	777	146	8.10	94.7	146	37.6	161	237	44.7
310 UB 46.2	307	166	11.8	6.7	11.4	284	42.3	6.75	5930	100	654	729	130	9.01	109	166	39.0	233	197	310 UB 46.2
40.4	304	165	10.2	6.1	11.4	284	46.5	7.79	5210	86.4	569	633	129	7.65	92.7	142	38.3	157	165	40.4
32.0	298	149	8.0	5.5	13.0	282	51.3	8.97	4080	63.2	424	475	124	4.42	59.3	91.8	32.9	86.5	92.9	32.0
250 UB 37.3	256	146	10.9	6.4	8.9	234	36.6	6.40	4750	55.7	435	486	108	5.66	77.5	119	34.5	158	85.2	250 UB 37.3
31.4	252	146	8.6	6.1	8.9	234	38.4	8.13	4010	44.5	354	397	105	4.47	61.2	94.2	33.4	89.3	65.9	31.4
25.7	248	124	8.0	5.0	12.0	232	46.4	7.44	3270	35.4	285	319	104	2.55	41.1	63.6	27.9	67.4	36.7	25.7
200 UB 29.8	207	134	9.6	6.3	8.9	188	29.8	6.65	3820	29.1	281	316	87.3	3.86	57.5	88.4	31.8	105	37.6	200 UB 29.8
25.4	203	133	7.8	5.8	8.9	188	32.3	8.15	3230	23.6	232	260	85.4	3.06	46.1	70.9	30.8	62.7	29.2	25.4
22.3	202	133	7.0	5.0	8.9	188	37.5	9.14	2870	21.0	208	231	85.5	2.75	41.3	63.4	31.0	45.0	26.0	22.3
18.2	198	99	7.0	4.5	11.0	184	40.9	6.75	2320	15.8	160	180	82.6	1.14	23.0	35.7	22.1	38.6	10.4	18.2
180 UB 22.2	179	90	10.0	6.0	8.9	159	26.5	4.20	2820	15.3	171	195	73.6	1.22	27.1	42.3	20.8	81.6	8.71	180 UB 22.2
18.1	175	90	8.0	5.0	8.9	159	31.8	5.31	2300	12.1	139	157	72.6	0.975	21.7	33.7	20.6	44.8	6.80	18.1
16.1	173	90	7.0	4.5	8.9	159	35.3	6.11	2040	10.6	123	138	72.0	0.853	19.0	29.4	20.4	31.5	5.88	16.1
150 UB 18.0	155	75	9.5	6.0	8.0	136	22.7	3.63	2300	9.05	117	135	62.8	0.672	17.9	28.2	17.1	60.5	3.56	150 UB 18.0
14.0	150	75	7.0	5.0	8.0	136	27.2	5.00	1780	6.66	88.8	102	61.1	0.495	13.2	20.8	16.6	28.1	2.53	14.0

Structural Steel Connections:

A critical element in the design of a structural steel frame is the connections.

For simplicity we will look at two key types of connections:

- A pinned or flexible connection allows for the transfer of shear loads in both the vertical and horizontal planes (F_x* & F_y*), but no bending moment.

- A fixed or rigid connection allows for the transfer of shear loads in both the vertical and horizontal planes (F_x* & F_y*), plus the transfer of bending moments (M*) through the joint.

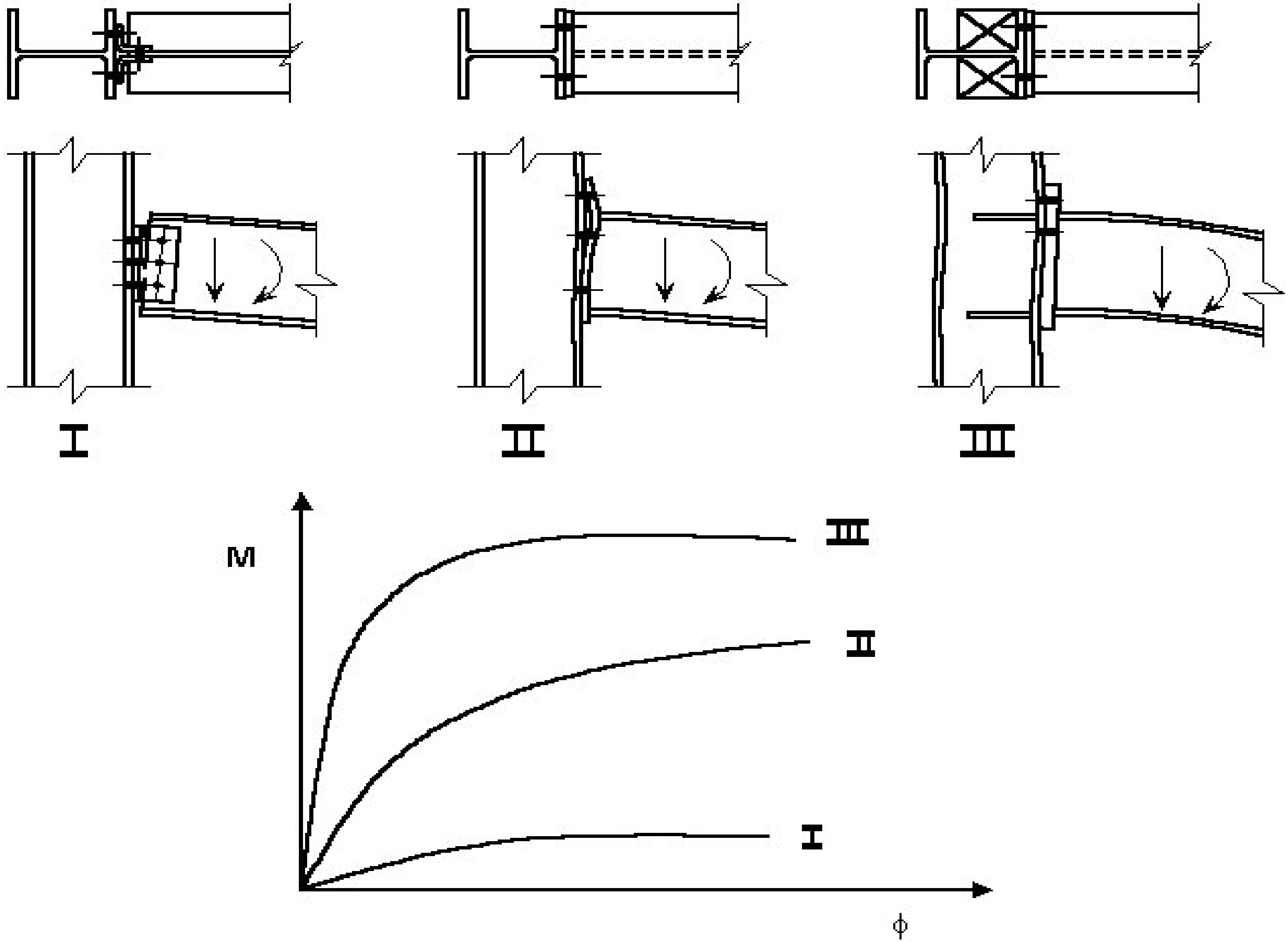
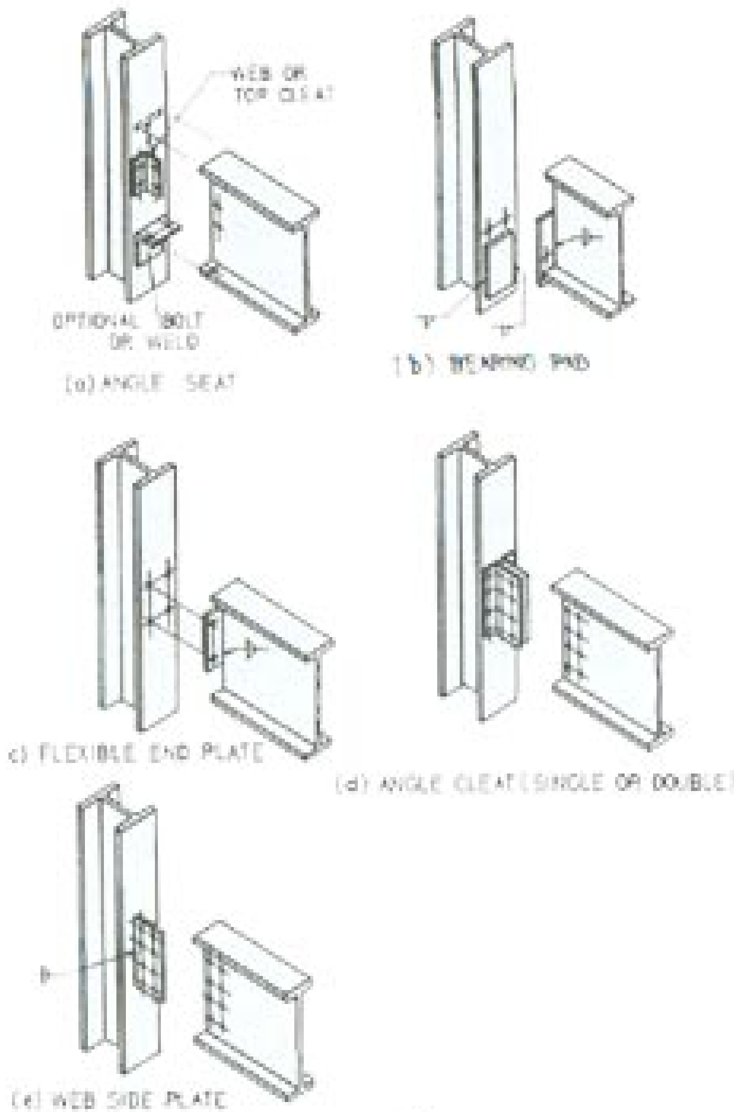
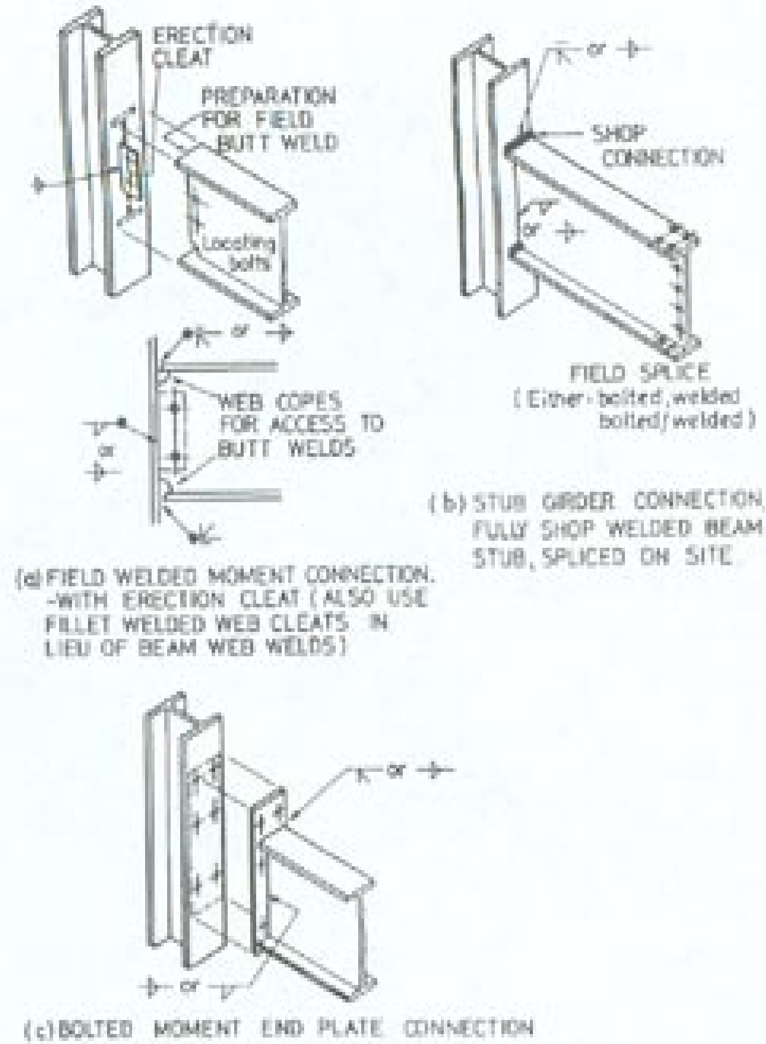


Figure 4 Moment-rotation diagrams (M- ϕcurves)



Flexible Connection



Rigid Connection

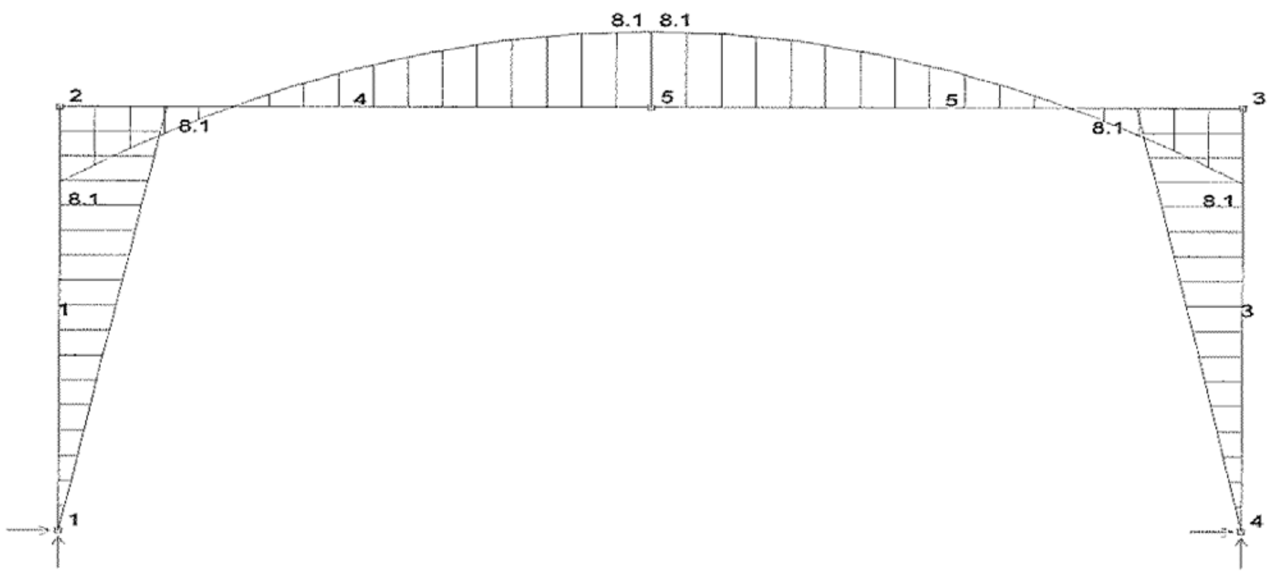
How are the connections critical to the design of a structure?

Structures with fixed or rigid connections transfer moments which thereby reducing the bending capacity required and deflection across a member.

For example:

- An unrestrained 200UB18.2 (6m long) with **fixed connections** at either end, carrying a dead load of 0.5kPa and subjected to a wind load of 1kPa over a load width of 6m will deflect 7.8mm with an M* of 8.1kNm. This represents a deflection is 1/769 whilst the bending capacity of this section is not exceeded $M^* < \phi M_b$ (11.6 kNm for L_e=6m).

- An unrestrained 200UB18.2 (6m long) with **pinned connections** at either end subjected to exactly the same loading pattern will deflect 19.2mm with an M* of 16.2kNm. This represent a deflection of 1/312 however the section actually fails in bending $M^* > \phi M_b$ (11.6 kNm for L_e=6m).


8.1 8.1
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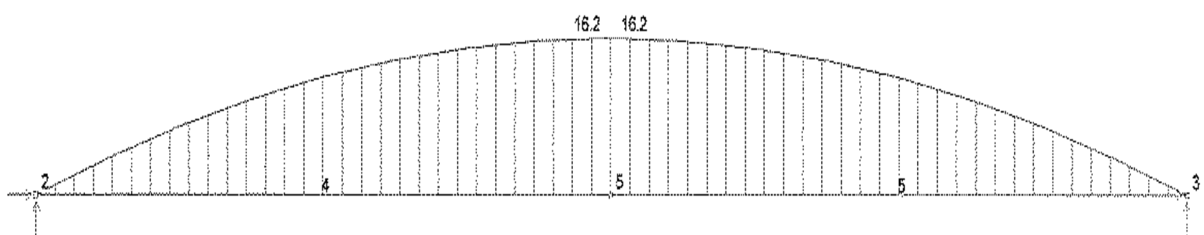

16.2 16.2
2
4
5
5
3

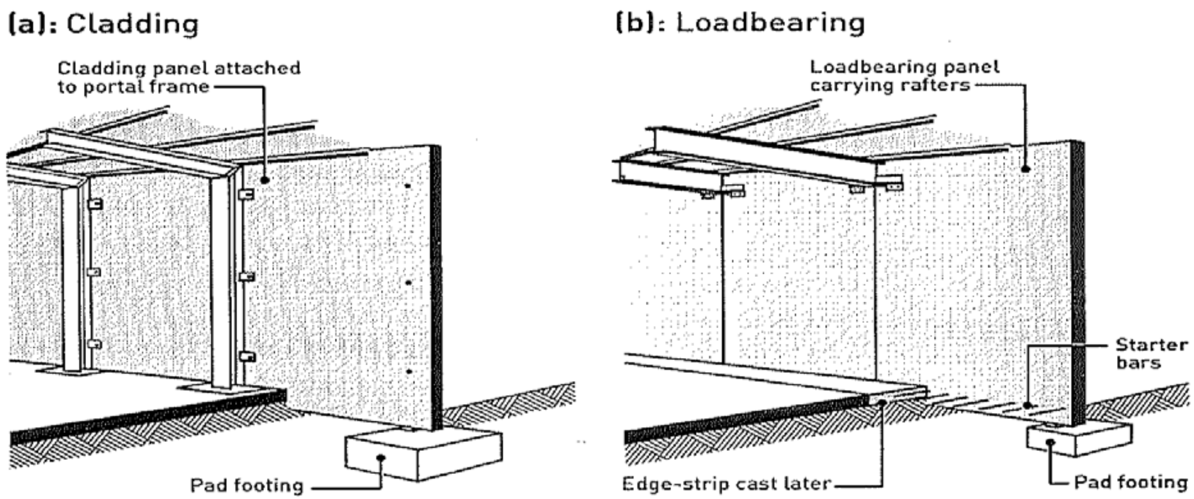
If a steel fabricator modifies the connection type without the Engineer's approval, this could possibly result in excessive deflection or at worst, catastrophic failure.

Below is a checklist of basic items which should be checked when inspecting erected structural steel:

- Steel section sizes match structural plans;
- Frame connection types match structural plans;
- No gaps exist between end plates and columns at connections;
- Base connections and tie-downs match structural plans;
- Bolts are correct diameter and are tightened as required;
- End plates, cleats and stiffeners at connections match structural plans; and
- All roof bracing, fly bracing and wall bracing have been installed as per structural plans.

Tilt Panel Buildings

Concrete panels can be used either as cladding to the building or as part of the load bearing structure supporting roof and wind loads. For the purposes of this presentation, we will be examining tilt panel buildings with load-bearing structure for low-rise industrial and commercial buildings.

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Tilt-panel buildings have several advantages over conventional masonry construction such as:

- Fast to erect;
- Strong under compression;
- Good fire rating;
- Good sound insulation;
- Good thermal properties;
- Good aesthetic properties;
- Cheap to produce; and
- Can create a range of different shapes.

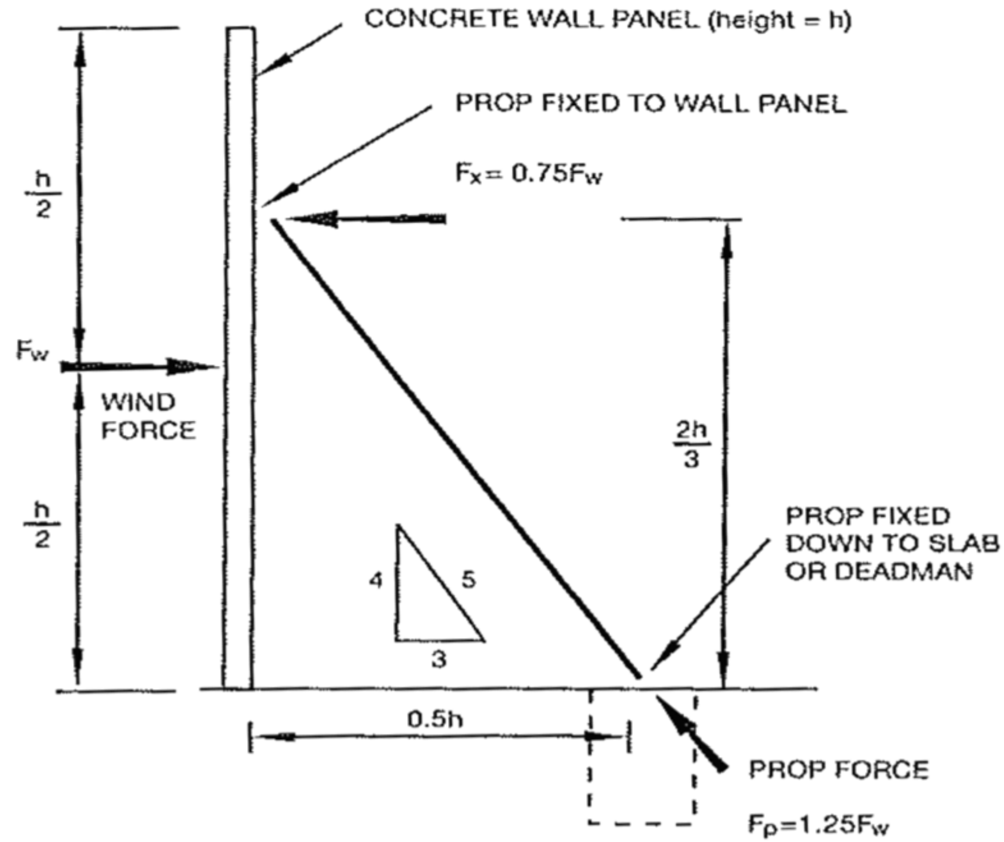
Temporary Bracing (Props):

Temporary bracing is used to support the panels prior to their incorporation in the final structure.

Important points to note are as follows:

- The anchorage of braces on either end must be secure;
- Each panel should be supported by a minimum of two uniformly loaded braces;
- Braces should be placed at an angle of 4:3 as per figure; and
- The Structural Engineer should inspect and approve erected structural steelwork prior to the removal of any temporary propping.

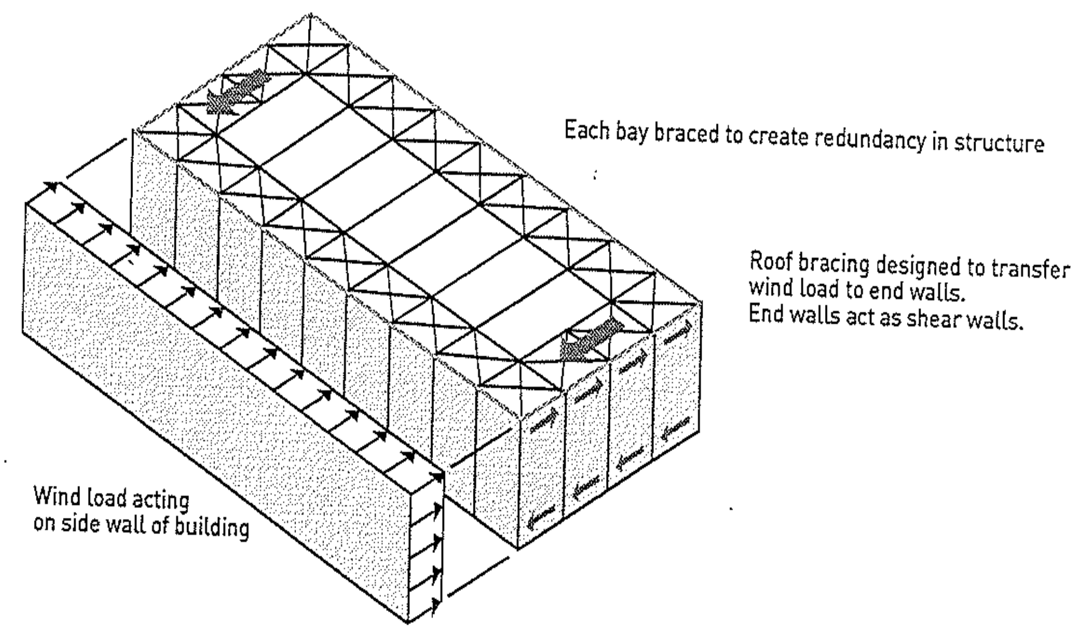
Falling panels have resulted in several deaths over the last decade.

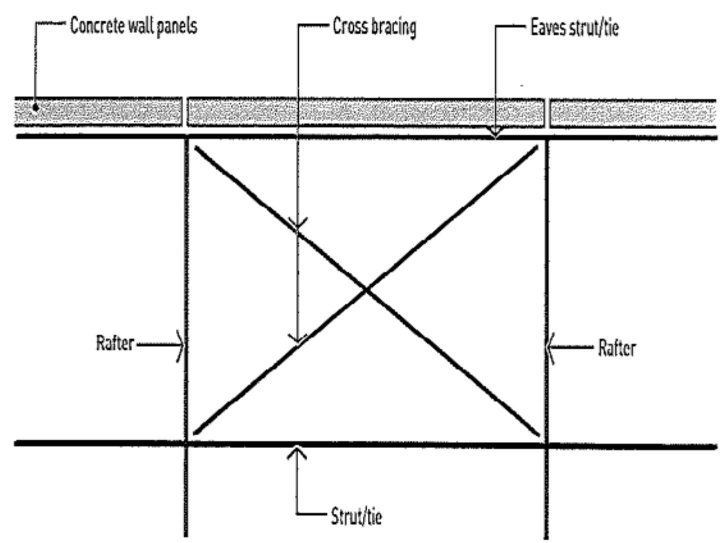


Typical Bracing Set-Up

Structural Steel Roof Framing:

Each bay must be braced in order to transfer the lateral loads on the walls to supporting cross walls.





The angle supporting the rafter ensures minimum eccentricity of the vertical load being transferred to the panel and limits the transfer of moments from the rafter into the panel.

Fully bolted end plate connections will transfer moments into the panel making the top row of ferules susceptible to pullout. In addition, insufficient tolerance will allow the lateral forces to be transferred into adjacent panels effectively connecting the panels and imposing high loads on the cast-in inserts adjacent to the edges.

During an inspection of erected structural steel it is therefore essential that connections have not been modified from the Engineer's construction drawings.

Below is a checklist of basic items which should be checked when inspecting erected structural steel prior to prop removal:

- Steel section sizes match structural plans;
- Rafter to panel connections match structural plans;
- Eaves strut connections match structural plans;
- All roof bracing, roof struts and fly bracing have been installed as per structural plans; and
- Bolts are correct diameter and are tightened as required.

Other Items:

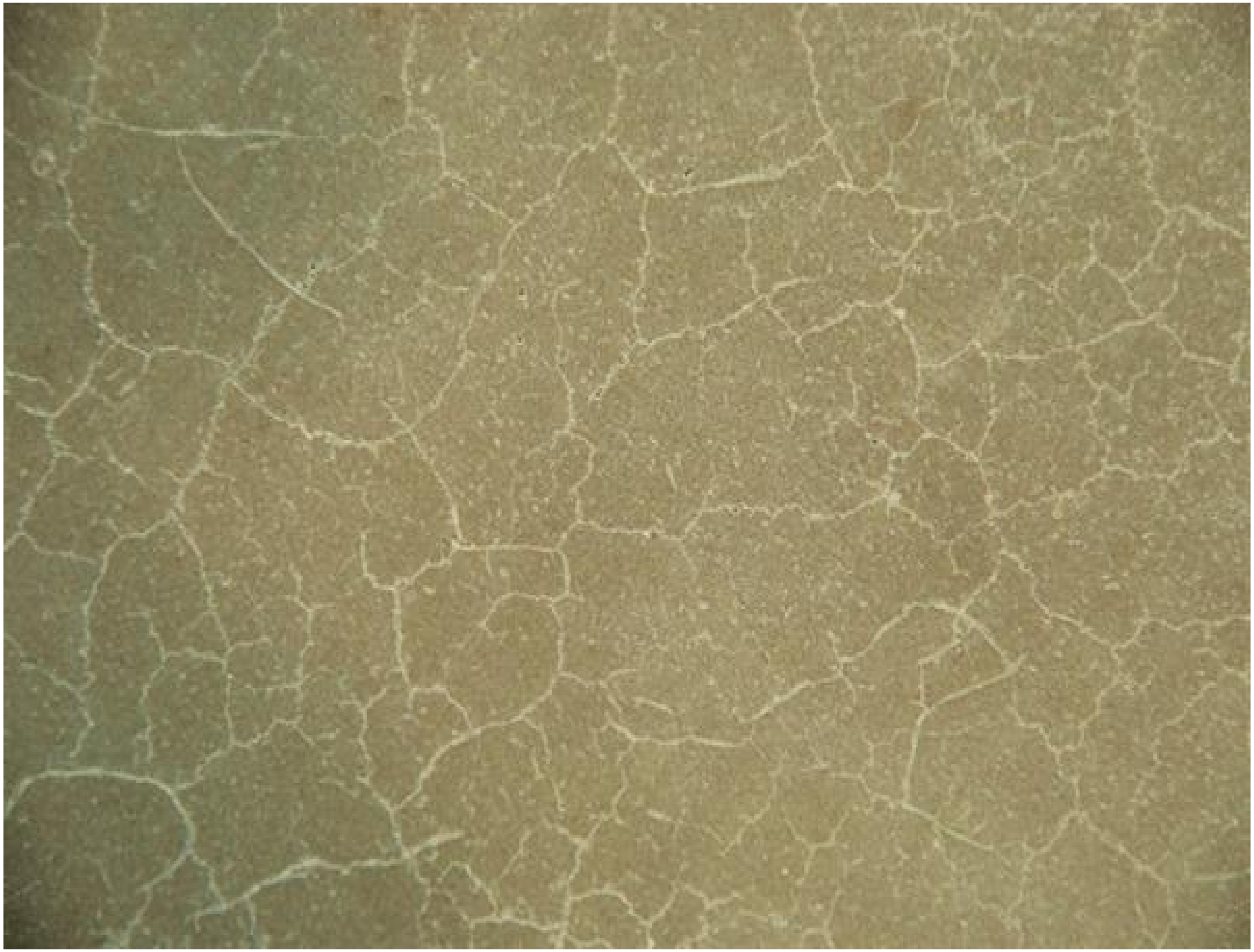
- Panel reinforcement plus threaded insert and lifting lug locations prior to pour;
- Adequacy and fixing of temporary props; and
- Engineer’s Certification regarding panel collapse during fire.

Residential Concrete Slabs

Below is a checklist of basic items which should be checked when inspecting residential concrete slabs prior to the pouring of concrete.

Physical Properties:

- Depth and width of edge and internal beams;
- Thickness of slab;
- The presence of contraction or construction joints;
- The installation of an impact resistant water-proof membrane beneath the slab and beams. This membrane should be taped at joins; and
- As a rule of thumb, concrete should be only poured between 5 degrees Celsius & 32 degrees Celsius.



Reinforcement:

- Size of slab mesh;
- Reinforcement diameter and quantity in edge & internal beams;
- Height of reinforcement chairs to match required cover;
- Cover maintained on edge and internal beams to walls of excavation;
- Laps and joints in reinforcement should comply with the Engineer’s plans;
- Size and location of re-entrant bars;
- Cuts in slab mesh for contraction joints as required;
- Welding of bars must be approved by the Engineer. Generally, tack welding may be permitted for residential slabs-on-ground;
- It should be noted that construction joints will use N bars (ribbed) whilst contraction joints will use R (smooth) bars. These bar types cannot be substituted; and
- The surface of the reinforcement should be free from rust, mud or grease.



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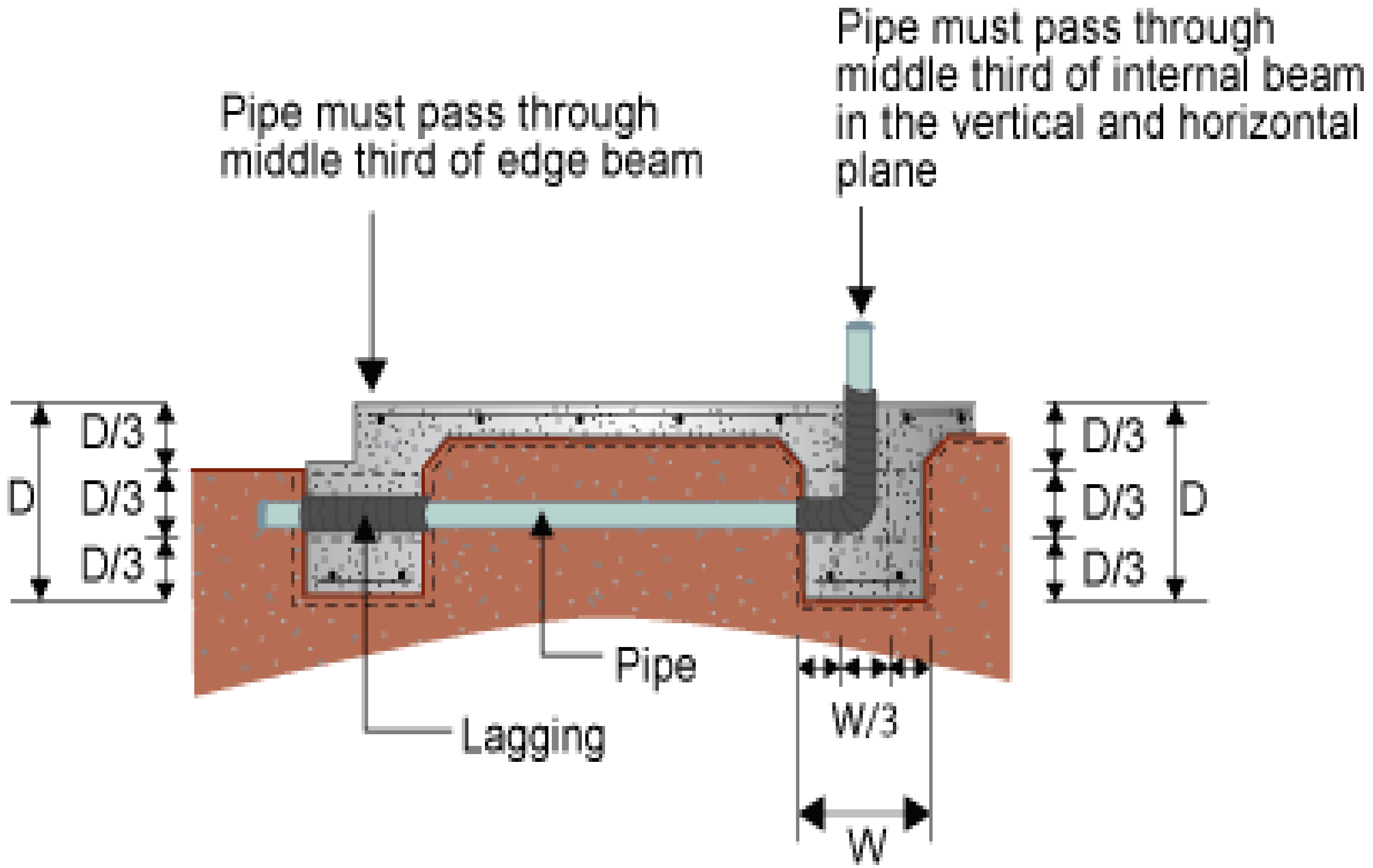
Pipe Penetrations:

- Pipes must pass through the middle third of beams to ensure that the strength of the beam is maintained. Where pipes penetrate the beams, additional strengthening of the edge beam with steel reinforcement or depth of concrete should be used; and
- The lagging of large pipe penetrations through slab and beams is required. 10mm thick *Abelflex* or similar should be used. Trimmer bars may also be required around large pipe penetrations.



Pipe must pass through middle third of internal beam in the vertical and horizontal plane
Pipe must pass through middle third of edge beam
D/3
D/3
D/3
D
D/3
D/3
D/3
D
Pipe
Lagging
W/3
W

Thank you for your time.

A copy of these notes may be obtained by Emailing me directly at tony@dcengineers.com.au

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