Economical Structural Steelwork

edited by

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AUSTRALIAN STEEL INSTITUTE

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8. Detailing for Economy

8.1 Detailing on Design Engineer's Drawings

It is in the design offlce that the potential economy of any steel structure is effectively determined. Judicious decisions on details at this stage can provide for simple, economic methods to be used at the fabrication stage.

The designer is faced with the problem that a different fabrication and erection technique could be favoured by each individual fabricator likely to tender for the project. It is a good idea at the outset for the designer to have some preliminary discussions with likely fabricators and steel detailers to check on latest techniques prevailing in the industry. From these discussions the design and detailing approach for the structure can be carried out with factors in uencing economics flrmly in mind.

In the normal course of events a steel structure passes through several separate stages involving design, detailing, fabrication and erection. With this in mind, it is important for designers to remember that a minimum of design detailing by them will assist towards economy, since the steel detailer is then left free to make the most efflcient use of the particular fabricator's capabilities (Ref. 2.12). The need for this exibility is often overlooked by designers in their anxiety to specify their requirements.

Such things as a fabricator's ability to fabricate large sub-assemblies in the shop and subsequently transport to site and erect them will obviously have a bearing on the design of connection types and therefore on the economy of the overall project. In this regard it must be stressed that a maximum of work done in the workshop will almost always produce better quality and more economical structures.

In the presentation of working drawings therefore, the basic key is 'communication' which normally takes place through a chain as illustrated in Figure 8.1.

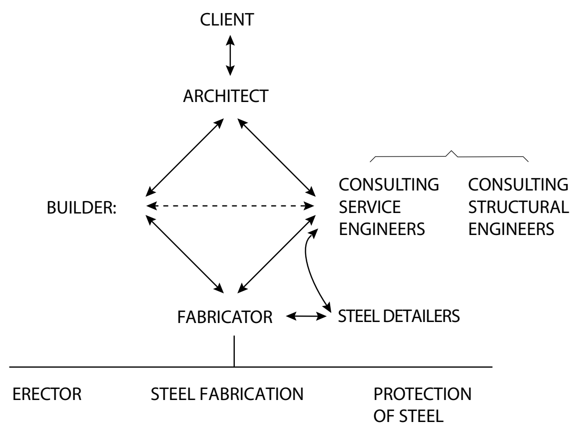


FIGURE 8.1: Chain of communication

The processes involved in the design can be summarised in the following sequence:

- Initial communication.
- Structural concept including consideration of connection types.
- Integrated design.
- Connection detailing.
- Framing plans.

The Engineer's structural framing plans must contain all the necessary information to enable the fabricator to have shop drawings prepared for the individual members, as well as the marking plans to identify each member for the erection phase.

Guidance for designers is provided by the Australian Institute of Steel Detailers Contract Documents Completion Checklists, Ref. 8.1.

The following discussion is intended to highlight aspects of the detailing of both members and connections to achieve economy in the overall fabrication and erection of structural elements.

As an additional consideration the use of ASI: Connections Design Guides – First Edition 2007 (Ref. 1.) will enable designers to specify standardised connections directly from the publication without detailing, and if necessary permit alternatives to be offered by the fabricator with the confldence of assured design capacity and behaviour.

8.2 Beams

8.2.1 GENERAL

The simplest and therefore the most economic beams in structures will be of rolled universal sections. Wherever possible, it will almost always prove more economic in one-off types of steel structures to use a universal section or welded beam section as a beam, even if a heavier solution results. The alternative fabrication of a three-plate girder introduces plate preparation, assembly and welding, the costs of which will generally exceed the cost of additional material in the rolled universal section or standard WB section, unless a vast amount of repetition is required.

8.2.2 PLATED SECTIONS

Where headroom limitations apply (distance from ceiling sofflt to oor level), it may be necessary to consider plating a universal section of a limited depth instead of choosing a deeper beam. Here, the extra cost of supplying plates, assembling and welding causes the cost of the member to rise and a plated solution should only be used when a net saving in cost results compared to other feasible alternatives.

Attention to the detailing of the member will assist in keeping fabrication costs down. For example, selecting cover plate widths as shown in Figure 8.2 will allow the

8. Detailing for Economy

welding of both plates to the beam to be done in the downhand position without the need to turn the member during fabrication.

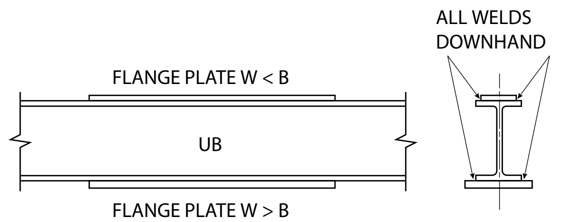


FIGURE 8.2: Plated sections

8.2.3 WEB PENETRATIONS IN BEAMS

Holes cut in the webs of beams to provide access for service ducts have proved to be very costly in the past due to uneconomic detailing. This is due to the fact that, traditionally, these openings have been compensated for by the provision of extensive stiffening systems around the openings (see Figure 8.3(a)).

The position of such openings in the beam length obviously has a major effect on the degree of stiffening required – openings near the centre of uniformly loaded beams will require little or no stiffening, while openings placed near the supports may require stiffening. An early dialogue between the structural engineer and the building services designer can lead to ducting being located in a favourable position structurally without detriment to service requirements.

Plain circular openings as shown in Figure 8.3(d) obviously represent the most economic solution. These can be cut by automatic means and result in minimum additional fabrication costs. If additional stiffening is required for round holes, it is most economic to use a pipe piece, fillet welded to the beam web (see Figure 8.3(c)).

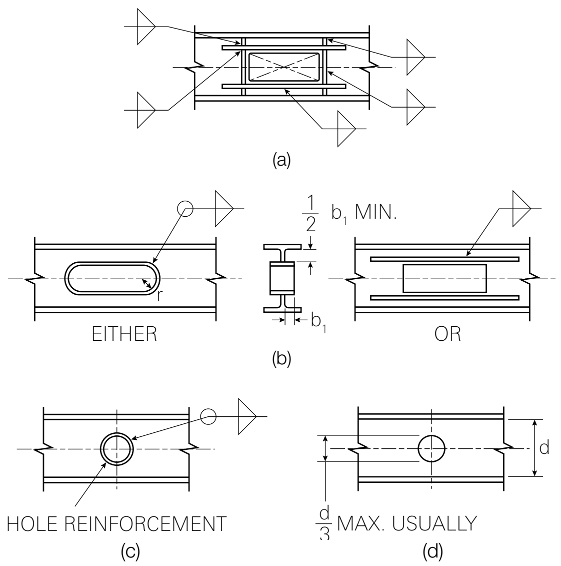


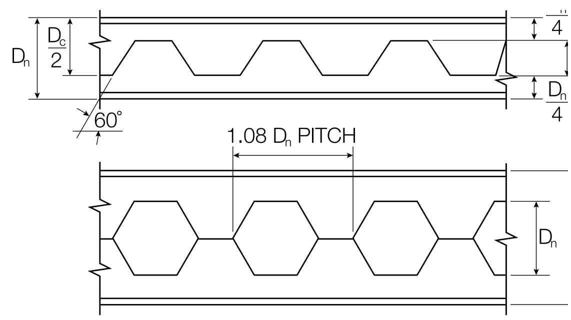
FIGURE 8.3: Web penetrations in beams (in descending order of cost, (d) being least costly)

Where rectangular holes cannot be avoided and stiffening is necessary, this can be economically accomplished by a web hole with half-pipe cuttings and make-up plates or, alternatively, simply reinforcing the beam web using square edge at bars fillet welded to one side of the beam web as shown in Figure 8.3(b).

By judicious planning, the duct penetrations required in beams should be selected in position, size and shape to gain maximum economy in the fabrication of such beams.

8.2.4 CASTELLATED BEAMS

Castellated beams are fabricated by cutting a profiled line in the web of a universal beam – Figure 8.4. Circular profiles in lieu of the hexagonal profiles are also available from fabricators using computer controlled fabrication equipment. The beam halves are then offset longitudinally and the part webs welded on member centreline.



D_c = overall depth of castellated section
D_n = nominal depth of original section
D = actual depth of original section

$$D_c = D + \frac{D_n}{2}$$

Example:
original section = 530 UB 82
D_n = 530 D = 528
D_c = 528 + 265 = 793

FIGURE 8.4: Typical castellated beam geometry

The use of castellated beams in steel structures is often seen as a method of increasing beam strength while using the same mass of material. While many instances have been reported where savings have been effected, it must again be remembered that a fabrication cost has been introduced which could be larger than the saving made in material cost – depending upon the quantities required and the methods used.

The cost involved for this additional fabrication varies depending on the equipment available within individual fabrication shops. In some cases, problems can be encountered with distortion of the beam during cutting, thus requiring subsequent straightening of the members and adding further to the cost. In general, most fabricating shops are now well-equipped to undertake the fabrication of castellated beams, but designers should carefully investigate the relative cost differences with the industry before specifying this type of section.

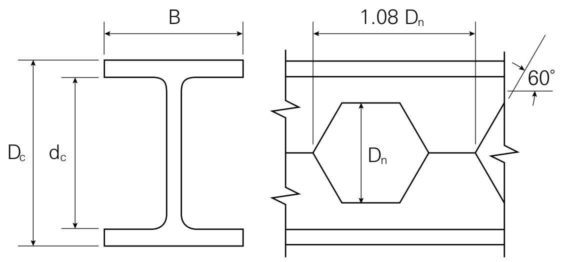


FIGURE 8.5 : Evaluation of economics of castellated beam

COST COMPARISON

DESIGN PARAMETERS:	Span 7m full restraint, Grade 300 steel W* = 900 kN	
ROLLED SECTION SOLUTION:	610UB113 Mass = 113 kg/m	
CASTELLATED BEAM SOLUTION:	800CUB82 cut from 530UB82 Mass = 82 kg/m	
COMPARISON OF COST INDICES:		**Cost Index**
Rolled Section (610UB113):		1.00
Castellated Beam using CNC Equipment:		1.15
Castellated Beam w/o CNC Equipment:		1.55
CONCLUSION:	Rolled Section is a more economic solution in this instance. Each individual situation should be readily assessed based on using updated cost information.	

In the example shown in Figure 8.5 the heavier 610UB113 would be more economic than the castellated 530UB82. This example highlights the need to consider each case on its merits by applying up-to-date cost data to the examination of the alternative solutions.

8.2.5 THREE-PLATE GIRDERS

Where beams are required of greater depth than the largest universal beam, consideration should be given to three-plate girders or the standardised range of welded sections. These will most often offer more economic solutions than trusses for such applications as oor supporting beams. Three-plate girders are fabricated in modern automatic assembly and welding machines using the submerged arc welding process.

In designing and detailing three-plate girders the following considerations are important in achieving economy:

- Use flat bar or preferred plate widths and thicknesses for the ange and web plates.
- Use edge trimmed plate of preferred width wherever possible for the web plate to avoid additional cutting in the fabrication shop. This type of prepared plate can be fillet welded to the ange plate without further preparation of the edge.
- When considering changing the flange width or thickness in order to reduce mass, take account of the lengths of plate available and whether continuation of an 'oversize' plate is a more economical solution than introducing butt welded splices in the ange plate. As a rule of thumb, it is probably economic to change the ange thickness when:

  Steel mass saved in ange > 100 × mass of weld metal required.

Where lengths of girders are such that butt welded splices are necessary, locate the changes of ange plate size to suit the available lengths of plate.

- The cost increase for three plate girders with stiffened webs against unstiffened webs is about 10-25%, depending on the detailing adopted. Consequently, when evaluating whether to use a stiffened rather than an unstiffened web, the cost saving due to the reduced mass of the web plate with a stiffened web must exceed this cost differential, for the stiffened web solution to be economic.
- If using a vertically stiffened web, use one sided stiffeners to avoid having to turn the girder during fabrication (see Figure 8.6). Terminate intermediate stiffeners by the allowable '4t' from the ange (see AS 4100) – this avoids cutting stiffeners accurately to length (see Figure 8.6).
- Avoid the use of horizontal web stiffeners if at all possible.

The example shown in Figure 8.7 illustrates an evaluation of the relative economics of stiffened vs. unstiffened webs in a typical three-plate girder application.

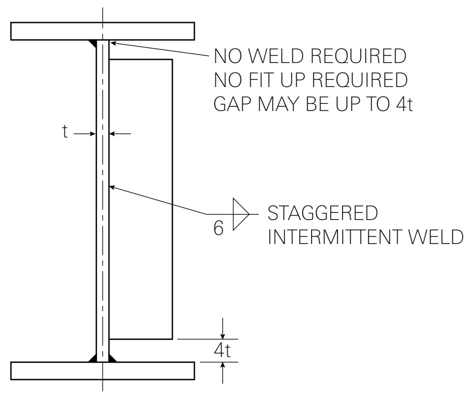
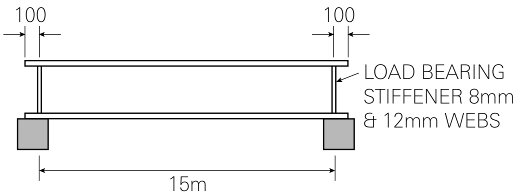
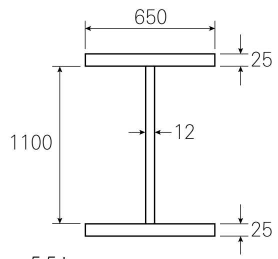


FIGURE 8.6: One-sided intermediate web stiffener



UNSTIFFENED WEB

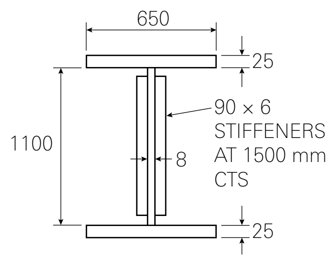


Total Mass	= 5.5 tonnes	
Cost Ratio	= 1.0	
Mass × Cost Ratio	= 5.5	[Cheaper Solution in this case]

INTERMEDIATE STIFFENED WEB

Either:
Stiffeners: 90 × 6 square edge at bars, both sides, at 1500mm centres (18 off)

Or:
Stiffeners: 90 × 6 square edge at bars, one side, at 1500mm centres (9 off)



Total Mass	= 5.0 tonnes
Cost Ratio	= 1.25 for two sided (av); 1.15 for one sided (av)
Mass × Cost Ratio	= 6.3 two sided; 5.7 one sided

The unstiffened web solution is most often the most economic solution but it is not intended to suggest that this is always so.

Each individual situation can be readily assessed by the above process using updated values of the cost ratio for the stiffened web solution.

FIGURE 8.7: Stiffened and unstiffened webs in three plate girders

8.3 Columns

8.3.1 GENERAL

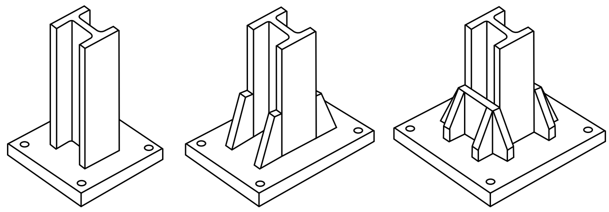
The most economical columns in most building frames will usually be universal beam or column sections. These sections are available in a range of sizes which suit most applications. For applications where good appearance is important, square hollow sections could be considered.

In high-rise buildings it is often economical to consider composite columns, where a relatively small universal column is sufflcient to carry dead and construction loads and which, when encased in concrete, becomes a composite column able to carry additional live loads (see Clause 5.5.2).

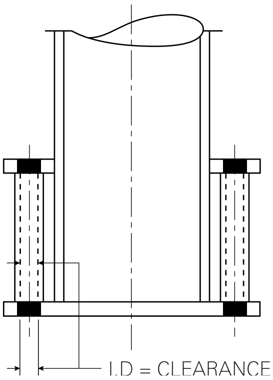
8.3.2 COLUMN BASE PLATES

In the design of column base plates, it is advisable once again to question the wisdom of minimising the mass of material and so introduce extensive fabrication, compared to a heavier base plate simply welded to the column shaft.

Figure 8.8 shows three alternative details for moment resisting base plates.



(a) Slab base plate. (b) Extended ange slab base. (c) Gusseted base plate – avoid, too expensive.



(d) A pipe sleeve allows easy entry of anchor bolts in a double baseplate.

FIGURE 8.8: Column base plate details (moment resisting or fixed)

Slab base plate (a) is used widely. It calls for a thicker base plate than the gusseted base plate (c) but requires far less labour for fabrication and therefore it is more economical. Column anges can be extended as shown in (b) to present a larger bearing surface.

Fillet welds should always be preferred for welding the column shaft to the base plate. Only in very rare instances will complete penetration butt welds be required – these should be avoided if possible for maximum economy.

Typical details for pinned base plate connections are shown in Figure 8.9. For the nominally pinned base, there is no need to provide true pin or rocker connections as these are unnecessarily expensive to fabricate. It is recommended that the base plates for main frame columns be of the four-bolt hole type in order to stabilise the columns during the erection stage. Two-bolt hole base plates are satisfactory for secondary columns.

Standardised dimensions for 'pinned base' plates are available in ASI: Connections Design Guides – First Edition 2007 (Ref. 1).