Cost Effective Steelwork Design for Fabrication

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INTRODUCTION

Structural Steel is still a relatively new material to be used entirely in the design and construction of buildings in Malaysia. This is in contrast to Europe and America, where steel structures are utilised in most of their new structures whether it is for public or commercial uses. Over here steel structures are predominantly limited to factories, manufacturing plants and industrial plants etc.

Over the past 15 years, the cost of steel sections in Malaysia has increased dramatically. The rise of Perwaja Steel in the mid 90's to overcome the cost and shortage of structural sections did little to spruce up the steel consumption locally and hence led to its closure of the structural sections mill at the turn of the century.

With rising cost in raw material and labour, it is evident that cost effective design, detailing, low weight (to a certain extent) and buildability concept should be employed to achieve an overall economic advantage.

Low weight structures should not be confused with least weight structural solutions which very rarely produce the most cost effective designs as generally low weight structures are more labour intensive per tonnage weight.

This technical note is compiled from recommendations driven by the steel industry's which educates designers on buildability and detailing issues which subsequently reduce fabrication cost.

PREFERRED CONCEPT FOR STRUCTURAL FORM

Some of the basic 'ideals' which will encourage economical solutions are as follows:

1) Structure should be a 'braced' where possible rather than an 'unbraced' structural frame. Lateral loads should be resisted via a stiff vertical braced element.
2) The arrangement of structural members should be on a regular, orthogonal grid for direct load path and also to give maximum component repetition.
3) Economic steel weight solutions in many buildings can be achieved by composite floor construction.
4) The maximum size and weight of member should commensurate with the site logistic, transportation and craneage available.

During the conception of structural solutions options, an overall compromise has to be reached which recognises the interaction between related cost areas, and unless this process is extended from material specifications to fabrication and site erection, cost perception may become distorted.

CONNECTION DESIGN AND DETAILING

Steelwork connections and detailing attribute almost 30% of the cost of typical frames. Connections details are largely dictated by the design concept which is the key factor in determining how the structure will be made, how it will be transported, and how it will be assembled on site. Therefore, it is imperative that designers have a good rounded knowledge of all aspect of steel construction during the preliminary design stage as design in isolation will risk an adverse cost penalty.

In the early 90's, the Steel Construction Institute in UK have produced design and detailing recommendations for simple steelwork connections. These have now been accepted as the UK industry standard. As a matter of fact, we should adopt these as our own as they are highly versatile and simple in their approach to connections design and detailing. The major benefits of these guides include:

- rationalisation of the different types of connection to those which are compatible with modern fabrication process and erection methods
- promotion of standard wide flats and

angles for fitting and M20 8.8 fully threaded bolts throughout. (thereby improving the efficiency of stock control and purchasing)
- holes in fittings should where possible be punched and welds comprise of single pass fillets (thereby streamlining production)
- capacity tables developed for standard details (thereby minimising the design and detailing effort expended)

Other recommendations that need to consider in addition to the above are:
- keep details simple and repetitive to reduce drawing office and workshop time
- Standardise bolt sizes, pitches and centers (each time a hole diameter is altered, if delay results while the drill bit is changed)

COST OF CONNECTIONS

Cost of connections will vary depending on the fabrication effort required. Many designers are unaware of the relative cost of connections–consequently, the indiscriminate, and unnecessary, specifications of full-strength or fully welded connections are commonplace. Bear in mind, that connections classification for beam to column are either 'simple', moderate or complex, where a full moment connections are often classified as 'complex' henceforth. The fabrication effort for 'complex' connections simply to reduce weight in structural frames is a false economy as the cost for producing 'complex' connections far outweighs the weight saved.

RATIONALISATION OF SECTION TYPES

The number of section and grades used in the design should be rationalised so that its benefits can be reaped. The benefits are:
- repetitive details and dimensions
- reduced design and fabrication efforts

In general the feasibility of rationalisation is project specific and the following guidelines will be generally applicable:

i) total weight of any one section types less than 10t should be avoided

ii) sections should be rationalised if the total increase in weight is less than 20%.

E.g. preferably, columns section should be spliced at intervals of 3, 6, 9 or 12m. In addition, one should also consider the weight of the column concerned where craneage limitation could dictate the splice locations.

MATERIALS SELECTION

Materials grades should be consistent for all elements. Generally, grade 50 is most cost effective in design. However, steel stockist do not ordinarily stock grade 50 steel sections. Therefore, where quantities are less than 150t or, where sections are required at short notice, grade 43 steel should be specified. Fittings are generally in Grade 43 steel.

WELDING

Welding and weld preparation are among the most cost intensive aspects of steelwork fabrication and erection. The relative cost to a 6mm fillet weld can be in the region of 2 to 15 for a 20mm plate single V-butt.

Very often, welds are over specified, with full penetration butt welds being specified where a partial penetration would suffice or fillet welds being used which are significant larger than the minimum required. However, a small increase in the size of fillet welds can have a disproportionately large effect on cost.

Butt welds involve preparation, which is costly if done manually. Nevertheless, for fillet welds larger than 12mm, butt welds will often provide a more cost effective solution.

If access for welding, and or for the subsequent testing of the weld is impeded, then the cost can also increase indirectly.

PAINTING

Elaborate paint specifications are unnecessary and can add up to 25% onto the fabrication cost which for most structure is an avoidable expense. Experience shows that unpainted steelwork can remain structurally sound, substantiating the case for no protection where the building provides a stable and dry environment. Where priming protection is specified, the function, environment and possible maintenance requirements should be considered in each case rather than adopting a 'blanket' philosophy.

DRAWINGS AND SPECIFICATIONS

It is imperative that the design intentions are correctly conveyed on contract documentations. This is particularly true where the fabricator doubles up as specialist contractor where they undertake alternative full design or simple connections design only from section sizes and forces supplied by the engineer.

Very often, unnecessary costs accrue from misunderstanding or assumptions made where information has been omitted. The following should be observed as a minimum:

- identify loading sources for force and moment components so that the correct combinations and load factors can be applied in the design. For simplicity the value of the forces can be given in ULS.
- highlight tying forces arising from the integrity requirements in BS5950 (these forces are catered for in isolation and large connection deformation can be assumed in the design)
- provide details of frame philosophy (highlight lateral stability system)
- identify where the following are required: HSFG connections
  Insitu welding
  Moment connections

Onerous requirements for construction tolerances and quality will have an effect on the cost of steelwork. It is advisable to use Standard Specifications such as those produced by the BCSA with SCI i.e National Structural Steelwork Specification should be used.

DO'S AND DON'TS DETAILS WHICH INFLUENCE COSTS

- Use standard flats or structural tee sections for fin plates to SHS bracing members.
- Avoid snipes or rounded corners at the ends of fin plates.
- Use less than 16mm thk plates to avoid through thickness testing
- Avoid stiffening at connections.
- Use standard connections detailing where possible such as those publish by SCI and CIDECT.
- Minimise d/t of chord and maximise d/t for braces (for CHS and RHS)
- For RHS use either gap or full overlap joints – not partial overlap
- Minimise fabrication effort to allow earliest delivery to site.
- Typically provide splices at three storey intervals or at 6, 9 or 12m height.
- Avoid thin stiffened baseplates, use thick unstiffened baseplates
- Only use 'all round' welds to base plates where necessary.
- Avoid changes in serial sizes at splices.
- Avoid web stiffeners, use heavier sections with thicker webs rather than large number of stiffeners
- For maximum efficiency use $\frac{\text{Secondary span}}{\text{Primary span}} = \frac{4}{3}$
- Use partial interaction design in composite design whenever possible (reduces number and hence cost of shear connectors)
- Avoid varying spacing and use either single or double rows of shear connectors.

REMEMBER THAT MINIMUM MATERIAL WEIGHT IS NOT NECESSARILY THE LOWEST COST

It will be apparent that a number of these aims will conflict when viewed collectively. For example, reducing the number of different components may be possible only at the expense of more complicated details, and decisions cannot be made in isolation without risking an adverse cost penalty.

The decision of particular emphasis remains a matter of calculated and experience judgment to minimise overall cost, and this will largely depend on the nature and extent of the work. ■

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