

1. OBJECTIVE

The objective of the guidance note is to identify the factors that control costs in welded fabrication and offer solutions to control or minimise such cost. The ultimate objective is to make the Australian fabrication industry more competitive by reducing fabrication costs.

2. INTRODUCTION

In civil structures fabricated steel structures are losing ground to concrete structures, and in engineering structures Australian fabrication is losing ground to imported fabricated structures. The main reasons for such changes are as follows:

- a) High cost of raw materials;
- b) High cost of domestic fabricated steel products due to higher local wages and overheads;
- c) Poor adherence to production and delivery schedules;
- d) Poor adherence to construction specifications and perceived poor quality.

This note identifies the cost elements involved in steel fabrication and provides some brief guidance to Fabricators on controlling costs during the fabrication of metal structures. One re-occurring cost element entirely under control of the Fabricator is re-work. Methods of minimising re-work are offered.

3. COST ELEMENTS

There are many cost elements associated with welded fabrication – some under the control of the Client (i.e. the purchaser or operator of the fabrication) and some under control of the Fabricator. Table 1 identifies many of these elements that ultimately need to be addressed. The table has two columns covering those under control of the Client and those under control of the Fabricator. However some elements are applicable to both parties. This note deals primarily with cost elements under control of the Fabricator although purchase of metal, specifications and design apply to both parties.

4. PURCHASE OF METAL

The rise in steel and aluminium costs places the purchase of metal as the most significant item for the fabricator. The fabricator must not get in a position where he is carrying the costs of the material whilst fabricating the product or awaiting payment from the client. Three options to control material costs are:

- a) Get the client to purchase the materials. The client probably has better purchasing power than the fabricator and can get the material cheaper. Additionally the client can probably secure better financial terms for purchase of the material;
- b) Structure the payment schedule such that all materials are paid for by the client upon receipt at the fabricators premises;
- c) Negotiate a deferred payment plan with the metal supplier. Australian metal suppliers now realise that without a fabrication industry there will not be a metal supplier industry. Some suppliers are now willing to supply metal with payment deferred until the product has been fabricated and shipped to the client.

5. SPECIFICATIONS

Rely on national standards such as AS 1554.1 for steel structures or AS 1665 for aluminium structures to cover the fabrication. Avoid producing and issuing client specific standards for welded fabrication. The chances are that the fabricator will not be familiar with client specific standards and will have to invest considerable time and energy amending production and quality systems to cater for “one-off” customer demands. This adds to cost and increases the likelihood of non-compliance.

Table 1. Common cost elements for welded fabrications

Cost Elements	
Client Controlled	Fabricator Controlled
Conceptual Design – Design Base Memorandum and Material Selection	
Project Estimating + Design	
Development of Specifications	Review of Client Specifications
Identification of Approved Fabricators	
Contract Preparation + Tendering + Tender Analyses	Tender Review + Estimating + Initial Production schedule + Bid Preparation
Contract award and pre-job meeting	Pre-job meeting + Production schedule + Critical Path Analysis
Design Changes	Preparation of Shop Drawings, detailed Bill of Material and Cutting Plan
Purchase of Metal (steel, aluminium etc) and specialist supply items for the project	
	Cutting and Stripping
Design Changes Change Control	Shop Fabrication; <ul style="list-style-type: none"> ➤ Fabrication sequence, ➤ Jigging and Fit-up, ➤ Manipulators, ➤ Welding Procedures, ➤ Welders, ➤ Welding Consumables, Production Welding
Auditing	Inspection and NDT
	Rework
	Painting and protective treatment
	Transport to site
	Site Fabrication and Erection
Site inspection	Site inspection and testing

6. DESIGN

Produce the design with ease of fabrication and site erection in mind. Use simple standardised connections whenever possible. Getting the design right means fabrication is simple and cost effective. Poor design means fabrication and later erection costs can be much higher.

Wherever possible design joints that can be made in the flat position and minimise positional welding.

Try to establish designs where fabrications are based on standard truck loads (around 20 Tonne lots) with the structure being able to fit within the standardised truck load dimensions. Such loads are easily transportable without impediments such as wide load permits. When fabricating for site erection ensure each shipment is fully self-contained with all the required brackets, fasteners etc. are included in the delivery package.

Avoid details that minimise weight at the expense of rationalised design. Optimising designs for minimum weight often complicates them unnecessarily. An example of this is base plates, webs and flanges of different sizes and thicknesses. This can lead to an increase in the amount of stiffeners required and the numbers of feed plates and joint configurations required. Such unnecessary complexity increases the potential for non-conformity in fabrication. Standardised design can simplify fabrication, reduce plate inventory and reduce the number of welding procedures. Plate cost is small compared to complicated fabrication costs.

Aim to use *full strength welds* as opposed to complete penetration welds. Complete penetration welds are more difficult and costly to make with the client often requiring NDT to verify joint integrity.

7. PREPARATION OF SHOP FABRICATION DRAWINGS

During the development of the shop fabrication drawings important decisions are made that will ultimately determine the production rate. The appropriate welding process can be identified for each joint and the optimum joint preparation designed at the shop drawing stage.

High productivity welding generally requires welds to be made in the Flat 1G or 1F welding position. It is also necessary to determine a welding sequence to control weld distortion. Consider the following items;

- a) Weld Placement;
- b) Reducing the quantity of weld metal required; - narrow gap welding – high penetration welding techniques
- c) Reducing the number of welding runs;
- d) Sequencing and balancing the welding to control distortion.

The welding techniques and joint configuration chosen will dictate the root gaps required and the overall shrinkage of the structure that must be anticipated. These considerations must be taken into account when determining the dimensions of the parts to be cut.

8. CUTTING AND STRIPPING

Where possible the fabricator should minimise cutting and stripping and contract these activities out. Service providers specialising in cutting and stripping utilise CAD/CAM into their laser and plasma cutting operations. This enables:

- a) cost effective nesting of parts leading to enhanced material utilisation;
- b) high accuracy in cutting leading to good fit up in the fabrication shop
- c) laser marking of cut pieces leading to enhanced traceability.

Many companies utilise machining for the welding bevels. Machining is more expensive than thermal cutting but it enables compound bevels to be produced with precision. This provides extremely accurate fitment of parts to be joined and also increases welding productivity due to less weld metal being required. Reducing weld metal decreases distortion and shrinkage as a result of welding.

9. PRODUCTION SCHEDULE AND CRITICAL PATH ANALYSIS

Fabricator initiated delays resulting from poor scheduling or the inability to recognise the critical path activity or critical path delivery of an item is disastrous for two reasons. Firstly schedule overruns soon eliminate all profit in the project. This is because the project will have been costed based on completing the project within a specific time frame. Secondly schedule over-runs provide an insidious indication that the fabricator is unreliable – the fabricator is likely to lose out on further projects if production schedules cannot be met.

It is imperative then that a production plan is made for every fabrication project. The plan needs to identify all the major purchases that need to be made and the delivery dates of the materials. Secondly all the marking, cutting, jiggling, fabrication, testing and delivery activities needed to complete the project have to be identified. The production plan needs to be reviewed and agreed to by all the parties involved in the fabrication shop including purchasing manager, production manager, quality manager, union stewards and team leaders.

Once the production schedule has been identified, the critical path activity(s) need to be identified and contingency plans put in place to meet the schedule. Against the production schedule a payment schedule needs to be established. Both the production and payment schedule need to be discussed at the pre-award meeting with the client. At this stage it is also necessary to review the penalty implications for not meeting the schedule.

The production schedule will be dependent on the timely receipt of specialist supply items such as dished ends, rolled sections, forgings, castings and machined components. Negotiations with suppliers need to take place early to ensure such parts can be delivered on time.

Provision for rework should be made and consideration of the potential effects on production and delivery schedules.

The fabricator should also ensure that the processes of final inspection, testing and sign off are understood. This is important to avoid issues leading to delays in acceptance and payment by the client.

10. WELDERS

There will be a continual shortage of welders in Australia. The relatively high labour rates in Australia compared with neighbouring countries in South East Asia essentially require Australian welders to be twice as productive as their foreign counterparts in order to remain competitive. The following items have been identified to assist in Fabricators getting the most from their welders:

- Maintain a current welder qualification register;
- Ensure all welders maintain their qualification status by using their qualified welding processes regularly;
- Avoid having to qualify welders prior to each job – welders should be continuously qualified;
- Train all welders how to perform macro examinations so that AS1554 welding procedure and welder qualification can be carried out in-house;
- Avoid using outside laboratories to carry out welder qualification tests;
- Introduce an incentive payment scheme based on the amount of code compliant welding produced by each welder;
- Monitor welders performance and establish quality benchmarks;
- Train all welders in welding inspection (leg length, undercut etc) so they can self inspect to identify and rectify flaws;
- Train all welders in the operation of their specific welding machines so they can perform routine troubleshooting and maintenance activities;
- Avoid RE-WORK – ensure all welders are trained and competent in their tasks – perform welder qualification tests under realistic shop floor conditions.

Training welders to inspect their own work and understand the quality requirements of the specifications they are working to is a significant step in avoiding re-work. Much re-work also arises from incorrectly supplied specialty parts. Such parts need to be inspected prior to leaving the suppliers manufacturing premises.

11. WELDING PRODUCTIVITY

There will be ongoing pressure to improve welding productivity in order to compete with imports and maintain current payment rates for welders.

Consider the following factors to improve productivity:

- Review the drawings carefully and identify areas where welding will be difficult – negotiate with the designer or client to determine if alternative weld designs are possible;
- Rotate all fabrication so that down hand welding is possible;
- Use Submerged Arc Welding when possible;
- Eliminate back-gouging and back-grinding from the production activities – it is a sure sign that welding procedures have not been developed properly;
- Avoid manual metal arc welding – the productivity of MMAW is so low that this is in fact a very expensive process;
- Utilise narrow gap welding bevels to minimise distortion and maximise productivity; both Submerged Arc and Gas Metal Arc welding can be adapted for narrow gap welding;
- Use the correct welding consumable diameter for the right application. Table 1 provides recommended consumable diameter for some typical GMAW, FCAW and SAW applications;
- Avoid RE-WORK – ensure welding procedures have been adequately tested. Avoid qualifying the welding procedure under ideal conditions with the “best” welder – be realistic.

Table 1. Typical single pass fillet and butt weld applications for common welding processes

GMAW Electrode diameter, mm	Fillet Weld leg length, mm (single pass fillet)	Butt weld wall thickness range, mm	FCAW Electrode diameter, mm	Fillet Weld leg length, mm (single pass fillet)	Butt weld wall thickness, mm/ # passes	SAW Electrode diameter, mm	Fillet Weld leg length, mm (single pass fillet)	Butt weld wall thickness, mm
0.9	3 – 4	3 - 6	-----	-----	-----	2.4	5 - 8	8 - 16
1.2	4 – 5	6 - 20	1.2	4 - 5	6 - 25	3.2	6 - 10	12 - 40
1.6	5 – 6	10 – 20+	1.6	5 - 6	10 – 25+	4.0	8 - 12	20 - 40

12. IMPROVING PRODUCTIVITY

In order to improve productivity it is necessary to address the following three activities:

- a) Identify the factors that affect productivity;
- b) Measure these factors;
- c) Implement improvements.

12.1 Identification of Productivity Factors

Even though each fabrication facility is unique, the factors that ultimately affect the productivity and hence competitiveness of that facility can be summarised as follows:

- a) **Operating Factor.** The Operating Factor for a welder is the amount of time per shift that the welder is actually welding. It is expressed as a percentage of the work shift. An arc time of 50% for a welder on an eight-hour shift means that the welder is actually welding for a period of four hours. The other four hours (consisting of meal breaks, personal breaks, fit-up, jiggling, chipping, wire-brushing etc) are non-productive from a fabrication standpoint.
- b) **Weld length or weld weight per shift.** Depending on the fabrication it may be appropriate to determine the acceptable length of weld or the weight of weld deposited each shift. This parameter can be related back to the efficiency of the welding operation.
- c) **Repair Rate.** The repair rate can be expressed in terms of length or in terms of the number welds made. For a given fabrication where a welder has produced ten meters of fillet weld in one shift with 200mm of that weld requiring repairs the repair rate can be given as 2% . For a welder producing 1000 spot welds per shift with 2 requiring re-work the repair (or defect) rate would be 0.2%.
- d) **Repair Time.** It may be more significant to determine the amount of time that is spent repairing defective welds than the actual length or number of defective welds made. This is often the case for heavy wall sections requiring pre-heat.
- e) **Re-work Time.** This is the total length of time required for conducting any re-work. Impacts on other activities and production schedules should be considered
- f) **Crane Time.** Other than lifting raw materials in and lifting the finished product onto the truck the amount of time expended on the shop floor moving materials or partly made components from one location to another is non-productive time. The aim is to try and introduce Henry Ford's production line principles into the fabrication process.
- g) **Fit-up, jiggling and handling.** It will be necessary to determine the length of time undertaken in fit-up, jiggling and handling operations.
- h) **Boiler-making, plating and metal forming.** These activities can be started well ahead of welding so they do not become critical path activities. Review these operations to determine whether they are impacting on the overall production schedule.

12.2 Critical Path or Rate-Determining Operation

By measuring the items listed in a) through h) it will be possible to identify the operation(s) that govern the overall productivity of the fabrication and establish benchmarks for the other operations. Improving productivity usually begins by identifying the rate determining operation and systematically improving it.

12.3 Benchmarking

Benchmarking consists of comparing ones individual performance to industry norms. Operating factors for common welding processes are given in Table 2.

Table 2. Operating factors for common welding processes

Welding Process	Operating Factor
MMAW/GTAW	15 – 30%
GMAW/FCAW (semi automatic)	30 – 40%
GMAW/FCAW (simple mechanisation)	45 – 60%
SAW	60 – 95%

Measured operating factors less than those given in Table 2 suggest there are productivity issues that need to be addressed within the workplace. Similarly, when employing multiple welders using the same process it is necessary to benchmark individual welders performance both in terms of productivity and quality so focussed improvements can be implemented.

13. PRODUCTION FLOW AND SHOP LAYOUT

Identifying and benchmarking productivity factors will eventually lead to an assessment of the shop floor layout. Efficient fabricators make use of the following techniques:

- Segregate large and small parts to be welded into separate bays;
- Arrange fabrication shop so material entering one end leaves as a finished product from the other end;
- Arrange fabrication shop so fabrication activities are carried out in a logical manner – cutting, forming, jigging, tacking, welding, inspection, protective coating and shipping;
- Avoid double or multiple handling of products;
- Perform prototype testing – ensure first off receives full inspection, dimensional checking and non-destructive testing before continuing with remainder of production;
- Issue job cards for all the components to be fabricated so progress can be tracked;
- Create activity based cost centres so individual activities can be tracked and costed;
- Arrange welding equipment maintenance and servicing outside regular hours;
- Arrange the work so it is presented for welding in an ergonomically friendly manner:
 - Set work on adjustable trestles so the welder can access the joint easily
 - Ensure welder(s) can weld:
 - with a comfortable posture (avoiding potential back aches);
 - outside of the welding plume – avoid situations where welder has to bend over into welding fume;
 - using natural ventilation where possible;
- Avoid RE-WORK – ensure the prototype fabrication meets customers expectations and areas where potential problems have been identified are rectified before the production of subsequent units;
- Involve QC/QA activities into the daily fabrication activities. Individuals involved with the implementation of quality systems should not be regarded as “policemen”. Integrate “hold point” inspection activities into the production activities to ensure production does not stop during inspection – never rely on final inspection of a product to demonstrate compliance;
- Develop an inspection and test plan that involves quality personnel at all stages of the production in addition to supply of materials and speciality products.

14. SUMMARY

Some of the factors controlling the cost of welded fabrications have been identified. A re-occurring factor is re-work. Determining the causes of re-work and implementing systems to eliminate it is the first step to improving both productivity and quality and controlling costs.

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NDNP TECHNOLOGY DIFFUSION ACTIVITY # 27	 Welding Technology Institute of Australia ABN 69 003 696 526	Document No: 9.4.5QR-0001
	NATIONAL DIFFUSION NETWORKS PROJECT TECHNOLOGY QUESTIONNAIRE Building & Construction Industry Group “Controlling Costs in Welded Fabrication”	Revision No: Rev 0
		Page 1 of 2 Date: 18 Nov 2005

As part of the WTIA National Diffusion Networks Project the Building & Construction Industry Sector has identified the need to understand and control costs in welded fabrication in order to keep the Australian steel fabrication industry competitive. The WTIA has prepared a Technical Guidance Note “Controlling Costs in Welded Fabrication to provide an understanding of the items that affect and control fabrication costs. As a valued technology expert in this area we would like you to be part of the Technology Expert Group to review this note. Please complete this questionnaire so that we can gauge the success of meeting this need.

Objective 1: Identify the need for controlling costs in welded fabrication

The Australian steel fabrication industry is under increasing competition from imports and substitution through the use of concrete structures. This guidance note is intended to provide the Steel Fabrication Industry understanding of the factors that control the costs of fabricated steel structures. How well does the document achieve these aims?

poor average good very good

Comments: _____

Objective 2: Identify appropriate technology receptors in the Building & Construction Industry

This document was written for Purchasers, Estimators, Project Engineers and Fabricators in the Building and Construction Industry. Are these the appropriate individuals, companies and industry sectors we should be targeting?

yes no

What other types of companies and/or personnel do you suggest we target? _____

Objective 3: Identify current best practice for measuring and specifying hardness

The document was written to provide advice on current best practice for the steel fabrication industry. Do you envisage opportunities for the use of this advice in the industry?

yes no

If yes, what and where, if no why not? _____

Objective 4: Is the information provided clear, concise and accurate?

yes no

If not, why? _____

Objective 5: Broad dissemination of technology to the Building & Construction Industry

Please indicate how best to disseminate this Technical Guidance Note to the appropriate Steel Fabrication Industry Recipients

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