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Welding and Post Fabrication Cleaning for Construction and Architectural Applications

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Summary

Stainless steel is used in building and architectural applications because of the unique combination of corrosion performance, aesthetic appeal, strength and ease of use.

The grades of stainless steel commonly used in these applications can be readily fabricated using known technology although there are various issues that must be considered.

Production of flat, thin skinned panels, for facades for example, starts at the design stage. Design to withstand fabrication stresses must be completed.

Welding inevitably produces contamination of the steel surface, not least of which is the heat tint at the weld line. Care must be taken to minimise and control this contamination. Similarly care must be taken when designing and implementing stud welded structures.

Welded structures should normally be cleaned after fabrication. Various methods are available which may influence the aesthetics of the unit. This can be advantageous.

Key Words

Stainless Steel, Fabrication, Design, Distortion, Welding, Cleaning.

Introduction

Stainless steels are used for structural and architectural applications because of the unique combination of corrosion performance, aesthetic characteristics, strength and ease of utilisation.

The most commonly used stainless steels are the “300 series” grades although duplex grades are also increasingly considered. The main characteristics of these steels are:

Name	Code Designation	Chemical Composition (Descriptive wt %)			Mechanical Props (Typical: MPa)	
	EN 10088 / ASTM	Cr.	Ni	Mo	0.2% Proof	Tensile
4307	1.4307 / 304L	18	8	--	210	510
4404	1.4404 / 316L	17	10	2	220	525
2205	1.4462 / 2205	22	5	3	450	670

The sections used in construction and architectural applications might be typically 10-20mm thick for structural members whilst lighter sections, as used for cladding, lintels etc, might be as thin as 1-3mm.

The product forms used would generally be hot rolled plates for the heavier sections where as cold rolled sheet, with or without decorative finishes, would generally be used as thinner cladding. Tubular sections are sometimes used as supporting members or as decorative features.

Stainless steel relies on its invisible inherent oxide film to provide corrosion performance and preserve its clean aesthetic appearance. Care must be taken to assure the high quality inherent oxide which can be degraded during the fabrication cycle.

This paper will highlight some of the issues to be considered when fabricating stainless steels for architectural applications. Whilst the data presented is generally appropriate to all of the grades noted above, it is specific to the most widely used grades, 4307 and 4404, the “300 series”.

Issues to be Addressed

The issues to be addressed fall into 3 basic sections:

Distortion and Distortion Avoidance

Welding and

Post Fabrication Cleaning

Distortion and Distortion Avoidance

Although angular "winging" distortion of heavier sections must be considered, the main issue in the context of architectural applications is buckling distortion of thinner sections.

Buckling distortion occurs in thin sections, particularly flat ones less than around 5-6mm thick. Buckling occurs when the fabrication stresses exceed the column strength of the "plate" and is characterised by high / low areas on the plate away from the weld line, Fig 1, (1). Spot and line heating can be used to flatten carbon steel structures however it is very skill intensive, very expensive and very time consuming. The heat spots and some distortion generally remain visible after final finishing.

It is not advisable to use spot and line heating on stainless steels as metallurgical damage can compound the issues associated with its use on carbon manganese steels. First time fabrication is particularly important for stainless steel.

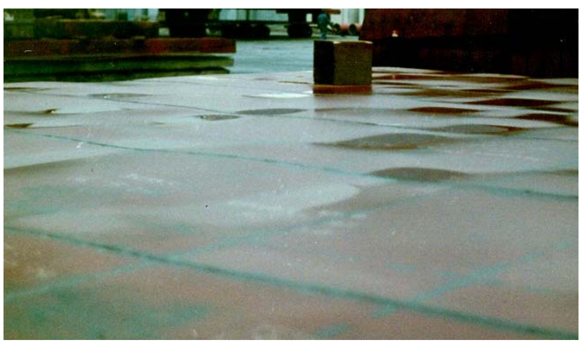

Fig 1. Buckling distortion and marks left after spot heat repair of C-Mn thin skin structures

There are 2 different aspects to consider in order to achieve first time fabrication and avoid buckling distortion; design and fabrication.

The designer is responsible for detailing a structure that can be fabricated "flat"; the fabricator cannot fabricate flat if the detail is not designed to withstand fabrication stresses. When buckling distortion does occur, arguably it should be called "lack of design buckling distortion".

The designer must consider the plate edge support and loading, shape (flat through to curved), material characteristics, stiffener spacing, weld size and extent of welding in relation to load requirements and resistance to buckling distortion.

The welding engineer must consider the welding technique that is to be used in fabrication, the control of that technique to achieve the specified weld detail and the production techniques, cycle and sequence that must be used to keep the thin skinned unit flat.

Each discipline needs to appreciate what is achievable and what the limitations are. For example, a mitred 3mm leg length fillet weld is not really achievable in production, despite what the drawings might say, and it is important that the welding engineer ensures that weld stop / starts are not in the stress hot spots identified in design.

The designer and the welding engineer must work together. The first action for this team is, probably, to address the issue, "What is flat and acceptable?"

A classic example of fabrication induced buckling distortion is the shell roofs on the Thames Barrier piers. It must be stated that there is no known issue of structural stability associated with this buckling: the stainless steel is purely aesthetic and the roof loads are taken by the wooden structure, Fig 2. The stainless steel is not welded. The stainless steel on the curved section of the roof is reasonably distortion free due to the shape factor. However, the installation stresses on the slab sided areas have resulted in buckling and the quilted appearance that is now a distinctive feature of this structure. It is ironic that buckling distortion, which would normally be considered doubtful or unacceptable, has become an architectural feature on this particular structure.

Fig 2. The Thames Barrier

Welding

The Welding Rules form the basis of Good Stainless Steel Fabrication Practice (2). The four main aspects of the Welding Rules are:

Welding Procedure Design

Heat (Energy) Input Control

Temperature Control and

Cleanliness

Various factors within these main aspects must all be considered and balanced in relation to the alloy being welded. For example, temperature and heat input control do not need to be controlled as closely for standard “300 series” grades as they do for the high performance grades. The welding codes, for example BS EN 1011 Part 6, reflect the Welding Rules.

As detailed in BS EN 1011 Part 6, all welding and all welders should be skilled and qualified appropriately. This is, of course, no different than for any other metal. The welding procedures and the welders are normally qualified to BS EN 288 and 287 respectively although there are other qualification codes available.

All of the standard arc welding processes can be used and they each have there own characteristics. The following table “bench marks” the arc welding processes:

Process	Weld Quality	Welding Productivity	Weld Bead Characteristics	Comments
Tungsten Inert Gas (TIG)	High	Low	Smooth	Typically thin section and pipe welds
Manual Metal Arc (MMA)	Good	Medium	Slightly coarse ripple.	Most thicknesses possible
Flux Cored Arc (FCA)	Good	Medium / High	Slightly coarse ripple.	Most thicknesses possible
Plasma	High	Medium	Smooth	Sections up to 8-10mm. Normally machine welding
Submerged Arc (SA)	Good	High	Can be fairly smooth	. Heavier sections (>~6mm). Normally machine welding

Inevitably there are variations to this associated with a wide range of factors.

The oxide at the weld line is thickened due to the high temperatures, albeit locally, associated with welding. The efficiency of the oxide (in providing corrosion performance) is reduced as it becomes thicker. The growth of this oxide, the welding heat tint, must be minimised and controlled even if the intention is to fully remove it after welding is complete.

The more visible the heat tint is, the more likely is it to prejudice the corrosion performance, not to mention any detrimental aesthetic affects. An invisible inherent oxide film is the objective. A “light straw” coloured heat tint (on the penetration bead) may be acceptable in some corrosive environments; a dark blue / black heat tint will seriously reduce the corrosion performance, Fig 3.

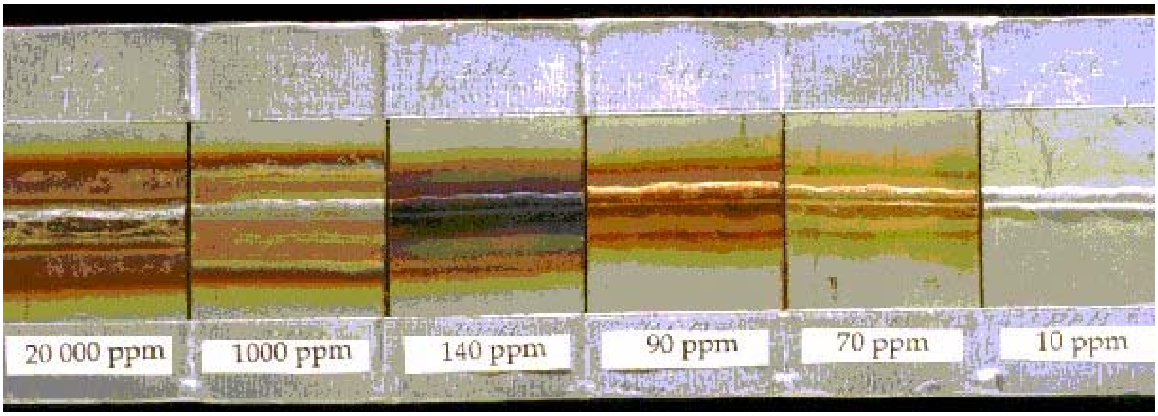

Fig. 3. Different levels of penetration bead heat tint associated with welding

The darker and more visible the heat tint, the more difficult it is to remove it during post fabrication cleaning. The heat tint in well-controlled production welding would normally be around the “light straw” colour noted above.

Backing gas should always be used for single sided gas shielded welds to minimise and control the heat tint growth. Argon is normally used. Backing gas is not normally necessary for the fluxing welding processes (MMA, FCA and SA) or for double sided welding.

The weld face and the weld toes are normally slightly oxidised too, although to a darker colour. This heat tint should be considered in exactly the same way as penetration bead heat tint, Fig 4.

Fig 4. Heat tint on the cap of a TIG weld

Filler metal is always used whilst welding anything except the thinnest sections. It is often used even on the thinnest sections too. (There are some process to process variations). The filler metal to be used is noted in the qualified Welding Procedure. It is, however, worth noting the recommended filler metal, in relation to the grade of stainless steel being welded, as this question is raised with supprising frequency.

Grade	Welded to	Using recommended generic filler metal
4307	4307	308L type
4404	4404	316L type
2205	2205	2205 or P100

There are variations on the theme within each recommended generic filler metal. For example, vertical down welding, completed with an appropriate electrode (308L MVR VDX), will have a much flatter weld cap than one completed welding vertically up, again with the appropriate electrode (308L MVR PW). This has implications on production welding and on weld visibility.

The designer and architect must assume that the weld will always be visible. This visibility relates to all metals, carbon steel, stainless steel etc. As deposited, the weld cap and weld penetration bead will be visible. If the weld is flushed smooth with the "plate" surface, there may well be a slight colour contrast, particularly if the weld is polished, Fig 5. (This contrast may be brought out a little further by any pickling and passivation operations). Flushing or polishing weld beads normally results in a slightly different texture in the area that has been polished. The architect and designer have three options, therefore:

- Accept that the welds are visible to a greater or lesser extent or
- Use the welds as a design feature in the unit or
- Hide the welds away from line of sight.

Fig 5. Welds on a tank after mechanical dressing and cleaning.

This has got to be a conscious early decision. It is supprising how often it is not considered until too late.

Dissimilar metals (e.g. stainless steel to carbon steel) can be welded using standard techniques. Each situation must be considered on a case by case basis from both a welding engineering viewpoint and in respect of corrosion engineering. However, the normal solution when welding 4307 and 4404 to carbon steel is to use either 309 or P5 filler metal.

Stud welding is frequently used when attaching façade sheets to sub structures. The façade probably has distinct texture or finish. The sheet is probably of the order of 1-2mm thick.

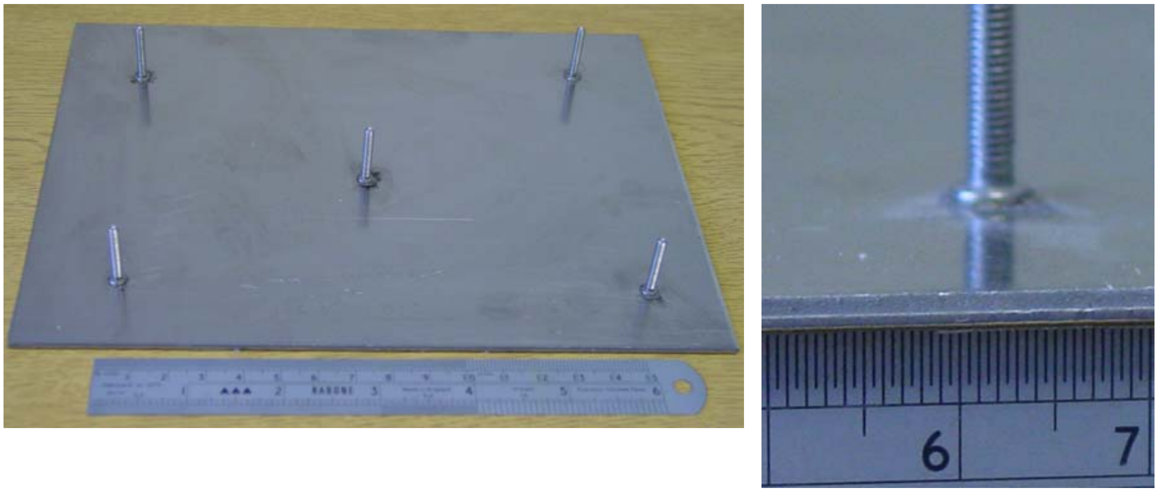

Fig 6. Grade 4404 (316L) Cambric, 2mm thick, stud welded with 2.8mm studs to give "no show" welds.

It is important to relate the stud diameter to the thickness of the façade sheet if it is hoped to achieve "no show" studs, Fig 6. Large studs, say 5-8mm diameter, will give a "show" stud on 2mm thick façade; distortion, heat tint and / or "quilting" will be visible. Such a large stud will not necessarily increase the load bearing capacity at the façade to substructure connection.

Post Fabrication Cleaning

As discussed, "300 series" stainless steel alloys are most frequently utilised for corrosion performance and for aesthetic characteristics.

Welding, almost inevitably, results in some weld zone heat tint. This thickened oxide can limit the corrosion performance if it is not correctly removed and treated.

Carbon steel, for example, can contaminate the surface of the stainless steel during the fabrication cycle. There are various sources of contamination of this type, contact with tooling and scaffolding poles for example. If the contamination is not cleaned off, "rusty stainless steel" can occur, Fig 7. Stainless steel cannot rust, per se; it is the carbon steel contamination that is forming the characteristic red rust. However, this rust should be efficiently removed as it is certainly unsightly and it may lead to premature corrosion failure of the stainless steel.

Fig 7. Grade 4404 (316L) stainless steel contaminated with carbon steel during installation.

The most commonly applied methods (3) of post fabrication cleaning are:

Mechanical and

Chemical cleaning.

Mechanical cleaning is done with grinders, heavier polishing, belts etc to remove a small amount of metal from the surface. Care must be taken to avoid smearing the contamination further across or into the surface. This is unlikely to happen if the techniques noted above are correctly applied. However, smearing is a significant concern with light polishing or blasting.

From a corrosion viewpoint, the final finish from mechanical cleaning should be as fine / smooth as possible.

Chemical cleaning is most frequently undertaken with "Pickling and Passivation" chemicals. The pickling removes the inherent oxide film, which has been thickened by welding, and it removes metallic contamination. It puts the stainless steel in an ideal situation to grow a new fully effective inherent oxide film. Passivation positively promotes the formation of that oxide film, the oxide film growing evenly and quickly.

It is appropriate to point out that pickling and passivation is best left to specialist firms because of, for example, the Health and Safety implications.

In practice, post fabrication cleaning is generally completed using these techniques in combination. The combined use of Mechanical and Chemical techniques gives maximum fabrication productivity and maximum corrosion performance of the stainless steel. There are advantages, in terms of corrosion performance, from using the pickling and passivation treatments.

Maximising the surface performance of the stainless steel after fabrication may well slightly change the aesthetic appearance of the surface. Notwithstanding the obvious implications of any grinding marks, pickling and passivation will always tend to dull a bright surface towards a white metal surface. A polished surface will become matt; a white metal surface may become a shade duller. Some chemical treatments result in a more evenly "dulled" finish than others do. Dipping in chemicals, for example, is better in this respect than paint on gels. Pickling and passivation will tend to "bring out" the welds.

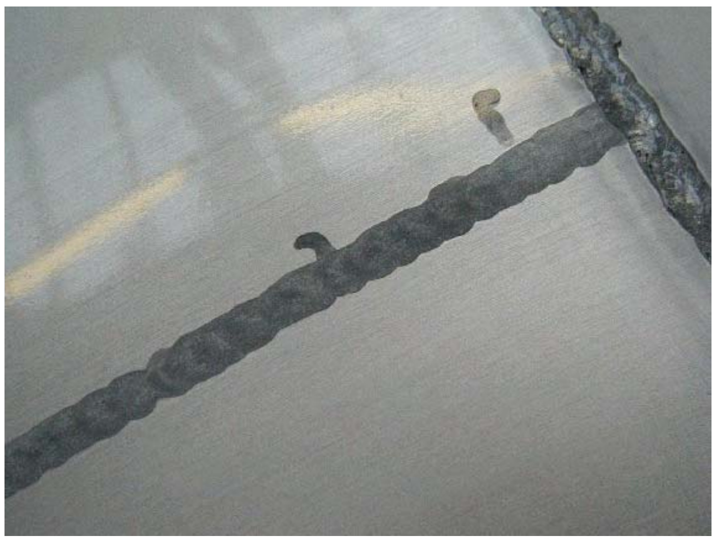

Fig. 8. Surface finish changed by pickling (Courtesy of Stainless Restoration Ltd)

The change in contrast is not necessarily detrimental; it can be used as an aesthetic signature.

It may be necessary to complete a hand over clean down. Dependant on what is to be cleaned off, this might be done with relatively mild chemicals or it may be sufficient to use the same techniques as have been identified for in service cleaning. This might be as simple as "hot soapy water" to remove any grime.

Conclusions

Stainless steels are used in a range of building and architectural applications.

Distortion, particularly fabrication induced buckling distortion of thin sections, is an issue that must be addressed from an early stage. The design detail has a very strong influence on the fabricator's ability to produce flat panels for facades, for example.

Welding the grades of stainless steel most frequently used in these applications is straightforward and known technology. The main issue is likely to be the visibility of the weld, what is causing that visibility (heat tint, weld bead shape etc) and how these issues are regarded and addressed

Post fabrication cleaning would normally be used to remove any welding heat tint or contamination, for example. This may have implications on the aesthetic characteristics of the stainless steel although this is not, by definition, detrimental.

Hand over clean down must be considered in the same context as in service cleaning.

References

1) "Distortion Control in Thin Plate Structures."
C Baxter. Eighth International Conference on Offshore Mechanics and Polar Engineering (OMPE), The Hague. March 1989.

2) "Duplex Fabrication: Design and Implementation"
C Baxter. Paper presented at BSSA Duplex Workshop Road Show, Spring 2001

3) "Post Weld Cleaning of Stainless Steels: Practical Application and Control"
C Baxter and L Wendelrup. Stainless Steel World 2001, The Hague, November 2001.