Don’t Break the Reo Quality Chain

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Abstract: It is essential to ensure that all reinforcement for projects is manufactured and processed in accordance with Australian Standards. In Australia, this is guaranteed by obtaining third party certification by a JAS-ANZ accredited organisation such as ACRS (Australasian Certification Authority for Reinforcing and Structural Steels). While Engineers can easily guarantee the quality of processed reinforcement delivered to site by requesting an ACRS or equivalent Certificate, there are many site practices that can quickly turn a complying piece of reinforcement, into a nonconforming product and a non-compliant building solution. The SRIA receives numerous enquiries for guidance from the industry concerning various site practices that can affect the quality of the reinforcement, including surface condition of reinforcement (from reinforcement that has been left exposed to the weather for some time), site bending and rebending, heating to facilitate bending, welding, use of couplers, bar chairs and wire tying. The question of large radius bends, and the practice of forming these as a series of smaller conforming diameter bends and straights (particularly for larger bar diameters in infrastructure projects), has also resulted in recent technical enquiries. Based on feedback from industry, this paper examines the most common site practices that the SRIA encounters, which can lead to reinforcement quality issues. Guidance on correct practices to avoid potential site problems is provided, so that having guaranteed the supply of quality processed reinforcement to the project, poor site practices will not break the reinforcement quality chain, impact design performance and potentially place your project at risk.

Keywords: reinforcement, quality, Standards, certification.

1. Australian Standard Requirements

The manufacture, processing and prefabrication (if welded) of steel reinforcement must comply with the requirements of a number of Australian Standards. These include AS/NZS 4671 (1), AS 3600 (2), AS 5100.5 (3) and AS/NZS 1554.3 (4).

AS/NZS 4671 contains extensive requirements for the mechanical, physical and chemical properties of steel reinforcement, as well as the frequency of testing to demonstrate that the results are statistically representative of the quantity of reinforcement either manufactured or processed. Mechanical properties include the yield stress, ductility parameters, bending and rebending properties, fatigue strength and shear strength of joints in mesh. Physical properties include bar diameters, cross-sectional areas, masses of bars, straightness tolerances, surface geometry, form and dimensions of mesh and quality of finished bar. Chemical composition is assessed by calculation of the carbon equivalence from the mass of carbon, manganese, chromium, molybdenum, vanadium, nickel and copper in the steel. Also, if long-term quality testing data is not available, the testing requirements to demonstrate product conformity are very onerous, so this expert data or data auditing and assessment process must be considered when purchasing from a source that cannot guarantee the quality of the reinforcement through the provision of a JAS-ANZ accredited third party certificate (refer **Sections 5 and 6**). Note that currently, there is some 140,000 tonnes of reinforcement sold in Australia from unknown manufacturers (supplier).

Also, Clause 7.1 of AS/NZS 4671 states that, “The reinforcing steels conforming to the Standard shall be deemed to be weldable under the conditions specified for each class in AS/NZS 1554.3.” As reinforcement is increasingly being prefabricated utilising welded connections, ensuring the weldability of reinforcement is a critical aspect of the material.

As well as the properties listed in AS/NZS 4671, other requirements are included in the design Standards AS 3600 and AS 5100.5. These relate to the bending of reinforcement (both in the factory and on site) which affects its mechanical properties, site practices such as impact and heating, plus fabrication tolerances. The importance of independent third party certification to verify conformance to all these parameters in multiple Standards is obvious.

To demonstrate the importance of ensuring the compliance of reinforcing steels, **Figure 1** shows two situations where the metallurgy of the steel has caused brittle failure of the bars.

(a) Bar (> 28 mm) fractures simply by being dropped on a concrete barrier (overseas project).

(b) D500L bar (<10 mm) fractured simply by walking on mesh (imported to Australia from unknown source).

Figure 1. Brittle failure of non-conforming steel reinforcement.

2. Processing of Reinforcement

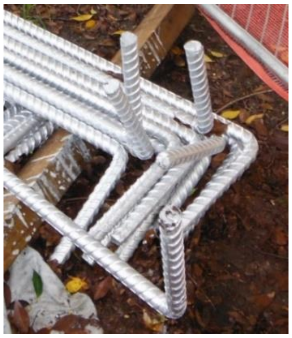
Processing of reinforcement is taking the manufactured reinforcement (either in coils or straight stock lengths for larger bar diameters) and cutting and bending this reinforcement to the required lengths and shapes for each individual project. A steel processor is defined in AS/NZS 4671 as an, “organisation responsible for subsequent processing of reinforcing steel supplied by a steel producer, which significantly changes the profile and properties of the reinforcing steel. This may include cold-rolling, cold-drawing, decoiling and straightening, or automatic, electrical-resistance welding.”

As the decoiling, bending and shaping of reinforcement alters its mechanical properties, these processes must be carried out in accordance with proper practices. To create a permanent deformation in a piece of reinforcement (ie straightening from a coil, bending or changing its shape), the material must be taken beyond its yield point to plastically deform it. This causes strain hardening of the material, and it is imperative that correct procedures are used to ensure the material has sufficient ductility after processing to satisfy serviceability requirements. These processes can be seen in **Figures 2(a) and (b)**. In **Figure 2(a)**, N12 reinforcing bar from a coil (to the left of the image) is fed through a series of straightening rollers and then bent around a central pin, the diameter of which is generally five times the diameter of the bar. **Figure 2(b)** shows a process for bending much larger bars. Note that the 3N24 bars shown are being bent around a much larger pin diameter of 120 mm (ie five times the bar diameter).

The 32 mm diameter galvanised bars shown in **Figure 2(c)** were bent around a pin diameter of 47 mm or 1.5 times the bar diameter, in a brake press. AS 3600 requires that galvanised bars be bent around an eight-bar diameter (in this case 256 mm) pin. We believe the galvanised paint to the ends of the bars was to cover fractures in the galvanised coating, along with possible cracks in the bars. This is an example of processing well outside the minimum requirements of the Standard, and demonstrates the importance of having the reinforcement supplied by a JAS-ANZ accredited third party certified processor in accordance with the requirements in the Standards.

(a) Off-coil machines used for bars up to 20 mm diameter.

(b) Bench bending machine for larger bars.



(c) Incorrect bending of steel reinforcement.

Figure 2. Processing of steel reinforcement.

3. Prefabrication of Reinforcement

Increasingly, reinforcement cages are being prefabricated in factories to reduce congestion on site and speed up construction. SRIA members fabricate and supply many different prefabricated items for projects (**Figure 4**), and the majority are held together using a combination of wire tying and welded connections, which are discussed in **Section 4**. Any welding of reinforcing bars must be undertaken by a person prequalified in that procedure, in accordance with the requirements in AS/NZS 1554.3. If sourcing from other than SRIA members, it is important to ensure that the people responsible for any welding are suitably qualified and certified. Also, the stability of the cages must be considered during preassembly, transport and erection, and lifting points indicating specially strengthened sections within the cage to support the weight, should be clearly identified to ensure safe lifting **Figure 4(c)**.

(a) Prefabricated column cage.

(b) Prefabricated beam cage.

(c) Lifting point marked to safely lift cage for Sydney Light Rail Project.

Figure 4. Examples of prefabricated reinforcement cages.

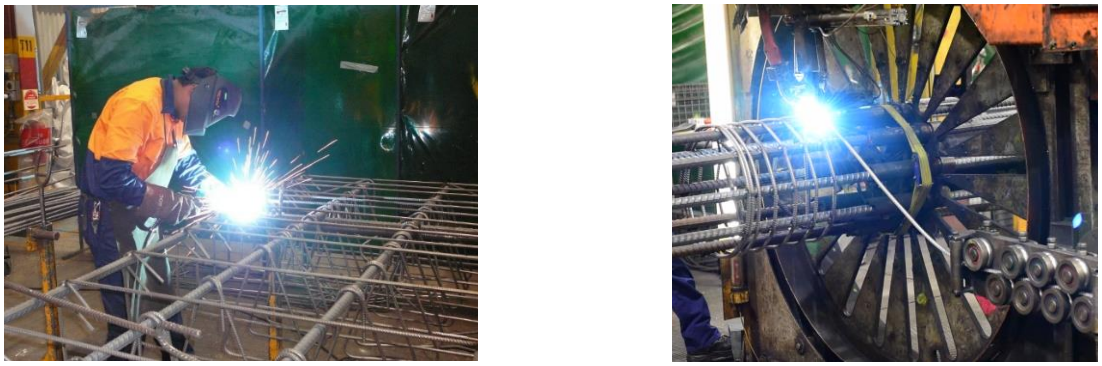
4. Welding of Steel Reinforcement

Welding of reinforcement is mainly used in the prefabrication of various reinforcing cages (refer **Figure 4**), but may also be used on site for correction of problems or splicing to existing reinforcement. Welding of reinforcing steels is covered in AS/NZS 1554.3 *Welding of reinforcing steels*. The Standard covers two types of welds that can be used for the prefabrication of reinforcement, to support the cage during transport, lifting and erection: locational (or tack welds) and non-loadbearing welds. In reality, both are considered as non-loadbearing welds, but their requirements vary.

Locational welds (commonly known as tack welds) are used to hold parts of a weldment in alignment until the final non-loadbearing welds complying with Clause 3.3 of AS/NZS 1554.3 are made. However, they may be left in place and included in the prefabrication (without the final welds having been made), if they meet the requirements of Clause 5.6 and Table 6.2 of AS/NZS 1554.3, which specifically requires that there is no loss of cross-sectional area or imperfections. Locational welds that are too small will change the bar metallurgy underneath causing insufficient strength when handling, transporting, lifting and concreting. If the weld size does not meet the requirments of Clause 5.6 of AS/NZS 1554.3, their limited heat affect and rapid cooling can lead to cracking. As locational welds can actually present much greater risks to damaging the steel reinforcing materials than the final non-loadbearing welds, if they do not meet the requirements, they must be removed. If done properly, there will be minimal (if any) impact.

Non-loadbearing welded joints can also be used to hold the cage during fabrication, transport, erection and concreting, and must be made in accordance with Clause 3.3 of AS/NZS 1554.3. The strength of the welds does not contribute to the structure and they must not reduce the full loadbearing capacity of the structural element.

We would recommend that all welding is carried out in a processor facility in a factory controlled environment (**Figures 5(a) and (b)**), by qualified welders that receive regular refresher courses and the weld quality of critical welds is tested for compliance. Examples of good quality welding in processor facilities are shown in **Figure 6(a) and (b)**, however, we have come across many site welds that appear inadeqaute **Figures 6(c) and (d)**. If welding is not undertaken by an SRIA processor member and there is any doubt whatsoever regarding the quality of the welding, certificates should be obtained to prove the quality before signing off on the project. Site welding is further dealt with in **Section 7.7**.



(a) Manual welding of reinforcement cage. (b) Prefabrication of circular cages using machine welding.

Figure 5. Examples of manual and machine welding in a processor facility.

(a) Good quality manual weld. (b) Good quality machine weld. (c) Poor quality manual weld. (d) Inadequate tack weld.

Figure 6. Examples of good and poor quality welds.

5. Role of Certification

One of the recommendations of the Shergold Weir Report (5) into building confidence and product conformity, was to have third party product certification. In other words, have someone independent from the manufacturer (supplier) or processor, undertake a conformity assessment of the product to verify that what the manufacturer (supplier) or processor of that product is claiming, is an accurate representation of that product.

The steel reinforcing industry in Australia, in conjunction with other organisations, established such an independent authority some 20 years ago, known as the Australasian Certification Authority for Reinforcing and Structural Steel, or ACRS. ACRS currently certifies the conformity of all reinforcement manufactured in Australia, and all reinforcement processed by SRIA members, to the requirements of AS/NZS 4671, AS 3600 and AS 5100.5. The importance of using conforming reinforcement cannot be overemphasised, as it is classified as a high-risk product due to the fact that if it fails, or fails to perform as required by the design Standards (refer **Figure 1**), the consequences could involve a serious risk to life safety, especially in an extreme event where the building or structure may need to carry loads in the inelastic range (eg earthquake and blast events).

SRIA members have adopted ACRS (which was based on the UK CARES certification scheme), as it is the most widely accepted and recognised scheme in Australia specialising in steel.

6. Importance of JAS-ANZ Accreditation

JAS-ANZ stands for the Joint Accreditation System of Australia and New Zealand and as the name suggests, is the Government appointed body for Australia and New Zealand. JAS-ANZ does not in itself certify or inspect organisations, products or people, but rather accredits the bodies such as ACRS that do, by developing the assessment criteria that certifiers and inspectors must meet to become accredited under a number of themes, one of which is product certification. According to JAS-ANZ, "Accreditation adds value to the ever growing and increasingly complicated market chain in many ways, including by providing a symbol of assurance that certifiers and inspectors are independent and competent to perform their duties. Third-party accreditation – the type that JAS-ANZ provides – is recognised around the world as the highest and most credible type a certification or inspection body can obtain." Being an internationally recognised accreditation system is imperative, as ACRS certifies steel reinforcement products in a number of overseas locations.

Having a certification authority such as ACRS, that has been assessed by JAS-ANZ as independent, provides assurance that their assessment of steel reinforcing products, whether manufactured or processed, is truly independent and can be relied upon as evidence of conformity.

7. Site Practices and Quality

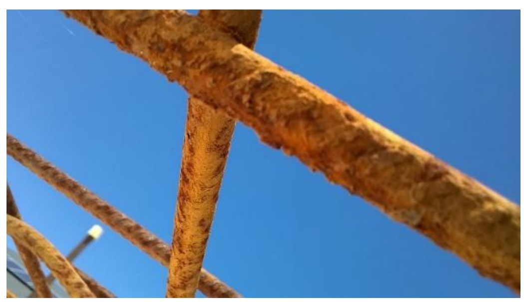
While SRIA members pride themselves on being able to guarantee the quality of the steel reinforcement they supply to the construction industry, what happens to it on site can render it non-conforming. This section considers some of the more common issues that we receive technical enquiries about concerning the risks to the conformance of steel reinforcement.

7.1 Surface Condition of Reinforcement

Surface corrosion which does not affect the geometry and hence bonding of the bar into the concrete is quite acceptable **Figure 7(a)**. However, any loose or flaking rust (**Figure 7(b)**), indicates a loss of steel section or mass, which may place the bar outside the limits in AS/NZS 4671: Table 7.5(A) for bars and Table 7.6(A) for mesh products. Reduced mass, and hence cross-sectional area, may reduce the strength of the bar to the point where it will no longer comply with the Standard. Refer SRIA Technical Note 1 for further information.

With the modern processing equipment available, supply of reinforcement these days is considered to be a 'just-in-time' process for steel fixing, so having to store reinforcement on site for any length of time and risk excessive corrosion is generally no longer required.

(a) Surface corrosion on bars.



(b) Loose and flaking rust on mesh.

Figure 7. Examples of surface condition technical enquiries received.

7.2 Site Bending (or Rebending) of Reinforcement

The correct procedures for bending reinforcement are covered in Clause 17.2.3 of AS 3600, and in particular, the requirements for site rebending have been elevated from a former note in the Standard, to new Clause 17.2.3.2 of AS 3600 (2018). This was due to the ongoing reports of issues and significant damage to steel reinforcing bars on construction sites **Figures 8(a) and (b)**. The intention of the Clause is to ensure that important site requirements and procedures are specified and adopted, to maintain the design properties of the steel reinforcing on site. Because of a lack of control over site bending processes, the use of a pipe for leverage (**Figure 8(c)**) is no longer noted in AS 3600, and therefore not allowed or recommended when site rebending bars.

Suitable tools are available for manual cold bending bars up to 16 mm diameter and electric cold bending up to 20 mm diameter **Figures 9(a) and (b)**. Electric benders are recommended due to the effort required to bend D500N reinforcing steels. It is important to check that the bar is being bent around the correct pin diameter in accordance with Clause 17.2.3.3 of AS 3600, usually five times the diameter of the bar being bent. Considering the tools available for site bending, our recommendation would be that wherever possible, bars be correctly bent by a processor, so that the mechanical properties are not adversely affected (by strain hardening during the plastic deformation process), to the point where the bar no longer complies with the ductility requirements within the Standard.

(a) Bent starter bars. (b) Starter bars backed over by a truck. (c) Using a pipe to bend reinforcement.

Figure 8. Site bending of reinforcement.

(a) Common bending tool. (b) Bending tools with various pin diameters are available.

Figure 9. Portable electric tools for site bending of reinforcement.

7.3 Heating of Reinforcement

As oxy-acetylene is often used to both cut and bend bars on site (**Figures 10(a) and (b)**), precautions must be taken to not overheat or otherwise damage the reinforcement **Figure 10(c)**. Hot-bending temperature requirements are covered in new Clause 17.2.3.1(b) of AS 3600, which states that bars must be heated uniformly, the temperature of the bar must not exceed 600 degrees Celsius, and if it exceeds 450 degrees Celsius, the design yield stress is to taken as 250 MPa and the design checked for strength. Note that at 600 degrees Celsius, you will not see any redness in the bar as can be seen in **Figure 10(b)**. Also, these requirements apply to both Ductility Class N and L steels, but the new higher-grade steels (600 to 750 MPa) should not be subject to any heating.

(a) Cutting bars for services. (b) Bending bars. (c) Damage to bars.

Figure 10. Using oxy-acetylene to cut and bend reinforcement.

7.4 Support of Reinforcement

This is now covered in Clause 17.2.5 of AS 3600, which requires designers to assess the bar chair requirements and specify the performance requirements to AS/NZS 2425 (6), including the type and spacing of the bar chairs to suit the applied construction loads and project exposure classification. If reinforcement is inadequately supported and construction loads cause deformation of the mesh or bars (**Figure 11(a)**), the mechanical properties will be affected and cracking may result **Figure 11(b)**. If reinforcement is either pulled up or walked into the concrete during placement (**Figure 11(c)**), the reinforcement could end up anywhere and will not be able to provide the necessary crack control or strength.

(a) Deformation of mesh under truck. (b) Cracking from placement in (a). (c) Mesh bent and incorrectly located.

Figure 11. Inadequate support of reinforcement.

7.5 Impact of Reinforcement

Clause 17.2.3.1 of AS 3600 allows reinforcement to be cold bent by the application of a force, “so as to avoid impact loading of the bar and mechanical damage to the bar surface.” Also, “bars shall not be bent using impact, such as with hammers.”

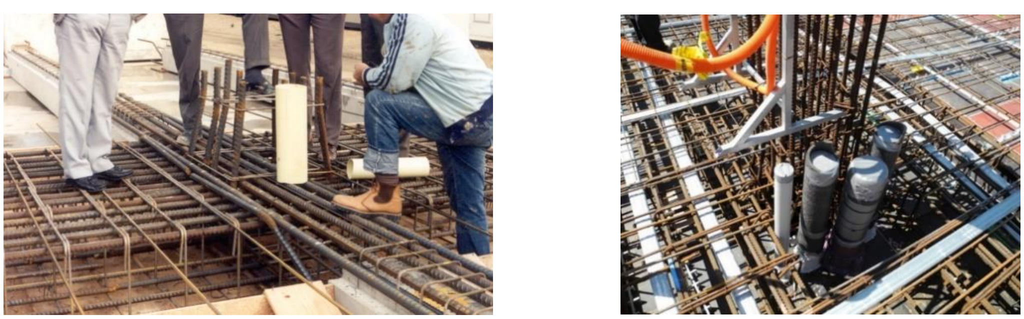
There is a good reason for this requirement. The damaged/flattened ribs (damaged surface) on the bar in **Figure 12** indicate that it was struck with a hammer in an attempt to provide additional cover to the formwork shutter. The resulting sudden loading has fractured the bar.

Such poor site practices can cast doubt on the quality of the reinforcement, but if ACRS Certified, the mistreatment on site is the probable cause. Any such site practices are not permitted.

Figure 12. Fracture due to impact.

7.6 Services

While not directly related to quality, if the detailing of reinforcement does not allow for services (**Figure 13**), the required adjustments to the reinforcement by heating to cut or bend bars or coring holes may cause issues with a compliant solution.



(a) No provision allowed for services. (b) Provision made for services.

Figure 13. Reinforcement must be detailed for services.

7.7 Site Welding

The SRIA has observed many instances of poor site welding practices that can affect the performance of the reinforcement (refer **Figure 6**) and receives numerous enquiries regarding welding of steel reinforcement to remedy site problems. These site issues are often the result of congestion from poor detailing not allowing for the physical dimensions of bars or included elements such as grout ducts. While we welcome any general questions regarding site welding, we recommend that for any specific technical questions relating to welding, Weld Australia be contacted for advice, as they are the experts on welding and who SRIA defers to for the highly technical matters.

Site welding should be avoided wherever possible, and welding procedures must still conform to AS/NZS 1554.3 requirements.

8. Conclusions

The reinforcement quality chain extends from manufacture, processing and welding as part of prefabrication, through to correct site practices. It is essential that each step of the process complies with the required Standards, to ensure that the steel reinforcement used on the project, which today is a high technology product manufactured to within stringent tolerances, will allow the structure to perform as designed. In the case of earthquake loading, complying reinforcement will provide the necessary ductility to allow the structure to carry the required loads inelastically and thus provide the important life safety we expect of our buildings and structures.

Builders need to provide a JAS-ANZ accredited third party Processor Certificate (ACRS or equivalent) to the Engineer and/or Building Certifier to guarantee steel reinforcing quality through the supply chain and obtain this prior to site delivery. Buying from an SRIA Member, all of whom meet these important requirements and whose certificates can be downloaded from the SRIA website, guarantees the quality of materials, processing and prefabrication, and provides the confidence that the structure is safe and robust, and adheres to the National Construction Code.

If an SRIA member is not supplying the reinforcement to your project, then the question must be asked, who is? Also, are they able to provide a JAS-ANZ accredited third party Processor Certificate? If this certificate cannot be provided, the procurer has no alternative but to implement a forensic process to verify conforming materials and welding (if part of prefabrications), which will involve rigorous testing and assessment of long-term quality production data and sometimes costly excavation of bars already cast into structures.

The use of complying steel reinforcement in buildings and structures is so critical, that it is simply not worth the risk of breaking the reinforcement quality chain by sourcing reinforcement from a processor that does not have JAS-ANZ accredited third party processor certification, such as an SRIA member.

9. References

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