**Introduction**

The Welding Inspections in Hong Kong are widely employed in various areas of the construction Industry. All the Welding works from Foundation to superstructure of a commercial, residential building, bridges, Walk ways etc. have to be compiled with well know welding standards such as BS5135/BS EN1011

**Quality Control in Structural Welding**

Formal procedures are adopted for control of welding when the risk of failure must be minimized. These are based on the selection of suitable materials, use of a qualified procedure, and qualification of the welder.

The **Welding Procedure Specification** (WPS) is a written qualified welding procedure, prepared to provide direction for making production welds.

The WPS references and is supported by the **Welding Procedure Approval Record** (WPAR) which reports variables recorded during the welding of test coupons and also contains the test results. Strength, ductility and toughness are commonly tested together with any other properties (e.g. hardness, corrosion resistance, creep strength) required for the application.

Together, the WPS and WPAR provide control of the structure and properties of the welded joint by ensuring that the essential welding variables do not differ significantly between the WPS and WPAR. Essential welding variables are those, which influence the joint properties and are specific to the welding process and other circumstances (such as application). For example, changing the heat treatment condition of the weld will affect properties, and thus be a change in the essential variables.

The **Welder Qualification** (WQ) determines the ability of welders to make sound welds. Here the essential welding variables are those influencing the difficulty in making the joint with the declared process.

The WPS provides the instructions, in all relevant detail, to make the joint in the structure. Some variables are non-essential; they do not significantly affect the properties of the joint but still need to be specified. The joint geometry including angle, root gap and root face is an example. All variables are thus specified and available to the fitter, inspector and surveyor. In some instances, particularly involving simple manual processes, there are fewer variables specified and greater reliance is placed upon the skills of the welder.
Inspection is an activity, focused upon the WPS, which occurs before, during and after welding.

Before production commences a Review of Welding Procedures should be carried out. The fabrication drawing shows where the WPS is to be used and the application standard or code (e.g. LR Rules for Ships; ASME Boiler and Pressure Vessel Code) plus requirements such as post weld heat treatment, corrosion allowance or design temperature. The WPS must conform to the drawing and be supported by a PQR reporting test results, which satisfy the requirements.

Before and during welding, checks should be made that both parent materials and consumables are in accordance with the WPS. Is the joint gap being maintained? Are the heat inputs and Interpass temperature within the limits?

Inspection carried out after welding should always include visual inspection (e.g. has the joint been welded at all? Particularly relevant for fillet welds in remote locations!). Non-Destructive Examination (NDE) carried out after welding, particularly when only required on a low percentage sample basis, does not enhance the quality of the welded joint. It provides assurance that the quality control has been successful. Conversely, if significant (potentially damaging) defects are detected, it indicates that the quality control has not been effective. It is then essential that the cause of the faults is established and all suspect work is examined and repaired where necessary.

Welding Inspection

Welding Inspections are done to Qualify a Welder or Welding Procedure to one of the international standards such as BSEN 288 / BSEN 287 respectively.
All the Inspections are carried out by approved welding Inspector who is being qualified either to British / American/International schemes example, CSWIP/AWS etc.
In Hong Kong HKIAS is operating a scheme for accreditating the Inspection body to perform welding Inspections.
The Welding Inspection is generally carried out at three stages
Inspection Before Welding
Inspection During Welding
Inspection After Welding

Inspection Before Welding

Though Inspection before Welding is not critical some of the Major defects are caused due to Improper Inspection before welding.
The common checks performed before a welding are
Verify the Grade of Material
Verify the Filler Wires, Electrodes for coating sizes, dimensions
Inspect the Parent Material for the cleanliness, straightness, any damages etc.
Inspect the Bevel Preparation Angle, Root face
Inspect the Fit up for Misalignment & Root Gap
Verify the Electrode treatment such as baking, drying.
Verify the treatment of Parent Metal such as Pre Heating.
**Inspection During Welding**

This Part is the critical part while conducting a Welding Inspection
The following are the general checks performed by WI during the welding process
Verify the Welding current, Voltage (Arc Length), and Speed as per WPS (Welding Procedure Specification)
Ensure correct electrode sizes are employed
Inspect the cleaning between each passes of welding for removal of slag etc.
Inspect for any cracks between passes of welding.
Ensure the correct Interpass temperature is maintained.
Verify the run sequence is as per WPS

**Inspection & Testing After Welding**

Inspection after Welding is done immediately after the welding or after an agreed delayed period say 16 Hrs / 48 Hrs as per contract requirements & based on risk of cracking.
The finished welds shall be free from slags, Tools marks, Spatters, & the weld face; cap height shall meet the stated standards.

Weld imperfections shall identify by various NDT tests or Visual examination or other DT such as Macro examination.
They can be grouped into five distinct types according to their nature and shape. It is important that an imperfection is correctly identified to allow the welding procedure to be suitably modified to prevent their re-occurrence.

**Cracks**
- Solidification Cracking
- HAZ Hydrogen Cracking
- Weld Metal Hydrogen Cracking

Cracks are more significant than other types of imperfection, as their geometry produces a very large stress concentration at the crack tip, making them more likely to cause fracture. Note that this section is concerned only with cracks produced at the time of welding, not subsequent service cracking, such as fatigue or stress corrosion cracking. Cracks can occur in the weld metal or heat affected zone. Due to their severity of stress concentration, crack-like imperfections are usually classed as defects.
Lack of Solid Metal
- Porosity
- Worm Holes
- Crater Pipe
- Root Concavity
- Under fill
- Slag Inclusions
- Inter-Run Imperfections

These imperfections are formed when there is insufficient weld metal to completely fill the cross-section between the parent metal plates. They are volumetric (blunt) in shape, and as such are usually only associated with a reduction in the load bearing capacity of a weld.

Fusion defects
- Incomplete Root Penetration
- Lack of Sidewall Fusion

These imperfections occur when there is incomplete fusion between the parent metal and weld metal or between weld runs. They are essentially two-dimensional in shape and so are effective stress raisers within the material. Therefore it is important to control them as they can lead to cracking within the weld.

Lack of Smoothly Blended Surfaces
- Surface Porosity
- Excess Weld Metal (Reinforcement)
- Excessive Penetration
- Undercut
- Overlap

It is not immediately obvious that irregularities on the surface of the weld are serious imperfections. However, any sudden change in the contours of the surface produces local stress concentrations. This can especially lead to the formation of fatigue cracks (most commonly at weld toes).

Miscellaneous
- Misalignment
- Arc Strikes
- Spatter

Several miscellaneous imperfections do not conform to any particular category.
Properties of Welding

The completed weld joint is required to have adequate strength, ductility, toughness and any other properties necessary for the application which is being verified for Welder qualification or welding procedure test specimen.

Transverse Tensile Test

In the transverse tensile test, all zones of the joint are equally loaded and any weakness is revealed. If the strength of a welded joint were significantly less than that of the parent material (under matched), local overload failure would be possible at the weld. Fortunately, adequate strength can be readily achieved in carbon-manganese steel weld metals and heat affected zones, and failure normally occurs in the parent plate. Even high heat input electro slag welds (which can show a soft over tempered zone in some thermo mechanically treated (TM) steels) do not appear to suffer from any significant loss of strength.

A more relevant and possibly unexpected threat arises when the strength of the weld metal is too high. Here, the yield strength of such an overmatched weld metal often approaches the tensile strength, and can be double that of the parent plate. Residual stresses from welding commonly approach yield and so are raised by increasing strength. Higher stress means that a smaller defect will be able to initiate fracture and so the integrity of the structure will be degraded.
**Bend Tests**

Bend tests apply strain to all parts of the welded joint, and are useful for the exploitation and detection of defects and embrittlement. When bend tests are specified for welder approval testing, the intention is to assess the ability of the welder to make sound joints. The bend test also reveals small cracks and embrittlement, which arise from the impurities within the steel. The phenomena of burning or the related overheating, which occur close to the fusion line, are likely causes of bend test failure when impure steels are welded. The welder could be unnecessarily rejected due to bad material!

**Impact Tests**

The number of impact tests required and the test temperature depends on the standard being followed. The typical locations shown are intended to sample the toughness of all relevant zones at heat inputs around 3kJ/mm. At higher heat inputs, the HAZ will be wider and other locations will be relevant. Note that heat input is an example of an essential variable which cannot be increased without qualification testing when impact properties are specified.

When high heat inputs are used, loss of toughness is most likely in the HAZ of the steel. Here, close to the fusion boundary, almost all the carbide, nitride and sulphide particles are dissolved. Impurities (such as sulphur and phosphorus) involved in burning and overheating are particularly detrimental in coarse structures, but have been significantly reduced in modern, clean, steels. Soft, low strength ferrite around the prior austenite grain boundaries also reduces impact toughness and control of the transformation (to give a fine ferritic structure) becomes especially important at high heat inputs.

Some special titanium refined steels contain very stable nitride particles, which restrict grain growth, and thereby reduce the grain size and width of the HAZ. Other low carbon special steels developed along the lines of weld metals) contain oxide particles, which promote nucleation of fine and therefore tough intergranular ferrite (which is similar to the acicular ferrite of weld metals).

Strain ageing caused by welding, forming or thermal correction of distortion can also cause loss of toughness at almost any location.
**Welding Inspection Report**

The Welding Inspection report will issue together with the welder certificate or Welding Procedure approval record provided the entire test results compiled with the standard. The Report provides in detail what are all the ranges the welder or Procedure is approved. In order to Maintain integrity & highest quality standard in construction industry all the Inspections are carried out by approved Inspectors or operators under HKIAS/Hoklas scheme.

**Conclusion**

From this Presentation it has been understood that quality of Welding in construction Industry is improved comparatively & will improve to provide better building in future.

**References**

Basic Metallurgy & Welding – The Welding Institute UK

Welding Handbook - Materials and applications - Part 2 (volume 4) eight edition