ROLE OF WELDING IN STRUCTURAL STEEL INTENSIVE CONSTRUCTION IN INDIA

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INTRODUCTION

Construction builds the basic framework and infrastructure of a country, which stimulates further economic, commercial and industrial activities. In building construction role of steel is same as that of bones in a living being. It is widely known that steel as a material of construction:

- Offers considerable flexibility in design and ease of fabrication.
- Facilitates faster construction of projects.
- Enables easy construction scheduling even in congested sites.
- Permits large span construction - a modern trend in architectural design.
- Permits easy structural repair/ modification.
- Is an ideal material in earthquake prone locations due to high strength, stiffness, ductility.
- Is environment friendly and fully recyclable on replacement.

Abroad, the use of structural steel has been growing, and has now become one of the important input materials of construction. In India, up to early nineties, availability of structural steel was in short supply and weather resistant and/or high strength grades were not readily available. Thus steel did not make much in-roads in building construction and highways, and its share in bridge construction also started decreasing. This coupled with many other reasons led to stagnation in steel demand, while large-scale production capacity has been created in the country. Proper development of steel application sector also depends on matching development and growth of the appropriate welding sector. Today, the prosperity lies in the coordinated and tandem effort of the two sectors.

Welding is an important method of joining in construction sector. The reliability, durability and safety of the structure primarily depends upon the strength of the joints. Today, new high performance grades of steel for structural applications have come up in the market. Parallely better understanding of metallurgical aspects of welding and procedures has been developed to produce sound joints. The organizers of this seminar have done a commendable job in providing a platform where both manufacturers and consumers of welding consumables can exchange their views.

The days of riveted construction have gone and the growth possibilities of welding sector appear to be tremendous. The Indian economy, though growing at an appreciable rate, is facing the challenge of massive infrastructure development in a short period of time. Like the developed countries, steel intensive construction will be adopted in a large number of cases to meet the demanding requirements. The trends of construction have already started in India with a good number of building and bridges being built with steel now-a-days. And with proper coordinated efforts, this can be a big business for both the steel and welding sector in India.

INDIAN STEEL SECTOR : CURRENT SCENARIO

Today, the per capita consumption of steel in India is 27 kgs. Plain carbon structural steel covering IS: 2062 Gr A, B and C is widely used in Indian construction sector. Due to higher strength to weight ratio as well as due to overall economy in its use, high strength low alloy structural steel (HSLA) is a preferred choice. For special applications, where thicker plates or sections with higher strength and toughness are required, heat-treatment is employed. At the same time, having accepted welding as a common and dependable method of fabrication, steel producers have been giving special attention to the weldability of every new grade of steel before standardizing the steel for introduction into the market. Thus, development of new grades of steel and development of welding consumables have proceeded hand-in-hand.

During the last three decades, the steel industry abroad has made rapid strides through remarkable technological developments in respect of processing techniques. This has resulted in improved cleanliness, strength levels, corrosion resistance, and impact toughness. Further efficient, larger and thicker rolled sections have been developed to expand the application range and enormous efforts have been devoted to create new markets for steel consumption. On the other hand, the Indian Steel Industry did not devote adequate efforts and resources for producing and marketing high strength and weathering steels at affordable prices. At the same time, unified efforts have been lacking for market development by the steel industry. This retarded the growth of fabrication industry, particularly at the medium and small level to expand the infrastructure base of steel intensive construction.

The situation has somewhat improved today on the material availability front in respect of both IS:2062 (mild steel) and IS: 8500 (high tensile) grade steel in the market. Structural pipes (IS: 1161) and hollow sections (RHS and SHS) as per IS: 4923 are gaining popularity. Use of weathering steel (Corten type or equivalent in different brand names) for structural purpose is also catching up. SAIL, TISCO, RINL, ESSAR and other leading manufacturers produce high quality steels in both Indian and foreign specifications. High performance painting systems providing long maintenance free life are now available in India. Further, in the liberalized economy, import of steel from foreign producers (with their wide products range) is now a reality. However, continuous efforts have to be made towards development of better steels and efficient sections.

New Grades of Steels

High Strength Low Alloy

Modern construction structures need higher strength steel with good ductility, formability and toughness to reduce weights and achieve economy. Mild steel plates have excellent formability but lower strength, this requires relatively thick section for a given steel, load bearing application. Most economical way of increasing strength of steel, to reduce weight of structures, is by increasing its carbon content. But ductility and toughness of steel decreases. Also in steels of this type, weldability and formability are adversely affected when carbon increases above a certain level.

The most common and economical route for increasing simultaneously strength and toughness of steels is by alloying with very small percentage of V or Nb or Ti singly or in combination and/or by controlled rolling. These steels are commonly called high strength low alloy (HSLA) or micro-alloy steels These categories of steel have been covered under IS 8500 specification, which is equivalent to BS 4360.

Weather Resistance Steel

In recent past demand is picking up for high strength steel with improved corrosion resistance. This type of steel is produced by alloying with Cu, Cr and P and the steel is known as Corten type or its equivalent and is generally referred to as weather resistant steel.

The vast coastline, the high relative humidity round the year and heavy rainfall in several areas, make weathering steel a good choice as a material of construction, combining a high degree of resistance to atmospheric corrosion at reasonable cost. These steels may be fabricated in the same manner as ordinary structural steels of the same strength. For all welding procedures, appropriate minimum preheat temperatures should be used. Electrode should be selected in order to remove the possibility of hydrogen induced cracking. Manual metal arc, gas shielded or submerged arc welding can be used for this type of material.

Closed Structures (SHS/RHS)

Due to their high torsional rigidity and compression strength, closed structures behave more efficiently than conventional structures. Their higher strength to weight ratio results in upto 40% saving in steel. The smooth, uniform profile of these sections minimizes corrosion and facilitates easy fabrication at sites. RHS/SHS are weldable without any preheating with standard electrodes available in the market.

Indian Welding Industry

Welding today has become one of the most important tools for quality fabrication in industry. The fate of welding industry is closely linked with the country's steel consumption, since on an average about 5 kg of weld metal is deposited for every tonne of steel consumed. In a study made by the CII in the recent past, the total weld metal deposited in the country during the year 1996-97 had been estimated at 1,10,000 tonnes considering the consumption of steel in the country at 22 million tonnes per annum. Based on assumption of 8% per annum increase in steel consumption, it was estimated that the total weld metal deposited in the country during the year 2000-2001 will be of the order of 1,49,700 MT which is equivalent to 2,17,600 tonnes of electrode/weld wire. However due to slow down in the steel consumption, electrode requirement will be much lower than the predicted estimate.

Traditionally welding is considered as a means of fabrication and the major part of the turnover comes from the welding industry. Welding technology today is not merely a joining method but it is effectively used for cladding, hardsurfacing, cutting and for a variety of other applications. With the growth of automobile, earthquake equipment, white goods, container manufacturing sectors in the country coupled with the need to compete in labour costs, the growth of semiautomatic MIG/MAG process using solid and flux cored wires has gained momentum.

Today matching with the steel availability, welding electrodes are available conforming to almost all the grades of steel available in India. The customer focus and market orientation has become essential requirement for both the steel as well as the welding sector in the buyer's market. Organizations today must appreciate and accept the latest trends in the welding technology, and upgrade their products and services to venture into the existing and emerging new markets more competitively. Both the sectors should aim to develop not only the requisite technical capacity, but also build confidence and patience to provide progressively improved customer service and results of tests as required by the customers. The fatigue studies of welded joints may be one such area.

Welding Technology

Welding is a process of connecting pieces of metal together by the application of heat with or without pressure. Welding is a part of the fabrication process which has generally replaced riveted connections and is an alternative to bolted connections. Its use enables a saving in weight by not having to use cleats or splice plates and a reduction in stress by not having to drill holes in the members. This in turn allows smaller sections to be used with equivalent strength. Steel has been a very attractive material for structural application due to its flexibility in fabrication and erection, ease of retrofit and repair in addition to its high strength to weight ratio and the consequent economy in large span application.

There are many welding processes available to the fabricator, each with its advantages and disadvantages. In the past the most widely used welding process has been manual metal arc welding .For welding of structural steelworks the most commonly used techniques are:

a. Shielded Manual Metal Arc Welding (SMAC)

b. Metal Inert Gas Welding (MIG)

c. Submerged Arc Welding (SAW)

d. Stud Welding (for composite construction)

The weld connections of structural steel start from the right type of weld joint configuration, the edge preparation, selection of weld process and procedures including selection of right type of filler materials, treatment to follow keeping in mind designer's requirement - static loading, cyclic loading and consequent fatigue failure. One needs to consider the distortion and welding defects, which may arise during fabrication - erection and in repair of weld defects.

SHIELDED MANUAL METAL ARC WELDING

For manual welding, single phase or three phase transformer AC or DC motor generator sets are used. These machines have regulators for controlling the welding current. The current is adjusted manually by the welder depending on the type of electrode and weld joints . From the point, of view of simplicity, generally AC transformers are used. For complicated and heavily stressed welding joints, DC generators are generally used.

AUTOMATIC AND SEMI AUTOMATIC WELDING

The basic stages of an arc welding operation are those of striking the arc, feeding the electrode, holding the arc at just the right length and manipulating the arc along with the seam. In automatic welding the entire operation is controlled by the machinery while in semi automatic welding the control is shared by machinery and the operator. A modern automatic welding machine incorporates a welding head which strikes the arc, feeds welding wire, while maintaining the arc at desired length. It has a truck to carry the welding head along the seam or a roller stand to move the work relative to the welding head. There are two types of automatic welding: Submerged Arc Welding and CO_2 process.

SUBMERGED ARC WELDING

In submerged arc welding the seam is shielded by a blanket of granular fusible material called flux and the arc is therefore submerged. This flux acts as good insulator and concentrates heat in a relatively small welding zone, thus improving the fusion of the welding rod and melting parent metal. Secondly it protects the molten pool from atmosphere, reducing pick-up of oxygen and nitrogen to a minimum. It calls for a more thorough joint and edge preparation and better fit up than manual metal arc welding. In CO_2 process CO_2 gas acts as a shield, so that the arc and the joint are fully visible and the operator can manipulate the machine and the flame.

STUD WELDING

It is a process by which metal fasteners are end welded rapidly to the surface of metal components and structures using an electric arc to produce the heat necessary for a fusion weld. The process is actually a combination of heat and pressure, the weld being made by drawing an electric arc between the studs, which is in effect the electrode and the part to which it is to be welded and then bringing the two pieces into intimate contact when the correct temperature is reached. Stud welding is widely used for shear connectors on beam flanges.

SELECTION OF WELDING CONSUMABLES

The base metal is selected by the designer for the specific application based on a specific property or combination of properties, such as yield or tensile strength, notch toughness, corrosion resistance, or density. One important job of the welding engineer is to select the welding consumables and process and to develop welding procedures and allow the design properties to be fully utilized in service. The consumables like electrodes normally conform to IS 814 / 815. Welding technique is in accordance with IS 816/ 9595 which is the latest. High tensile steel electrodes should comply with the requirement of IS 1442. The size of the electrode may be 1.6 mm to 9.0 mm in dia and length depends on diameter. There is no single answer to the question 'which is the best electrode? Each application must be tackled by examining a number of aspects, for example

a) What is the composition or type of the metals/steels to be joined?

b) Is there a risk of cracking weld metal?

c) What mechanical properties are required?

d) Is ac or dc plant available?

e) What is the position of welding?

f) What is the thickness of the parent material?

g) What is the type of joint?

h) Are there any limitations in heat input?

Having answered these and other queries an electrode type is selected, which gives the optimum performance at an economic price.

To achieve mechanical and physical properties that nearly match those of the base metal, the weld metal is often similar in chemical composition to the base metal. This is not a universal rule and sometimes, the weld metal composition is deliberately made significantly different from that of the base metal. The intent is to produce a weld metal having properties compatible with the base metal. Therefore, variations from the base metal composition are not uncommon in filler metals.

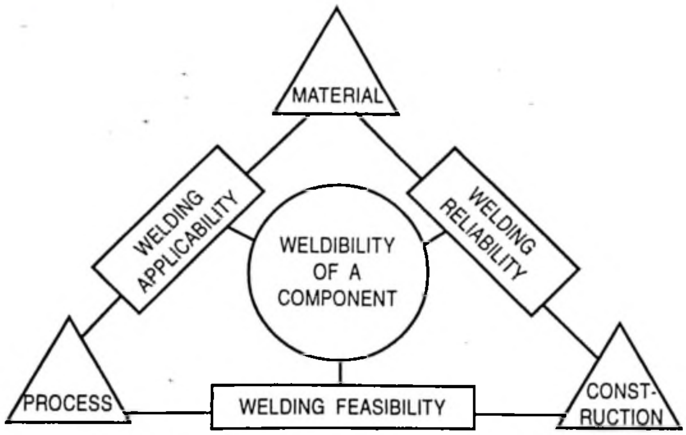


Fig 1 : Welding compatibility (Source Ref. 6)

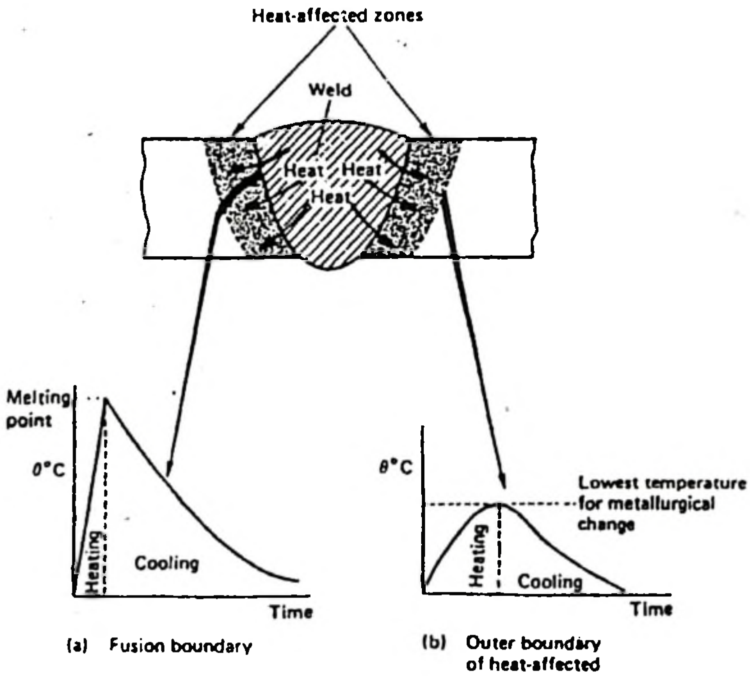


Fig 2 : Heat affected zone boundaries (Source Ref. 2)

Basically all welded connections are either a fillet weld or a butt weld based on the various types of loads acting on the structural members. Welding can also be horizontal and vertical depending on the positions where they are welded. The requirements which the structural members are to comply with are : Tensile strength; Compression Strength; Stiffness against distortion; Strength

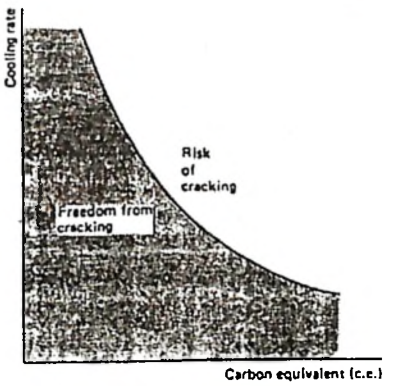


Fig 3 : Interaction of cooling rate and carbon equivalent (Source Ref. 2)

against shock loads; Rigidity & vibration damping quality.

WELDABILITY

The weldability of steel is defined as the ease with which the required degree of joinability and performance can be obtained with a given welding process and welding procedure. There are a number of tests for assessing the weldability. One of the first tests to judge the weldability of steels is the chemical composition of steel. Structural steels with carbon ranging between 0.15 to 0.22% are easily weldable. However, addition of alloying elements such as chromium, molybdenum, vanadium, titanium, niobium etc. slightly decreases the weldability potential of steel. These elements increase the hardenability of weld metal and / or of heat affected zone (HAZ) necessitating special precautions to avoid cracks. The link between weldability of a component, welding process and their compatibility is shown in Fig.1.

The hardenability of the alloying elements can be expressed as a percentage of carbon and thus the concept of carbon equivalent (CE), as given below, provides a general guideline to assess the weldability of steel :

CE = %C + %Mn/6 + (%Cr + %Mo + %V) / 5 + (%Ni + %Cu) / 15

HEAT AFFECTED ZONE AND HOW TO AVOID RISK OF CRACKING?

The region of the parent metal, which undergoes a metallurgical change as a result of the thermal cycle is called heat affected zone (HAZ). A typical HAZ is shown in Fig. 2. If the CE exceeds. 0.4, the welding situation changes due to the possibility of cracking in the heat affected zone (HAZ) and due to increase in volume of martensite, cracks will usually develop the phenomenon called underbead cracking. During cooling of the molten weld metal, only a small part of the heat escapes through the surface of the pool and major part flows through the parent metal on each side of the joint. As a result, the parent metal is subjected to heating and cooling cycle. The high thermal cycles accelerated the formation of HAZ cracking. The two critical components of the cycle are the highest temperature reached and the subsequent rate of cooling.

The cooling rates experienced in the HAZ of a weld joint are often high enough to give quenching effects similar to those experienced in heat treatment practice. Not only the hardness of HAZ is high but it has the presence of tensile stress. When hydrogen level is above the critical level, the cracking of HAZ takes place. The risk of cracking depends upon type of hardened structure, the joint profile, actual level of hydrogen.

The normal structural steel has a hardness of 190-200 BHN. In HAZ, depending upon thickness, carbon content, hardness of 350-450 BHN may be reached. The level of hardness depends upon cooling rate. The risk of cracking is higher when hardness exceeds a certain level corresponding to higher rate of cooling. The critical cooling rate at which higher hardness of 350 BHN is reached depends upon composition of steel. The interaction of cooling rate and carbon equivalent is illustrated in Fig. 3. At low levels of CE fast cooling rates can be tolerated before

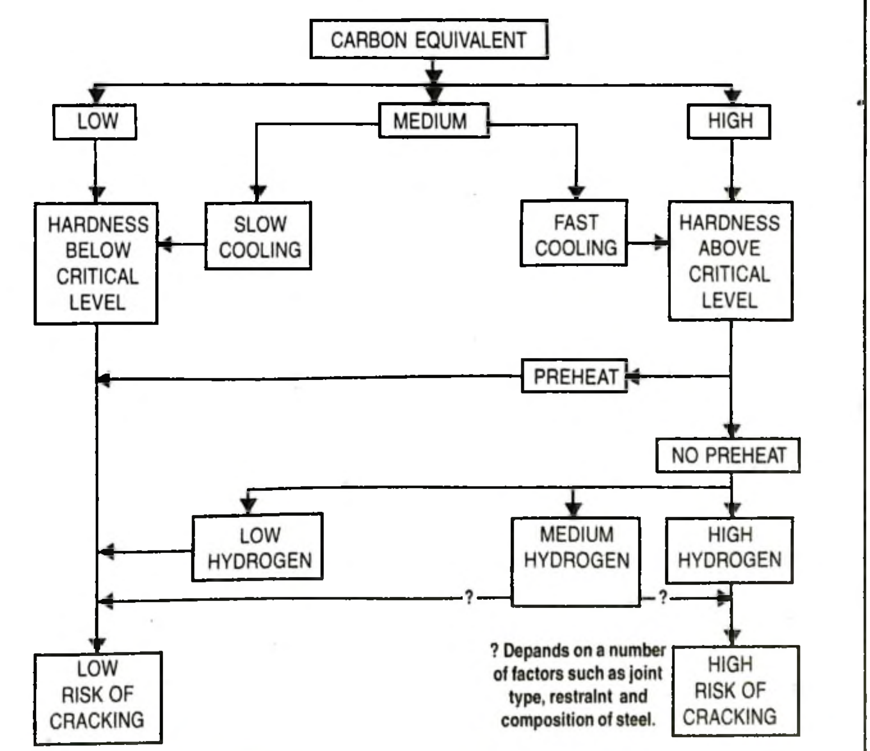


Fig 4 : Principal factors affecting cracking tendency of HAZ (Source Ref. 2)

there is risk of cracking ; except in thick section, HAZ cracking is rarely experienced with CE values below 0.39%. At high levels of CE, say around 0.48%, there is high risk of cracking even at slower cooling rates. However, appropriate preheating of the parent metal and/or lower levels of hydrogen in the weld metal can eliminate this problem.

It may be noted that even when hardened HAZ is subjected to tensile stresses caused by heating and cooling of the joint, cracking will not occur if the hydrogen level in the weld metal is low,. Higher level of hydrogen is harmful. Hydrogen is absorbed in the molten weld pool from a variety of sources; moisture in the flux covering of an electrode or in the shielding gas, grease on the joint faces and so on. Hydrogen can flow (diffuse) readily through hot steel and pass from the weld pool into the HAZ causing a major risk of cracking . Gas shielded processes such as MAG and TIG are inherently low in hydrogen with levels 5-10 ml/100g and are thus effective in avoiding cracking.

Heat input and the thickness of the metal in the joint affect the cooling rate in the joint. In thick sections cooling rate is faster than in thin. Preheating temperature slows down the cooling rate through the temperature range within which a hardened structure is formed i.e:, 300-200°C. Preheat also helps to reduce the risk of cracking by allowing any hydrogen in the heat affected zone to flow into the parent metal where hardening has not taken place.

The interdependence of principal factors i.e., CE, cooling rate (heat input, joint type and thickness), hydrogen content and preheat (temperature of parent metal during welding) governing the risk of HAZ cracking is complex, but is shown in a simplified diagram (Fig. 4), which can help choosing an appropriate combination to avoid the risk of cracking.

The problem of under bead cracking can easily be overcome by preheating the weld joint just prior to welding or by choosing a proper low hydrogen electrode. Nomograms have been prepared for ascertaining combined thickness and energy input at different CEs for defect free welding of steel. A typical example is shown in Fig. 5.

WELD JOINT

The designer has an unlimited scope regarding the choice of weld edge preparation. One can choose any one of the recommended designs of a weld joint and these joints have to pass through various fabrication and inspection stages. The criteria for the selection of an edge preparation are:

a) Ease of assembly

b) Resistance to lamellar tearing

c) Accessibility for visual inspection

d) Weld inspection by radiography, ultrasonic, etc.

Grading of typical weld joints is given in Fig.6

DISTORTION IN STEELWORKS

Stresses are induced by the unequal expansion and contraction of the weld metal, the heat affected zone and unaffected base metal during welding. In welding, the heat of the arc causes the weld metal and the adjoining parent metal to expand on solidification of the weld deposits and the base metal shrinks and contracts towards centre. This phenomenon causes distortion in the work piece. The degree of distortion occurs in any structure depending on the co-efficient of expansion, thermal conductivity, modulus of elasticity of base and weld metals involved, the thickness of section and heat input. The reasons for distortion and the suggested remedies are :

CAUSES OF DISTORTION

- Amount of weld metal deposited
- Number of runs
- Extent to which parts are free to move
- Conditions of the parts to be welded

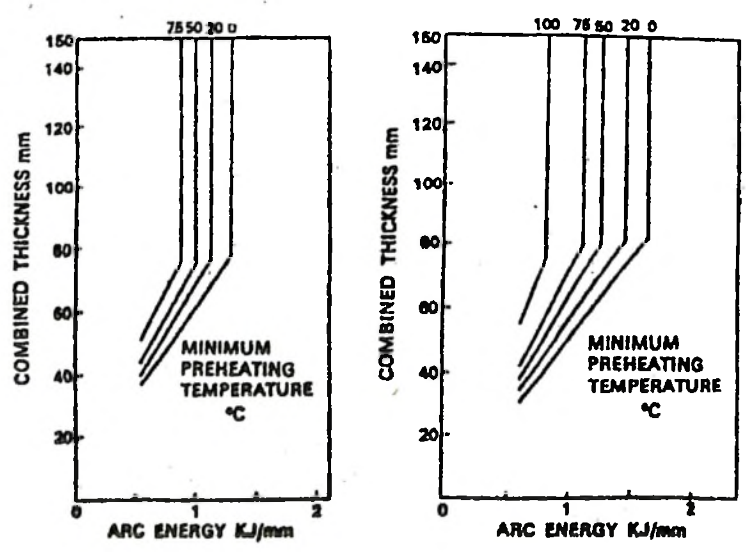


Fig 5 : Conditions for welding of stanted CE (Source Ref. 6)

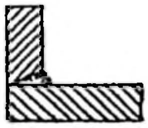
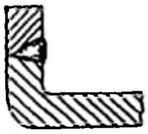
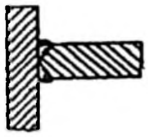
TYPES OF JOINT	EASE OR ASSEMBLY	WELD INSPECTION BY RADIOGRAPHY
	GOOD	POOR
	GOOD	GOOD
	GOOD	POOR
	GOOD	GOOD

Fig 6 : Grading of weld joints (Source Ref. 6)

REMEDY TO MINIMIZE DISTORTION

- Adopt proper welding procedure (w.r.t heat input)
- Planning welding sequence for correct angular distortion
- Preheating parts prior to and during welding

STRATEGY FOR EXPANDING ROLE OF WELDING IN CONSTRUCTION SECTOR

One of the major problems faced by the steel industry today is creating new domestic markets for increased steel consumption. The Institute for Steel Development and Growth (INSDAG) has been formed at Calcutta recently by the Govt. of India and major steel producers to address the problem systematically. The institute has taken up several projects/ activities which are aimed at increasing steel consumption in India. The institute has already published Buyer's Manual and Directory of Steel Supply Chain, while it is working on to bring out : Hand book of Composite Construction; Document on Life Cycle Cost Assessment of Buildings and Bridges; Teaching Resource Material for the Faculty of Civil Engineering Departments; Reference Manual For Structural Engineers; Handbook On Steel Detailing; Corrosion Protection Guide for Steel, Welding Guide on Structural Steel etc.

To upgrade the knowledge and expertise of middle level executives, it is organizing Refresher Courses on Composite Construction. It has introduced Award Schemes for Architecture and Civil Engineering students on Innovative. Application and Design of Steel. The Institute also brings out two regular publications (Steel in Construction and INSDAG News) and maintains its own Website. Efforts are also being made to upgrade the design codes on structural steel design and application.

A lot need to be done in terms of welding infrastructure development for steel intensive construction. Some of the welding codes need to be updated to suit the current requirements. Shop facilities for welding of heavy sections and thick plates in large numbers at competitive price are also essential. Development of medium and small-scale fabrication and welding houses located all over the country with state-of-the-art equipment and offering quality service is a must for the widespread development of steel intensive construction. The availability of Shear Studs and Stud Guns, and trained man power for their operation is a basic prerequirement for success of composite construction in India. Imparting appropriate training to welders on new materials / technologies (and also on safety, health and working environment) is an important area so as to ensure wider availability of skilled welders in the country. Both INSDAG and the Indian Institute of Welding can work jointly in the above areas for an effective solution.

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