



DESIGN OF WELDED STEEL STRUCTURES

PRINCIPLES AND PRACTICE



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Utpal K. Ghosh

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Preface

Arc welding represents the state of the art for fabrication of steel structures. In this technique, controlled heat is applied for joining the components of structures along the line of connection. The performance of welded steel structures depends on a number of factors, of which characteristics and quality of welded joints are the most important. In recent decades, there has been phenomenal development in this technology, which has made arc welding highly attractive in the construction industry globally. In fact, welded construction has already proved to be of great advantage to stakeholders, namely, architects, structural engineers, contractors, and their clients—end users. It is necessary that more people acquire knowledge and experience in this field to make welding a more powerful tool for an expanding construction industry. It is in the backdrop of this situation that the present book is immensely relevant.

The book deals with both the principles and practice of welding technology, which is required for satisfactory design of welded steel structures and thus should be of deep interest and value not only to the practicing engineers in the design office or in the workshop, but also to teachers and students in academia.

The presentation of text in this book is somewhat different from that in normal engineering books. This book should be regarded as a complementary work to the more analytical studies, which present worked-out examples. Consequently, topics not usually covered in existing textbooks but are nevertheless important for the understanding of the subject have found place in this work.

The text can be broadly divided into four parts. Chapters 1 through 6 deal with the basics of arc welding and include brief notes on the salient features of modern arc welding processes, types and characteristics of welded joints, their common defects and recommended remedial measures, and quality control aspects in the workshop. Chapters 7 through 9 primarily deal with analysis and detail design of welded structures. Chapters 10 through 15 provide useful information and discussions on the detail design of joints in respect of some common welded steel structures. The concluding chapter (Chapter 16) discusses cost factors involved in welded steelwork.

The material covered in the text has been drawn from the vast pool of accumulated knowledge and experience of distinguished engineers gained through studies in different countries, primarily Europe and America, and supplemented by the author's own experience. As far as possible, references to the published literature have been mentioned at the end of each chapter. The author thankfully acknowledges his indebtedness to these writers. However, if the ideas of earlier writers have appeared in the book without

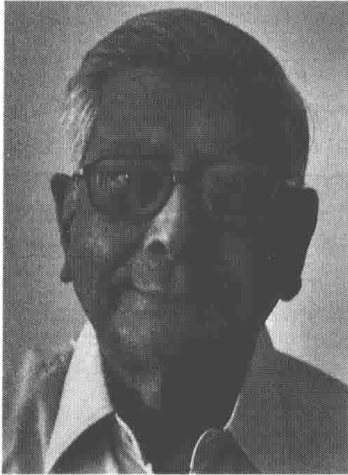
appropriate acknowledgment, it is quite unintentional, and the author would like to extend his apologies. If such instances are brought to the author's notice, the same will be gratefully acknowledged in the subsequent edition of the book.

The author has also gained immense knowledge from personal interactions with a large number of individuals. Many a time, small points raised in discussions have led to a major change in the text or the inclusion of an additional topic. It is practically not possible to list such individual names. However, the author gratefully acknowledges his debt to each of them. Special thanks are due to the author's longtime colleague and friend Amitabha Ghoshal for his support throughout the preparation of the manuscript and valuable suggestions. The author thanks his son, Indranil, and daughter-in-law, Supriti, for their assistance in the preparation of the manuscript, particularly during his several visits to the United States. Thanks are due to Tilokesh Mallick for the long hours he spent ungrudgingly for keying in the bulk of the text into a computer and helping the author in surfing the Internet as well as other various activities. Sanjoy Bera also deserves special mention for drawing electronically all the figures appearing in the book.

And last, but by no means the least, the author is grateful to his wife, Manjula, for her encouragement and support in writing the book.

Utpal K. Ghosh

Author



Utpal K. Ghosh worked, among others, with Freeman Fox and Partners, London; Sir William Arrol & Co. Ltd., Glasgow, Scotland; and Braithwaite Burn & Jessop Construction Co. Ltd., Kolkata, India, after graduating in civil engineering in 1954 from Bengal Engineering College, Shibpur, Calcutta University (currently Indian Institute of Engineering Science and Technology). Subsequently, he set up his own practice as a consulting engineer.

During his long career, he participated in the planning, design, fabrication, erection, and overall management of a wide variety of projects, such as bridges and industrial structures, which included new construction as well as repair and rehabilitation work. He has worked on projects in several countries, including the United Kingdom, New Zealand, Malaysia, Indonesia, Singapore, and India.

He has published a number of articles and is the author of two books entitled *Design and Construction of Steel Bridges* and *Repair and Rehabilitation of Steel Bridges*.

He is a Chartered Engineer and is a Fellow of the Institution of Engineers (India), a Member of the Institution of Civil Engineers (UK), and a Member of the Institution of Structural Engineers (UK).

Contents

Preface.....	xvii
Author.....	xix
1. Electric Arc Welding Processes.....	1
1.1 Introduction.....	1
1.2 Manual Metal Arc Welding.....	2
1.3 Metal-Active Gas Welding.....	4
1.4 Submerged Arc Welding.....	6
1.5 Stud Welding.....	8
1.6 Control of Welding Parameters.....	8
1.7 Selection Criteria of Welding Process.....	9
1.7.1 Costs.....	9
1.7.2 Location of the Work.....	10
1.7.3 Welding Position.....	10
1.7.4 Access.....	10
1.7.5 Composition of Steel.....	10
1.7.6 Availability of Welding Consumables.....	10
1.7.7 Availability of Skilled Welders.....	11
1.8 Safety Aspects.....	11
Bibliography.....	11
2. Welded Joints.....	13
2.1 Introduction.....	13
2.2 Types of Welds.....	13
2.2.1 Fillet Weld.....	13
2.2.2 Butt Weld.....	14
2.3 Types of Welded Joints.....	15
2.3.1 Butt Joints.....	15
2.3.2 Tee Joints.....	15
2.3.3 Corner Joints.....	15
2.3.4 Lap Joints.....	16
2.4 Heat-Affected Zone.....	16
2.4.1 Chemical Composition of Steel.....	17
2.4.2 Rate of Cooling.....	18
2.5 Interacting Variables.....	19
2.5.1 Composition of the Parent Metal, Electrode, and Flux.....	19
2.5.2 Welding Process.....	19
2.5.3 Environment.....	20

2.5.4	Speed of Welding	20
2.5.5	Thermal Cycle of Weld	20
2.5.6	Size and Type of Joint	20
2.5.7	Manipulation of Electrodes	20
2.6	Residual Stresses	20
2.6.1	Heat Treatment	22
	Bibliography	22
3.	Defects in Welded Joints	23
3.1	Introduction	23
3.2	Defects in Welds	24
3.2.1	Undercut	24
3.2.2	Porosity	25
3.2.3	Slag Inclusion	25
3.2.4	Pin Holes	26
3.2.5	Incomplete Root Penetration	26
3.2.6	Lack of Fusion	26
3.2.7	Solidification Cracks	27
3.2.8	Defective Weld Profile	27
3.2.9	Issues Related to Defects in Welds	27
	3.2.9.1 Discontinuity in the Load Path	28
	3.2.9.2 Stress Concentration	30
3.3	Defects in HAZ	30
3.3.1	Hydrogen Cracking or Cold Cracking	30
3.3.2	Lamellar Tearing	30
3.4	Concluding Remarks	32
	Bibliography	33
4.	Control of Welding Distortion	35
4.1	Introduction	35
4.2	Basic Causes of Distortion	35
4.2.1	Properties of Materials	35
4.2.2	Inherent Stresses in Parent Material	36
4.2.3	Uneven Heating	36
4.2.4	Restraint during Welding	36
4.3	Types of Distortion	37
4.4	Control of Distortion	39
4.4.1	Prevention of Distortion	39
	4.4.1.1 Design Stage	39
	4.4.1.2 Fabrication Stage	42

4.4.2	Correction after Fabrication	48
4.4.2.1	Mechanical Means	48
4.4.2.2	Correction by Heating	49
4.5	Concluding Remarks	52
	Bibliography	52
5.	Brittle Fracture	53
5.1	Introduction	53
5.2	Factors Influencing Brittle Fracture.....	53
5.2.1	Metallurgical Feature	54
5.2.2	Temperature of Steel in Service	54
5.2.3	Service Conditions.....	54
5.3	Prevention of Brittle Fracture	54
5.3.1	Selection of Appropriate Steel Material.....	54
5.3.2	Design of Details.....	55
5.3.3	Quality Control during Fabrication	56
5.4	Learning from Failures	56
5.5	Concluding Remarks	58
	Bibliography	58
6.	Quality Control and Inspection	59
6.1	Introduction	59
6.2	Documentation.....	60
6.3	Materials.....	60
6.4	Welding Procedure	61
6.5	Skill of Welders and Operators	62
6.6	Layouts, Templates, Markings, Jigs, and Fixtures	62
6.7	Weld Preparation, Fit-Up, and Assembly	63
6.8	Inspection Personnel	63
6.9	Inspection.....	64
6.9.1	General	64
6.9.2	Nondestructive Inspection and Tests	64
6.9.2.1	Visual Inspection.....	65
6.9.2.2	Liquid Penetrant Testing	67
6.9.2.3	Magnetic Particle Inspection	67
6.9.2.4	Radiographic Test.....	68
6.9.2.5	Ultrasonic Test	68
6.9.3	Destructive Tests	69
6.9.3.1	Chemical Analysis	69
6.9.3.2	Metallographic Testing.....	69

6.9.3.3	Mechanical Testing	69
6.9.4	Inspection of Trial Assembly	74
6.10	Concluding Remarks	75
	Bibliography	75
7.	Design Considerations for Welded Joints	77
7.1	Introduction	77
7.2	Layout, Locations of Joints, and Make Up of Sections	77
7.3	Weldability of the Material	78
7.4	Load Conditions	78
7.5	Joint Types	79
7.6	Weld Types	79
7.7	Weld Size	79
7.7.1	Cost	79
7.7.2	Residual Stresses and Distortion	80
7.8	Edge Preparations	80
7.9	Ease of Fabrication and Inspection	82
7.10	Concluding Remarks	85
	Bibliography	85
8.	Design of Welded Joints	87
8.1	Introduction	87
8.2	Butt Weld	87
8.2.1	Full Penetration Butt Weld	87
8.2.2	Partial Penetration Butt Weld	89
8.2.3	Effective Length	90
8.2.4	Intermittent Butt Weld	90
8.3	Fillet Weld	90
8.3.1	Types of Fillet Welds	90
8.3.1.1	Normal Fillet Weld	90
8.3.1.2	Deep Penetration Fillet Weld	91
8.3.2	Size of Fillet Weld	91
8.3.3	Effective Throat Thickness	93
8.3.4	Effective Length	96
8.3.5	Strength of Fillet Weld	96
8.3.6	Design Procedure	97
8.3.7	End Return	97
8.3.8	Lap Joint in End Connection	97
8.3.8.1	Longitudinal Fillet Weld	97
8.3.8.2	Transverse Fillet Weld	100
8.3.9	Combined Stresses in Fillet Weld	100
8.3.10	Packing in Fillet Welded Joint	100
8.3.11	Bending about a Single Fillet	101

8.3.12	Fillet Weld in Compression	101
8.3.13	Intermittent Fillet Weld.....	102
8.3.14	Analysis of Typical Fillet Welded Eccentric Connections	103
	8.3.14.1 Load Lying in the Plane of the Weld	103
	8.3.14.2 Load Not Lying in the Plane of Welds	105
8.3.15	Fillet Welds in Slots or Holes.....	106
8.4	Concluding Remarks	107
	Bibliography	108
9.	Fatigue in Welded Joints	109
9.1	Introduction	109
9.2	Fatigue Crack	110
9.2.1	Causes of Fatigue Crack.....	110
	9.2.1.1 Stress Concentration	110
	9.2.1.2 Intrusions	110
9.2.2	Crack Growth Rate	111
9.3	Design.....	111
9.3.1	Implications on Design	111
9.3.2	Design Method.....	112
9.4	Environmental Effects.....	114
9.5	Prevention of Fatigue Cracks.....	115
9.6	Improvement of Welded Joints.....	118
	9.6.1 Grinding.....	118
	9.6.2 Peening.....	118
	9.6.3 Dressing	119
9.7	Concluding Remarks	119
	Bibliography	119
10.	Beams and Columns	121
10.1	Introduction	121
10.2	Beams.....	121
10.2.1	Beam Sections.....	121
10.2.2	Splices in Beams.....	121
10.3	Columns	124
10.3.1	Column Sections	124
10.3.2	Eccentrically Loaded Columns.....	125
10.3.3	Column Weld Details	125
10.3.4	Column Splices.....	126
10.3.5	Column Bases	129
	10.3.5.1 Pinned-Type Base	130
	10.3.5.2 Rigid-Type Base	130
10.3.6	Column Caps.....	134

10.4	Connections	135
10.4.1	Types of Connections	135
10.4.1.1	Simple Connection	135
10.4.1.2	Rigid Connection	135
10.4.1.3	Semi-Rigid Connection	135
10.4.2	Design Considerations	136
10.4.3	Beam-to-Beam Simple Connection.....	136
10.4.4	Beam-to-Beam Rigid Connection	137
10.4.5	Beam-to-Column Simple Connection	138
10.4.6	Beam-to-Column Rigid Connection	140
10.5	Castellated Beam.....	142
	Bibliography	143
11.	Plate Girders	145
11.1	Introduction	145
11.2	Flanges.....	146
11.2.1	Variation in the Thickness of the Flange.....	146
11.2.2	Variation in the Width of the Flange.....	150
11.3	Web.....	150
11.4	Web-to-Flange Welds.....	150
11.5	Transverse Stiffeners	151
11.5.1	Intermediate Stiffeners.....	151
11.5.2	Load Bearing Stiffeners.....	152
11.6	Stiffener-to-Web Welds.....	153
11.7	Stiffener-to-Flange Welds	153
11.7.1	Load Bearing Stiffeners.....	153
11.7.2	Intermediate Stiffeners.....	154
11.8	Splices	154
11.8.1	Shop Splices	155
11.8.2	Site Splices.....	155
	Bibliography	159
12.	Portal Frames	161
12.1	Introduction	161
12.2	Types of Portal Frames	161
12.3	Knee and Apex Joints	163
12.3.1	Simple Joints	164
12.3.2	Haunched Joints.....	164
12.4	Rafter Site Joints	167
12.5	Bases.....	168
	Bibliography	171

14.9	Joint Failure Modes.....	200
14.9.1	Chord Face Deformation	200
14.9.2	Chord Side-Wall Buckling/Yielding.....	200
14.9.3	Chord Shear.....	200
14.9.4	Chord Punching Shear.....	201
14.9.5	Web Member Failure.....	201
14.9.6	Localized Buckling.....	202
14.10	Joint Capacity.....	202
14.11	Joint Reinforcement	203
14.12	Typical Joint Details.....	203
14.13	Economy in Fabrication.....	212
	Bibliography	212
15.	Orthotropic Floor System	213
15.1	Introduction	213
15.2	Advantages	215
15.2.1	Savings in Weight of the Structure	215
15.2.2	Reduction in Seismic Forces.....	215
15.2.3	Saving in Substructure	215
15.2.4	Ease of Erection.....	216
15.2.5	Saving due to Reduction of the Depth of the Structure	216
15.3	Structural Behavior.....	216
15.4	Analysis.....	217
15.5	Typical Details.....	218
15.5.1	Longitudinal Ribs.....	218
15.5.2	Transverse Cross Girders	219
15.5.3	Splices of Longitudinal Ribs	220
15.5.4	Site Splices of Panels.....	221
15.6	Distortion	222
15.7	Corrosion Protection.....	224
	Bibliography	224
16.	Economy in Welded Steelwork	225
16.1	Introduction	225
16.2	Mechanics of Costing	225
16.2.1	Direct Costs	226
16.2.1.1	Labor Cost	226
16.2.1.2	Costs of Consumables.....	226
16.2.2	Indirect Costs	227
16.3	Factors Affecting Welding Costs	227
16.3.1	Design Stage	228
16.3.1.1	Choice of Sections	228
16.3.1.2	Welding Position	229
16.3.1.3	Accessibility of Welds.....	230

16.3.1.4	Joint Preparation and Weld Volume	230
16.3.2	Fabrication Stage	231
16.3.2.1	Rectification of Mistakes	231
16.3.2.2	Accuracy of Edge Preparation and Fit-Up.....	231
16.3.2.3	Jigs and Manipulators.....	231
16.3.2.4	Choice of Welding Process.....	231
16.3.3	General Remarks.....	232
16.3.3.1	Overheads.....	232
16.3.3.2	Labor Costs.....	232
16.4	Concluding Remarks	233
	Bibliography	233
Index	235

1

Electric Arc Welding Processes

ABSTRACT The chapter begins with the basic principles of making a welded joint and goes on to briefly describe the development of welding processes, from 1400 BC to modern times. The arc welding processes commonly used now are described along with their advantages and disadvantages. Criteria for the selection of a particular process for welding are discussed. The chapter concludes with a short discussion on the safety aspects to be considered for using any of these welding processes.

1.1 Introduction

Welding has now become the most common method of fabrication of steel structures in preference to traditional techniques such as riveting and bolting. Consequently, for a designer, a basic knowledge of the welding process is necessary in order to properly design welded structural steelwork, particularly the design of joints.

Welding is the process of joining two metal components by bringing them to the molten state at the faces to be joined and then allowing the molten metal to intermingle and, when cool, establish a metallurgical bond between the components. Thus, the process is essentially a fusion process.

The technology of forge welding is believed to have been used first by the Syrians in about 1400 BC. Since then, the technology may have been lost and rediscovered a number of times by our ancient forefathers residing in various parts of the globe. Coming to the more recent past, the term *welding* has been generally associated with the village blacksmith's smithy shop, where two metal pieces are softened in the concentrated heat developed by charcoal fire and joined together, or *welded*. In a modern structural fabrication shop, however, the welding process commonly used is the electric arc process. This concept of using electric arc as a suitable source of intense heat to reduce the metal into a liquid was first used in a practical application in the nineteenth century, by forming an electric arc between a carbon piece and the metal workpiece (UK Patent No. 12984 of 1885, Benardos and Olszewski), hence the name *electric arc welding* process. Subsequently, the carbon piece was replaced by a steel rod, called *electrode*.

Essentially, the arc is a sustained spark formed between the workpieces to be welded and the electrode. As the electric arc is brought close to these workpieces, a low-voltage (15–35 V), high-current (50–1,000 A) electric arc is formed between the tip of the electrode and the work, and the temperature at the location under the tip of the electrode jumps to approximately 6,500°F (3,600°C). This concentrated heat melts metal from each component as well as the electrode, forming a common pool of molten metal, called the *crater*. This pool on cooling forms a solid bond between the components, thereby providing a continuity of metal at the interface. By moving the electrode along the line of the joint, the surfaces to be joined are welded together along their entire length. Normally, the composition of the electrode is so chosen that the resultant weld becomes stronger than the connected components.

During the past four decades, welding technology has undergone phenomenal developments, and quite a number of welding processes are now available for use in the fabrication industry. In all these processes, the arc is shielded by a number of techniques.

The most common of these techniques are a chemical coating on the electrode rod/wire, inert gases, and granular flux compounds. The primary purposes of such shielding are to

- Protect the molten metal from the effects of air
- Add ingredients for alloying the resultant weld metal
- Control the melting of the electrode and thereby ensure effective use of the arc energy

Some of the common processes used in fabrication of welded steel structures are briefly discussed in the following paragraphs.

1.2 Manual Metal Arc Welding

The manual metal arc (MMA) welding process is one of the oldest processes of arc welding and is also known as *stick electrode welding*, *shielded metal arc welding*, and *electric arc welding*. In this process, the electrode is a steel stick coated with flux containing alloying elements such as manganese and silicon. The electrode stick is generally 350 mm long. The diameter of its steel core is 3.2–6.0 mm to match the level of the current used. The bare section of the electrode is clamped to an electrode holder, which is connected to the power source by a welding cable. The holder is held by hand. As an arc is initiated between the end of the handheld electrode and the parent metals