DESIGN OF WELDED STEEL STRUCTURES

PRINCIPLES AND PRACTICE

CRC Press
Taylor & Francis Group

Utpal K. Ghosh

DESIGN OF WELDED STEEL STRUCTURES

PRINCIPLES AND PRACTICE

Utpal K. Ghosh

CRC Press
Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Printed on acid-free paper
Version Date: 20150717

International Standard Book Number-13: 978-1-4987-0801-2 (Hardback)

Visit the Taylor & Francis Web site at
http://www.taylorandfrancis.com

and the CRC Press Web site at
http://www.crcpress.com

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

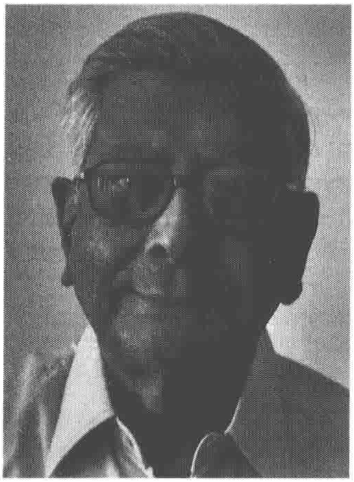
appropriate acknowledgment, it is quite unintentional, and the author would like to extend his apologies. If such instances are brought to the author's notice, the same will be gratefully acknowledged in the subsequent edition of the book.

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

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