CORROSION PROTECTION OF STEEL STRUCTURES

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Preface

The protection of structural steelwork from corrosion is a matter of concern to many engineers, architects and designers. It covers most engineering fields and, although apparently simple in concept, requires a considerable degree of understanding of the processes involved to achieve economic solutions to the problems that arise. Much steelwork is nowadays required to withstand particularly aggressive conditions. Consequently, new types of coating and techniques have been developed to ensure adequate protection of the steel.

The number of standards, codes of practice and publications on this topic has grown to a stage where it has become increasingly difficult for non-specialists to keep abreast of the situation. This book has been written for such non-specialists in the field for whom the protection of steelwork is an important, albeit a comparatively minor, part of their total professional activities. The aim is to draw to their attention recent developments and to describe in a comparatively simple and straightforward way the materials and processes used in the protection of steelwork. Other matters which relate directly to the successful achievement of sound protection such as specifications and quality control are also dealt with.

The book is not intended to be a comprehensive textbook on the many aspects of coatings technology, but rather a practical guide to the principles involved and the methods to be used in achieving the specifiers' requirements. No attempt has been made to summarise or review the many texts produced on this subject. Where appropriate, references have been included, but usually only where specific data have been provided or where it is felt that the reader may wish to cover certain aspects in greater detail.

The views expressed are those of the authors, but when there are clear differences of opinion among various authorities on certain topics, attention has been drawn to them.

We take this opportunity of acknowledging the work of our colleagues in

this field. They are too numerous to list, but many of the views expressed in the book have arisen from discussions with them and the study of their contributions to journals and conferences over the years.

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CHAPTER 1

Introduction

The application of coatings to metals has been carried out for centuries. Various types of naturally occurring materials were used for the coatings and they were applied mainly for decorative purposes, although they were also sometimes used to retard the deterioration of some metals. However, it was the development of steel as a structural material that led to the use of coatings to prevent or control corrosion. The coatings were originally based on naturally occurring oils and bitumens and were often pigmented to provide some colour. They were usually applied by simple methods such as brushing. Generally, the steelwork was given a fairly perfunctory clean to remove foreign matter and loose rust.

These coatings, generally paints, provided reasonably satisfactory protection to a range of structures built during and after the industrial revolution. The environmental conditions were generally less corrosive than today because industrial pollution was less intense. Furthermore, many of the great bridges and viaducts were constructed away from the industrial areas of the country so the basic environment was clean—that which nowadays might be described as rural.

Over the years, coatings were improved and materials other than paints, e.g. zinc, were used for some steel articles. The situation with regard to the protection of steelwork appeared to be satisfactory; maintenance painting was carried out regularly and over the lifetime of a structure as many as 30 or 40 coats of paint might be applied. This provided a very thick protective coating over large areas of the steelwork. The overall approach to steel protection was well illustrated by the story of the re-painting of the Forth Railway Bridge, where it was suggested that by the time the whole bridge had been re-painted it was time to start again at the other end.

Clearly, because of the regular maintenance, the total time spent protecting any structure was fairly considerable. Furthermore, unnecessary amounts of paint were often applied to some areas, whereas at

critical areas where paint breakdown occurred prematurely there was insufficient protection. However, on important structures, corrosion was not usually a serious problem because of the regular re-painting and, even more importantly, because heavy steel sections were usually employed with a built-in corrosion allowance.

Over the years there were improvements in the materials and techniques used for steel protection but, around the time of the Second World War and immediately afterwards, some fundamental changes occurred. The requirements to protect off-shore structures in aggressive marine environments led to further developments. New synthetic coating materials were developed, coupled with improved application techniques.

Probably the most important factors in these developments in coatings technology arose from the steep rise in labour costs and the requirements to reduce the time spent on coating steelwork. At one time, virtually all painting was carried out on-site after the structure or building had been erected. Generally, steelwork was given only a shop primer at the works, the rest of the system being applied after erection. Most steelwork was cleaned by hand using wirebrushes and scrapers. This method was reasonably effective when oil paints were used. In particular, red lead in oil proved to be a satisfactory primer on rusted surfaces. However, such cleaning methods proved to be far less effective with paints produced from synthetic materials. Furthermore, work carried out in the 1930s had shown the advantages of thoroughly cleaning steel by sand blasting or pickling. Panel tests demonstrated the considerable increase in the 'life' of a coating when applied to thoroughly cleaned steel. However, the costs involved in using such methods were at the time thought to be excessive and while a small proportion of heavy steelwork was pickled before painting, virtually none was blast-cleaned. These views changed with the need to streamline the whole painting operation in order to reduce overall costs and also to reduce the time spent on coating steelwork.

The ship building industry, in particular, appreciated the advantages to be gained by blast-cleaning steel plate in automatic plants, followed by the application of special quick drying primers. General fabricators also realised that if steelwork was to be cleaned and painted in the works, then the old-established red-lead-in-oil primers would not be suitable because of the long period required for drying.

The developments in the cleaning of steel and the use of quicker drying synthetic coating materials altered the pattern of steel protection. Improved application techniques were developed to coat steel more quickly and, resulting from this, fewer but thicker coatings were applied. Most

recently, the requirements for protective systems capable of withstanding the aggressive off-shore conditions, especially with regard to suitability for maintenance, have resulted in a range of new synthetic types of coating materials.

The above discussion has been concentrated on paints, to illustrate the changes that have taken place in the last few decades, but there have also been developments with other coating materials. Although the process of hot-dip galvanising has not changed in any significant way, there have been improvements and developments in other methods of applying metal coatings. Furthermore, materials such as elastomers and plastics are being used to an increasing extent for special situations. The increased employment of submarine pipelines has also led to a range of new application methods such as fusion bonding.

The vast majority of steelwork is protected by paints but other materials have become increasingly important for special situations and for critical areas. The application techniques for these coatings are often very different from those used for paints. Compared with the straightforward application by brush, the present variety of coatings and application techniques has developed into a technology of its own, which requires to be considered as such. Coatings technology is concerned not only with materials and application but with economics.

Coating requirements for many important structures lead to a considerable expenditure of effort and money. Often the costs for the coatings are a significant percentage of the total expenditure on a project. It is, therefore, essential to obtain good value for such a financial outlay, and this has resulted in two significant changes in the attitude to coating steelwork, both of which arise from the nature of the process.

The coating process involves many different groups and a number of operatives. To achieve a sound protective system is not always straightforward; though the concept of protecting steelwork with coatings is simple, the execution may be complex. Each part of the process must be carried out correctly but, unlike most industrial processes, faults at one stage are not immediately apparent at the next. For example, inadequate cleaning of the steel surface before painting may be hidden by the application of the paint system. Although the 'life' of the system will be reduced, this will be a longer-term problem. Therefore, it has become necessary to ensure that proper specifications are prepared so that all concerned with the project are aware of the requirements. Additionally, sound quality control procedures are necessary to make sure that the clauses in the specification are properly followed.

These two factors—specifications and quality control—necessitate an understanding of coatings technology. Attempts have been made to overcome this requirement, which is often lacking in those responsible for determining steel protection, by using 'guarantees'. This is discussed in detail in Chapter 9, but basically this approach, sometimes termed 'performance specifications', relies upon a guarantee of the performance of the protective system. This is given by the contractor for a fixed time period, e.g. 7 years, so the problems of selecting systems, preparing specifications and adopting quality control procedures is largely eliminated. In practice, matters are rarely as simple as that, not least because a premature failure may result in considerable costs other than those for re-coating the steelwork.

It follows that those engaged in specifying protective systems should have a basic understanding of the factors involved. This book has as its aim a straightforward approach to the various aspects of coatings technology, so far as they affect the decisions that designers and engineers have to make. It is concerned with structural steelwork and steel used for structures, buildings and pipelines. The treatment of steel sheet used for cars, domestic appliances and products such as 'tin cans' is not covered, except where materials may be chosen for cladding or formed into structural members.

No attempt has been made to consider the chemistry or formulation of paints and other coatings in detail. This is the primary concern of the manufacturers of the products and, generally, only those specialising in such matters are likely to be involved in formulating materials. The general properties and composition of such materials are considered where such information or data is relevant to the satisfactory protection of steelwork.

It is important to appreciate that this book is concerned with situations where protection from corrosion is the economic priority. Much steelwork is used for purposes where corrosion either will not, or is unlikely to occur. Again, some structures have a short-term use where corrosion can be allowed for in the design. In all these cases the protective coatings are of minor importance, except possibly for decorative purposes. Where steel is completely encased, for example in concrete, coatings may not be required at all. However, the design of such structures and buildings may be a crucial factor in deciding whether protection by coatings is required. If moisture and atmospheric pollutants can reach the steel surface, corrosion may occur. Even steel encased in concrete can corrode if corrosive species, especially chlorides, penetrate the concrete and reach the steel surface. This can happen if concrete reacts with the environment leaving a carbonated layer which allows ingress of corrosive ions to the steel.

Even in apparently dry conditions moisture may penetrate masonry and brickwork, and leaking roofs are by no means uncommon. The design of a structure has an important influence on the corrosion of steel and the performance of coatings. Designers should, therefore, have a reasonable appreciation of coatings technology so that, where practicable, changes can be made in details to avoid corrosion problems.

Coatings are the most widely employed form of corrosion control for steelwork. The term 'control' rather than prevention illustrates the approach to corrosion. Although, in most situations, corrosion can be avoided, it is usually more economic to control it to within acceptable limits. This is why heavy duty coatings are not used for every situation. It is often more economical to use cheaper coatings with an increased number of maintenance re-paintings over the life of the structure. However, this is not always the case and a decision must be made based on suitable data for each specific situation.

Other corrosion control methods are also used for structural steelwork either in combination with coatings or as an alternative. Cathodic protection, humidity control and inhibitors are all used; they are discussed in later chapters. It is, of course, possible to use corrosion-resistant alloys as alternatives to carbon steel. Generally, such alloys are too expensive to be considered for structural purposes. They are widely used in process plants for valves, pumps and heat exchangers, and for other special situations. These are beyond the scope of this book, although some alloys such as 'Monel' are used in sheet form to protect structural steel and are discussed where relevant.

Two groups of alloy steels are used for constructional purposes. Stainless steels are used for cladding buildings and for various components such as nuts and bolts. They are too expensive for use in general construction although they are widely used in chemical and allied plants (the topic of which is outside the scope of this book). Weathering steels, containing about 2% of alloying elements, are used for some structures without applied coating; these are considered in Chapter 13.

There is, among specifiers, an increasing awareness of the importance of coatings for new steelwork. However, most structures and buildings are re-painted a number of times during their lifetime and, generally, less attention has been paid to this aspect. Undoubtedly, improvements are required in the area of maintenance and changes in the approach to re-painting are occurring, as discussed in Chapter 12.

Many groups are involved in the field of steel protection; steel producers, fabricators, paint applicators, galvanisers and paint manufacturers being