

# **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.

KENNETH A. CHANDLER

DEREK A. BAYLISS

# Contents

<i>Preface</i>	v
<b>Chapter 1 Introduction</b>	1
<b>Chapter 2 The Corrosion of Steel</b>	7
2.1 Corrosion—the basic process	7
2.2 The electrochemical nature of corrosion	9
2.3 Potential	12
2.4 Polarisation	14
2.5 Potential-pH equilibrium diagrams	15
2.6 Passivity	15
2.7 Corrosion in air	16
2.7.1 Steel composition	19
2.7.2 Rust	20
2.8 Corrosion in water	20
2.8.1 Composition of water	20
2.8.2 Operating conditions	21
2.8.3 Steel composition	22
2.8.4 Corrosion rates of steel in water	22
2.9 Corrosion in soil	22
2.10 Bacterial corrosion	23
References	25
Further reading	25
<b>Chapter 3 Factors Influencing Protection by Coatings</b>	26
3.1 Adhesion to the steel surface	26
3.2 Intercoat adhesion	27
3.3 Thickness of coating	27
3.4 Application procedures	28
3.5 Reaction of the coating with the environment	29
3.6 Physical changes in the coating	29
3.7 Fabrication and design	30
3.8 Handling, storage and transport	31

3.9	Environment of exposure	31
3.10	Cathodic protection	33
3.11	Chemicals and solvents	33
3.12	Maintenance re-painting	33
	References	34
<b>Chapter 4</b>	<b>Surface Preparation of Steel before Coating</b>	<b>35</b>
4.1	Millscale	35
4.2	Rust	39
4.3	Types of methods available for the removal of rust and scale	42
4.4	Abrasive blast-cleaning	44
4.4.1	Air blast-cleaning	45
4.4.2	Centrifugal blast-cleaning	46
4.4.3	Wet blast-cleaning	47
4.4.4	Abrasives for cleaning steel	50
4.4.5	Surface cleanliness	58
4.4.6	Surface profile	60
4.5	Hand-cleaning methods	63
4.6	Flame cleaning	65
4.7	Pickling	66
4.7.1	Inhibitors	67
4.7.2	Hydrogen embrittlement	67
4.7.3	Pickling procedures	67
	References	68
<b>Chapter 5</b>	<b>Paints and Paint Coatings</b>	<b>70</b>
5.1	General requirements	70
5.2	The nature of paint	72
5.2.1	Paint systems	74
5.3	Protection by paint films	75
5.4	Properties of paint films	80
5.4.1	Adhesion	80
5.4.2	Flexibility	82
5.4.3	Hardness	83
5.4.4	Abrasion resistance	83
5.4.5	Permeability	83
5.4.6	Resistance to microorganisms	85
5.4.7	Ageing of paint films	85
5.5	Paint as an organic coating material	86
5.5.1	Chemical bonding	87
5.5.2	Concepts of organic chemistry	88
5.6	Binders	91
5.6.1	Alkyds	91
5.6.2	Epoxides	92
5.6.3	Epoxy esters	94
5.6.4	Polyurethanes	94

5.6.5	Chlorinated rubber	95
5.6.6	Vinyls	95
5.6.7	Bitumen	96
5.6.8	Silicones	96
5.6.9	Silicates	96
5.7	Pigments	97
5.7.1	Inhibitive pigments	98
5.7.2	Other pigments	99
5.7.3	Extenders	101
5.8	Solvents	101
5.9	Types of paint	102
5.9.1	Oil-based and oleo-resinous	103
5.9.2	Chlorinated-rubber paints	106
5.9.3	Acrylated-rubber paints	108
5.9.4	Vinyl paints	108
5.9.5	Bituminous coatings	109
5.9.6	Two-pack epoxies	110
5.9.7	Coal-tar epoxies	111
5.9.8	Urethanes	112
5.9.9	Urethane pitches	113
5.9.10	Zinc-rich coatings	113
5.10	Finishes and systems for painting metal surfaces subject to heat	117
5.10.1	Coloured finishes	117
5.11	Other coating materials and fillers	118
	References	119
	Further reading	120
<b>Chapter 6</b>	<b>Paint Application</b>	<b>121</b>
6.1	Methods of application	121
6.1.1	Brush application	122
6.1.2	Roller application	123
6.1.3	Airspray application	124
6.1.4	Airless spraying	125
6.1.5	Heated spray units	126
6.1.6	Application of two-component paints by spray	127
6.1.7	Electrostatic spray	128
6.1.8	Other application methods	129
6.1.9	Comparison of application methods	131
6.2	Application procedures	131
6.2.1	The painting shop	131
6.2.2	Temperature	132
6.2.3	Relative humidity	133
6.2.4	Ventilation	133
6.2.5	Lighting	133
6.2.6	Storage of paint	134
6.2.7	Preparation of paint before use	134
6.3	The painter	135



6.4	Paint manufacturers' data sheets	135
6.5	Paint defects	136
<b>Chapter 7</b>	<b>Plastic and Other High-Duty Coatings</b>	<b>139</b>
7.1	Coatings for tanks and aggressive immersed conditions	139
7.1.1	Requirements for tank linings	140
7.1.2	Application methods for linings	142
7.1.3	Coating materials	143
7.1.4	Specifications and inspection	147
7.2	Pipelines	148
7.2.1	Submarine pipelines	149
7.2.2	Buried pipelines	153
7.3	Powder coatings for general use	155
7.3.1	Application methods	155
7.3.2	Plastic coatings	157
7.3.3	Comments on plastic coatings	158
7.4	Coil coatings	159
7.5	Wrapping tapes	161
	References	163
<b>Chapter 8</b>	<b>Metal Coatings</b>	<b>164</b>
8.1	Application methods	164
8.1.1	Hot-dipping	165
8.1.2	Sprayed coatings	169
8.1.3	Coatings produced by diffusion	172
8.1.4	Electrodeposited coatings	173
8.1.5	Other application methods	174
8.2	Corrosion protection by metal coatings	174
8.3	Additional protection to metal coatings	177
8.4	Corrosion data for metal coatings	179
8.4.1	Corrosion data for zinc coatings	180
8.4.2	Corrosion data for aluminium coatings	182
8.4.3	Corrosion data for cadmium coatings	183
8.5	The selection of metal coatings	183
8.6	Choice of metal coating and application method	185
8.7	Treatment of welded areas	186
8.8	Wet storage stain	187
8.9	Fasteners	187
	References	188
<b>Chapter 9</b>	<b>Specifications</b>	<b>189</b>
9.1	Standards and specifications	189
9.2	The purpose and drafting of a specification	191
9.3	Types of specification	193

9.4	Specification requirements	195
9.4.1	Surface preparation	196
9.4.2	Coating system	200
9.4.3	Control of paints and other coating materials	201
9.4.4	Coating application	202
9.4.5	Treatments of special areas	204
9.4.6	Handling, transport and storage	207
	References	210
<b>Chapter 10</b>	<b>Quality Control of Coating Operations</b>	<b>211</b>
10.1	Introduction	211
10.2	Inspection requirements	213
10.3	The approach to quality control	214
10.4	Requirements for an inspector	217
10.4.1	Training and certification of inspectors	217
10.5	Inspection operations	219
10.6	Reports and records	221
10.7	Methods of inspection	225
10.8	Surface preparation	225
10.8.1	Steel surface before blast-cleaning	226
10.8.2	Surface cleanliness	226
10.8.3	Surface profile	232
10.8.4	Weld areas	237
10.8.5	Blast-cleaning operations and equipment	237
10.8.6	Abrasives	240
10.9	Coating application	242
10.9.1	Paint application	242
10.9.2	Inspection of metal coatings	256
10.9.3	Inspection of other coatings and linings	258
	References	259
<b>Chapter 11</b>	<b>Designing for Corrosion Control</b>	<b>260</b>
11.1	Environment of exposure	261
11.2	Materials	261
11.3	Bimetallic corrosion	262
11.4	Access for inspection and maintenance	264
11.5	Crevices	267
11.6	Ground level corrosion	272
11.7	Entrapment of moisture and condensation	272
11.8	Geometrical effects	273
11.9	Tanks	274
11.10	Weathering steels	276
11.11	Reinforced concrete	276
11.12	Corrosion of steel in contact with other materials	277
	Reference	277
	Further reading	277

<b>Chapter 12 Maintenance Painting and Economics</b>	<b>279</b>
12.1 Economic assessments	280
12.1.1 Net present value (NPV)	282
12.1.2 Technical aspects involved in NPV	283
12.1.3 Calculating the costs of alternative protective systems	285
12.1.4 Comparing the costs of protective systems	288
12.2 Maintenance of protective systems	290
12.2.1 The general approach to maintenance painting	292
12.2.2 Planning maintenance	293
12.2.3 Inspections and surveys for maintenance	295
12.2.4 Maintenance procedures	297
12.3 Maintenance painting	300
12.4 Environmental conditions during repainting	301
References	303
<b>Chapter 13 Control Methods other than Coatings</b>	<b>304</b>
13.1 Cathodic protection	304
13.1.1 Basic principles	305
13.1.2 The application of cathodic protection	306
13.1.3 Sacrificial anode method	307
13.1.4 Impressed current method	307
13.1.5 Choice of method for cathodic protection	309
13.1.6 Practical applications of cathodic protection	310
13.2 Conditioning of the environment	312
13.2.1 Treatment of the air	312
13.2.2 Treatment of aqueous solutions	313
13.3 Alloy steels	314
13.3.1 Stainless steels	314
13.3.2 Low alloy weathering steels	317
References	323
<b>Chapter 14 Coating Defects and Failures</b>	<b>324</b>
14.1 Surface preparation	325
14.2 Coating materials	327
14.3 Coating application	328
14.4 Transport and storage	329
14.5 Types of coating defects	330
<b>Chapter 15 The Selection of Coating Systems</b>	<b>337</b>
15.1 Factors influencing the selection of coating systems	338
15.2 General steelwork exposed to the atmosphere	341
15.2.1 Bridges	343
15.2.2 Buildings	344
15.2.3 Storage tanks (exterior)	345
15.3 Offshore structures	346
15.3.1 Atmospheric zone	347
15.3.2 Immersed zone	348
15.3.3 Splash zone	348

15.4	Ships	348
15.4.1	Surface preparation	349
15.4.2	Areas to be protected	349
15.4.3	Underwater plating	350
15.4.4	Anti-fouling paints	350
15.4.5	Boot topping	351
15.4.6	Topsides and superstructures	351
15.4.7	Steel decks	352
15.4.8	Machinery, pipes, etc.	352
15.4.9	Cargo and ballast tanks	352
15.4.10	Fresh water tanks	353
15.5	Chemical plants	353
15.6	Oil refineries and installations	355
15.7	Sewage systems	355
15.8	Sheet piling	356
15.9	Jetties and harbours	357
<b>Chapter 16</b>	<b>Testing of Coatings</b>	<b>359</b>
16.1	Introduction	359
16.2	Test requirements	360
16.3	Laboratory testing of paint films	363
16.3.1	Determination of drying time	365
16.3.2	Adhesion tests	365
16.3.3	Abrasion resistance	367
16.3.4	Physical state of the film	367
16.3.5	Film thickness	369
16.4	Testing of paints	371
16.5	Laboratory performance tests	372
16.5.1	Artificial weathering	372
16.5.2	Salt-spray tests	373
16.5.3	Sulphur dioxide tests	374
16.5.4	Humidity and condensation tests	374
16.5.5	Other laboratory tests	375
16.6	Field tests	376
16.6.1	Type of specimen to be used for the tests	377
16.6.2	The coating	378
16.6.3	Exposure of specimens	380
16.6.4	Test sites	382
16.6.5	Monitoring of test sites	384
16.6.6	Methods of measuring atmospheric pollution	385
16.6.7	Conduct of field tests	386
16.7	Service trials	388
16.8	Tests in water and soil	390
16.9	Formulating the test programme	390
	References	391
	Appendix: British Standard 3900 tests with International Standards Organisation equivalents	391
<b>Index</b>		<b>395</b>

## CHAPTER I

### *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