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MasterProtect 8500 CI
Specifier Handbook

Contents

INTRODUCTION

The corrosion of reinforced concrete is one of the main concerns in construction today, especially in coastal areas, which are aggressive environments. Corrosion damage in concrete infrastructure is difficult to repair, and specifying an appropriate treatment is a complicated task.

This document is intended for architects and engineers acting as specifiers. It indicates whether the corrosion inhibitor MasterProtect 8500 CI can be applied to concrete elements that cannot be replaced or the replacement of which is to be avoided with a view to achieving the levels of performance and durability for which the elements were initially designed.

In the event that a corrosion inhibitor can be applied, this manual indicates the conditions under which it should be applied to achieve the benefits of the product.

This document is intended as a support manual for specifiers, who will find answers to questions or issue connected with the specification of material for a construction project. It aims to provide all the information which is necessary with a view to avoiding errors and omissions that may result in problematic situations or unanticipated cost disadvantages.

The document discusses in sequence the phases that all specifiers must consider in order to prepare a successful proposal. It is divided into four stages corresponding to the phases in the specification process.

Stages

A. Information
In this stage, all the necessary information on the inhibitor is collected: What is it? How does it work? How is it applied? When can it be applied?

B. Prospecting
The purpose of this stage is to obtain all the necessary information about the building with respect to the application of the inhibitor. During this stage, the data required for an objective decision on the feasibility of application (in the next stage) are collected.

C. Specification
On the basis of the information on the material and its application collected in stage A and the data of the building and the possible application of the inhibitor collected in stage B, the next stage is to decide whether or not to specify the product, to select the areas where the inhibitor is to be applied and to define the specifications for the application, the control and inspection tasks required and the conditions for acceptance and rejection.

D. Documentation
In the documentation stage, a review of all the information to be included in the project documentaion for a precise definition of the application of the inhibitor is compiled. The review includes various documents with sections corresponding to the stages of the project.

The methodology proposed includes the following tools:

- Limit system
- Corrosion indicators

1. Limit system

The limit system is a tool that allows the use of the inhibitor to be defined in a clear and unequivocal way. The system, which consists of numerical limits, is easy to use. The data of the concrete element to be compared with the limits of the system are normally obtained by an approved laboratory, which greatly simplifies the work of the specifier.

The limit system includes two types of limits:

- Operating limit
- Application limit

Operating limit
An operating limit is a value which makes it impossible to specify the product if it is exceeded. In other words, it is a limit that excludes the use of the product. Operating limits are based on the characteristics of the reinforced concrete to be protected against corrosion.

Not all areas to be protected have the same characteristics or are exposed to the same conditions. This means that each concrete element has areas with different operating limits. The operating limits can be considered to be permanent because they cannot easily be changed within a short period of time. Changing these limits can also be an expensive process.

Application limit
If an application limit is exceeded, the product cannot be applied. Such limits may either be temporary or permanent.

Limits that depend on environmental conditions may be temporary because they often change from one day to the next, such as wind, temperature, rain, humidity, and sunlight.

2. Corrosion indicators

Corrosion indicators are tools that allow the state of corrosion of concrete to be determined. The following two indicators are used in this manual:

- Electrical resistivity of concrete
- Corrosion rate

These indicators provide initial data and only give an indication of the level or risk of corrosion of the concrete reinforcement. Using these values, it is possible to determine the degree of corrosion of the reinforcements at a given time. If indicators are determined before and after applying the inhibitor, it is possible to see the significant improvement that takes place in the protected element. The change also provides evidence of this improvement. If the indicators are only determined taken after protection has been applied, they only indicate the results of the application of the corrosion inhibitor.

As the two values are measured in the same way using the same equipment, the measurement of two values requires very little additional work compared with the measurement of one value.

Although neither of the indicators has the precision required by the limit system, indicators are an excellent tool for assessing condition of the reinforced concrete and also allow the specifier to monitor the effectiveness of the corrosion inhibitor over time.

This manual aims to provide specifiers with all the information they need for their work. It offers technical support to resolve any doubts that may arise on this subject.

A. Information stage

This section describes the basic characteristics of the material and the uses of its features. The principles for the application of the product to concrete elements are explained in detail to provide a better understanding of the data.

A.1. PRODUCT

A.1.1. Possible uses

MasterProtect 8500 CI is recommended for treating all types of reinforced concrete structures including:

- Pretensioned structures
- Posttensioned structures
- Precast elements

Protection using the corrosion inhibitor to reduce the corrosion rate of steel is especially recommended for the structures listed below (EN 1504, ”Products and systems for the protection and repair of concrete structures“).

Building	Residential or commercial	Facades
		Balconies
		Columns
		Beams
		Floor slabs
Civil work	Parking garages	Panels
		Floor slabs
		Columns
		Beams
	Industrial	Cooling towers
		Silos
		Chimneys
	Bridges	Pillars
		Beams
		Protective barriers
		Joints
		Deck waterproofing
	Marine structures	Docks
		Pontoon
		Desalination plants
		Jetty
	Tunnels	

The degree of corrosion determines the action that needs to be taken

MasterProtect 8500 CI is a dual-function, silane-based, surface-applied corrosion inhibitor, suitable for use as part of a corrosion prevention, protection, or inhibition strategy. It is a revolutionary blend of high-quality silanes with an additional corrosion inhibitor, which lies dormant within the concrete until activated by moisture which penetrates the surface due to cracking or aging of the concrete. MasterProtect 8500 CI has two functions. The silane base provides similar benefits to water-repellent sealing compounds, and the integral corrosion inhibitors are carried into the concrete along with the silane. The inhibitors remain in the concrete until the water repellency diminishes over time, or until the concrete cracks. They then become mobile, and are carried deeper into the concrete by moisture. MasterProtect 8500 CI has a surface tension roughly 1/3 that of water, and low viscosity to improve penetration into concrete.

This product is particularly well-suited for exposed outdoor structures, piers, panel facade cladding, terraces, and balconies. As a corrosion inhibitor, it can be employed in combination with concrete repair systems.

A.1.2. Limits

The inhibitor is ineffective if the contamination of the concrete exceeding certain limits. Before specifying or applying the product, tests must be carried out to ensure that these limits are not exceeded.

Chloride content
The inhibitor must not be applied to substrates with levels of chloride contamination exceeding 2.0 % of the weight of the cement. Standard EHE-08 sets the limit of the total chloride content in reinforced concrete or mass concrete works at 0.4 % of the weight of the cement. Therefore, the limit set by the product is six times higher.

The condition of the concrete with respect to this limit must be established by laboratory testing, i.e., analysis of the total chloride content in the concrete (see Annex 2, paragraph 2.2).

Material deterioration
Check that the concrete to be protected has not, deteriorated to the point where delamination or spalling has occurred. Verify that there are no serious cracks and that the surface is sufficiently rough and porous to facilitate the penetration of the inhibitor. Similarly, check the deterioration of the reinforcements: since the inhibitor does not restore the eroded sections of steel bars, they must comply with the relevant structural stability requirements. To test this point, see Annex 2.

In such situations, the product must not be applied until structures which have deteriorated to the point where they can no longer perform their function have been repaired or replaced.

A.1.3. Properties

Properties are grouped according to their relevance for the functioning, application and monitoring of the product.

Performance features

- Penetration — Class Ⅱ > 10 mm
- Fire reaction — Class F
- Surface tension — Approx. 23.7 dynes/cm

The product is much less viscous than water, and can therefore penetrate the concrete more easily. Viscosity is inversely proportional to fluidity. The lower the viscosity, the greater the fluidity, which means that the material takes less time to flow through capillaries. It is absorbed by the concrete more easily than water.

- **Does not evaporate/not washable**
  Since the silane chain is chemically bonded to the cementitious matrix, the product cannot evaporate or wash out in wet/dry cycles after being applied.

- Solubility in water — Not soluble
- Permeable to water vapor

Physical properties

- Approximate density — 0.9 g/cm³

Although the quantity to be applied is stated in g/m², the inhibitor is sold by and stored in liters. The density is necessary in order to determine the quantity of inhibitor to be used in each zone.

- **Color — Colorless to yellowish**
  As it is colorless, the inhibitor does not alter the appearance of the concrete after application.

Application features

- **Application temperature (substrate and material) — Between 5 °C and 40 °C.**
  The product must not be applied when the temperature of the structure is outside these limits.

- Drying rate — Class II > 10 %

Although the waiting time between the application of various coats is approximately 15 minutes, this period is indicative as it depends on the absorbency of the concrete. BASF prepares technical reports stating the waiting time between coats for specific projects.

- **Low odor profile**
  The product does not cause any nuisance to users.

- **Does not attack parts of non-mineral origin**
  The product does not attack glass. However, it is recommended that any components not forming part of the surface to be treated should be protected to prevent staining.

- **Irritating to eyes and skin**
  Precautions must be taken.

A.1.4. Effects on reinforced concrete

Effects on concrete

- **Waterproofs concrete**
  The product renders the concrete surface and the pore network hydrophobic. The product permeates the capillary pores of the concrete and adheres to its surface, forming a very strong chemical bond. The capillary network is not completely saturated, leaving enough space to allow water vapor molecules to pass through but not those of liquid water, as they are larger.

- **Lowers humidity of concrete**
  Because of the difference in size between water molecules and those of water vapor, the concrete is waterproofed but remains breathable. As it is hydrophobic and prevents the penetration of water from the outside, the product significantly lowers moisture levels in the concrete, which drastically reduces the corrosion of the steel reinforcement bars.

- **Increases electrical resistivity**
  The electrical resistivity of the concrete corresponds to its ability to resist corrosion, and is, inversely proportional to the moisture level in the capillary network. This is the case, because, in the complete absence of moisture, there is no electrolyte, which could act as a conductor of electricity and therefore as an oxidizing agent. The higher the moisture content, the greater the risk of corrosion. If, concrete is waterproofed, the humidity is reduced and the corrosion resistance of the reinforcement is increased.

- **Reduces penetration of chlorides**
  Chlorides dissolved in water penetrate concrete. By preventing the penetration of water, the penetration of chlorides is significantly reduced.

- **Prevents the formation of incipient anodes**
  When, concrete contaminated by chlorides is repaired using the traditional technique of patching, corrosion can be transferred to adjacent areas, (This mechanism is called the “formation of incipient anodes.”) With conventional repair methods, it would be necessary to remove all the chloride-contaminated concrete in order to prevent corrosion. Even then, corrosion could still occur if the concrete were not sufficiently alkaline.

  The, migrating inhibitor has an electro-chemical effect. It prevents the flow of the corrosion current by, drastically reducing the amount of water in the pores. This prevents the formation of incipient anodes and is equally effective against corrosion of the concrete caused by carbonation.

- **Does not change the appearance of the concrete**
  As the product is transparent, the appearance of the concrete is not changed.

Effects on steel

- **The corrosion rate is reduced**
  The corrosion rate depends on the level of moisture in the concrete and on the penetration of oxygen to the depth of the reinforcements. If water penetration is reduced and the moisture level falls to almost 0, the corrosion rate will also fall, to values below 0.2 μA/cm². Below this level, the reinforcements are considered to be in a passive condition and are therefore protected against corrosion.

- **Electrochemical reactions between the anode and cathode are blocked**
  Electrochemical reactions between the anode and cathode occur in aqueous media. These reactions are blocked because the penetration of water is reduced. Furthermore, the material has a high affinity with metal, being attracted by it and chemically joining to its oxide layer. For that reason, in addition to repelling chloride ions (Cl^-) – causing the timely depassivation of steel and inhibiting the corrosion of the damaged areas – the product protects the passivation layer of steel in areas not affected by corrosion.

A.1.5. Chemical performance

MasterProtect 8500 CI is a dual-function, silane-based, surface-applied corrosion inhibitor, suitable for use as part of a corrosion prevention, protection, or inhibition strategy. It is a revolutionary blend of high-quality silanes with an additional corrosion inhibitor, which lies dormant within the concrete until activated by moisture which penetrates the surface due to cracking or aging of the concrete.

MasterProtect 8500 CI has two functions. The silane base provides similar benefits to the water repellent sealing agents, and the integral corrosion inhibitors are carried into the concrete along with the silane. The inhibitors remain in the concrete until the water repellency diminishes over time, or until the concrete cracks. They then become mobile, and are carried deeper into the concrete by moisture.
MasterProtect 8500 CI has a surface tension roughly 1/3 that of water, and low viscosity to improve penetration into concrete. Its special blend of silanes provides a balance between drying time and penetration over a wide temperature range, as well as lower VOC content and a higher flash point than many other corrosion inhibitors.

The most observable property of MasterProtect 8500 CI is water repellener on the concrete surface. It prevents corrosion of steel reinforcement by keeping the mositure and the chlorides from penetrating the concrete.
MasterProtect 8500 CI provides this same benefit with the added feature of its ability to act as a corrosion inhibitor.

The product initially penetrates the concrete through the pores, then the chemical reaction with the cement base takes place, and it finally goes deeper into the concrete mass thanks to its low viscosity and chemical attraction to the steel. It is important to apply the product in several coats. Each coat then pushes the previous coat layer further into the concrete.

If the steel bars are in the area of influence of the product, corrosion will be inhibited. In other words, the bond between the contaminating/oxidizing chloride molecules will be broken and the corrosion of the steel will be prevented while the inhibitor is active.

In the event that the reinforcements are beyond the penetration depth of the inhibitor, corrosion, will not be inhibited. This does not mean that they are not protected since the coating prevents more chloride from entering the concrete and keeps the concrete dry. In conclusion, the silanes reduce the absorption of water, leaving the concrete dry and therefore increasing its electrical resistivity. Moreover, they protect steel from corrosion by facilitating the formation of a new passivation layer that reduces the corrosion rate and extends the life of reinforced concrete. (For a complete explanation of the processes involved in the deterioration of steel-reinforced concrete by corrosion of rebars, refer to Annex 1.)

A.1.6. Guarantees

The inhibitor has two separate guarantees: one for the product, for which BASF is responsible, and the other for application, for which the application contractor is responsible. The warranty period for the product is 10 years. However, good application is necessary to maintain expected outcomes during those 10 years. Normally, applicators do not provide such a guarantee.

In order to provide them with the technical knowledge required for an application guarantee, BASF organizes training courses for applicators and issues certificates upon successful completion. BASF is committed to a joint guarantee with these companies. Firstly, BASF certifies that the product has passed the relevant quality assurance and meets the specifications described in the technical documentation. Secondly, the applicator certifies that the products have been applied in accordance with the specifications using proper application techniques.

A.1.7. Complementary Products

MasterProtect 8500 CI is a colorless product. The application of successive layers of inhibitor can be made visible using a photodegradable dye, which disappears after a few weeks of exposure to sunlight. This allows easy monitoring of product application. The dye Rhodamine B, is used as it does not interfere with the chemical behavior of the inhibitor in any way.

A.2. MONITORING AND MAINTENANCE

The development of further corrosion after the application of the inhibitor is measured using the corrosion indicators already mentioned in this manual:

- Electrical resistivity of concrete
- Corrosion rate

Both data are obtained by monitoring the electrical resistivity of the concrete using registers. This way it can be determined whether or not the product is reacting as expected. Moreover, the effectiveness of the inhibitor can still be monitored after the warranty period has expired in order to precisely ascertain when the steel bars are depassivated.

The electrical resistivity test is performed by connecting two points of the steel reinforcement to the outer concrete with cables. An electric current is passed through the steel bars and the electrical resistance (Ω) is measured. Corrosion on the surface of the bars reduces its cross-sectional area, which implies an increase in electrical resistance. It is necessary to protect the steel reinforcement when the resistivity reaches between 10 and 50 kΩ·cm. It is recommended that these measurements be made every three years, unless results are close to the limits stated, in which case measurements should be made more frequently.

B. Prospecting stage

In this stage, the specifiers analyse all the data on the special features of the project. The objective is to evaluate the suitability of the inhibitor for use on the project and to define the appropriate specifications.

B.1. DATA COLLECTION

The objective of data collection is to gather the information needed to make appropriate decisions regarding the adequacy and applicability of the inhibitor. The data collected must provide the following values:

- Level of corrosion
- Operating limits
- Application limits

Level of corrosion
Before the inhibitor is applied, the corrosion indicators must be determined with a view to identifying the level of corrosion. This provides a baseline for assessing the effectiveness of the inhibitor when it has been applied.

Operating limits
The operating limits are values which prevent the application of the inhibitor to the area where the results have been obtained if they are exceeded.

Application limits
Application limits are values that temporarily prevent the application of the inhibitor when they are exceeded. In some cases, these application limits are exceeded so frequently that they make it impossible or very difficult to apply the product. For this reason, they must be taken into consideration in this phase.

B.1.1. Corrosion are indicators

The state of corrosion is determined by measuring two indicators:

- Electrical resistivity of concrete
- Corrosion rate

These indicators are both obtained by means of a Gecor 6 or Gecor 10 device. The details of these tests are given in Annex 2.

1. Electrical resistivity of concrete
Electrical resistivity is a material property of concrete that indicates its resistance to the flow of electric charges. This value has considerable impact on the corrosion rate of steel reinforcement bars. The resistivity depends mainly on the moisture contained in the concrete pores: the higher the humidity, the lower the resistivity.

Resistivity [kΩ·cm]	Risk of corrosion
100–200	Very low
50–100	Low
10–50	Moderate to high
< 10	Very high

Since the inhibitor stops the ingress of water to the concrete, it considerably reduces the moisture contained in the pores. The electrical resistivity of the concrete therefore increases when the inhibitor has been applied.

2. Corrosion rate
The corrosion rate is the key factor that determines the longevity of the material. This depends on many other factors such as the humidity and temperature of the concrete.

Steel reinforcement is considered to be in a passive condition if the corrosion rate is lower than 0.2 $\mu A/cm^2$. If it is not possible to test the state of corrosion during the prospecting stage, testing after the application of the product may be sufficient to assess the effectiveness of the product. However, it is advisable to determine the corrosion rate first in order to quantify the improvement.

The corrosion rate is also useful for estimating the cross-sectional loss of steel bars and therefore the time remaining until corrosion becomes visible. This information is summarized in the table below:

Corrosion rate [µA/cm²]	Corrosion level	Cross-sectional loss of steel bars [µm/year]	Time until corrosion becomes visible
< 0.1	Passive	< 5.8	–
0.1–0.5	Low	5.8–58	> 10 years
0.5–1.0	Moderate	58–174	3–10 years
> 1.0	High	> 174	< 2 years

B.1.2. Operating limits

The operating limits determine whether the product can actually be used. This information must therefore be obtained before the product is specified.

1. Chloride content

As mentioned in section A.1.2., it is not certain that the inhibitor will function properly if this limit is exceeded.

Chlorides occur in concrete in two forms: as free chlorides – ions in the water contained in the pores – and as combined chlorides, which form during the hydration of the cement.

Free chlorides have a corrosive effect on steel reinforcement. However, it should be taken into account that combined chlorides can redissolve as a result of concrete carbonation or increased temperature and become aggressive. Therefore, the total amount of chloride in the concrete, whether free or combined, must be determined (see Annex 2).

The chloride content limit is set at 2 % of the total weight of the cement in the concrete sample. The use of the inhibitor should be ruled out in cases where this limit is exceeded.

If the chloride content exceeds 2%, all the contaminated concrete should be removed – especially where it is close to the steel bars – or other techniques should be used to reduce the chloride content of the concrete.

Since the limit refers to the weight of cement, it is essential to know the cement content in the concrete.

2. Inhibitor concentration

The concentration of inhibitor at reinforcement depth is another limit. The test measures the quantity of product that has penetrated the concrete to the point beyond the reinforcement.

The minimum inhibitor amount considered to provide effective protection is 600ml/m^2 on hardened concrete surface. Effective use of the inhibitor is impossible if its minimum amount cannot penetrate the concrete in order to protect the steel reinforcement.

3. Deterioration of materials

Steel bars and concrete elements must be replaced where possible if significant cross-sectional loss is discovered when the steel bars are exposed during the application of the inhibitor. A concrete element that might require replacement is facade cladding, for example. Replacing reinforcements is more complicated than completely replacing an element.

As already mentioned in section A.1.2., we also need to check that the concrete to be treated has not deteriorated to the point where it could break off.

B.1.3. Application limits

In general terms, environmental conditions are simply circumstances to be monitored during the application of the product. However, some of the conditions may persist for a considerable time, affecting the time schedule for the work.

1. Wind

At wind speeds above 15 km/h, the product should not be applied using low-pressure spray equipment. Otherwise, significant quantities of product may be lost and the quantity of product applied to the concrete may not be adequate.

When working under unfavourable wind conditions, special precautions need to be taken. Either the quantity of inhibitor applied can be increased or wind screens can be positioned to shield the structure. If the quantity of product applied as increased, this will cater for possible losses. However, it will be necessary to carry out comprehensive tests to ensure that the minimum amount required for project approval has been applied.

The potential cost of these solutions must always be taken into consideration.

2. Temperature

The product should not be applied to substrates with temperatures lower than 5°C or higher than 38°C. Depending on the climate of the area where the concrete is located, temperature conditions may restrict the application schedules or even prevent application at certain times of the year.

3. Moisture of concrete

The chemical reaction of MasterProtect 8500 CI is not affected by the moisture of hardened concrete. On the other hand, the hydration of new concrete must be over 90% complete in order to ensure chemical bonding. For higher penetration levels, it is recommended to apply the inhibitor to dry concrete (<4% moisture).

3.1. Rain

Weather may affect the moisture level of the concrete to be treated. As already mentioned, the concrete must be dry when the inhibitor is applied. Therefore the concrete surface must be allowed to dry for between 24 and 72 hours after heavy rain or cleaning with water before the inhibitor is applied.

In the case of unexpected rain within four hours following the application of the product, the surface must be protected as water affects the chemical composition of the inhibitor. Do not apply the product if rain is expected within four hours after application.

Environmental conditions on the construction site must also be taken into consideration. When planning, it is important to remember that it may not be possible to apply the product during months with frequent rain.

4. Sunlight

Application in bright sunlight must be avoided as the product may evaporate before it is absorbed. As a result, the quantity of product absorbed by the concrete could be insufficient. This would invalidate the guarantee, especially when the product is used on facades or roofs.

For this reason, the inhibitor should not be applied during the hottest times of hot days.

B.2. SAMPLING CRITERIA

In many cases, different specifications need to be defined as a result of differences in the condition of the elements to be treated. These differences may be the result of different moisture conditions in the concrete or the use of different types of concrete. The tests to be performed depend on the conditions for the individual project.

In the case of variations in moisture levels and the use of different types of concrete, samples must be taken from the areas concerned in order to identify the differences, which may call for different types of treatment.

B.2.1. Zoning on the basis of moisture content

The chloride and sulphate contents are determined in order to identify areas of the structure with different moisture levels.

Moisture determines the level of chloride contamination of the concrete. The wettest areas often have the highest chloride concentrations. Zoning on the basis of the moisture level is therefore carried out to detect the different areas of chloride contamination. It may be impossible to apply the inhibitor to some areas and possible to apply it without any problems in other areas.

Different levels of moisture may arise as a result of the orientation, ventilation, and relative humidity of the different areas of concrete. Areas of concrete can be categorized by orientation as follows:

- Areas with direct sunlight throughout the day
- Areas with sunlight at some point in the day
- Areas with no direct sunlight

Areas of concrete can also be categorized according to ventilation as follows:

- Well-ventilated areas
- Poorly ventilated areas

The moisture concent of concrete is determined by contact with air (humidity) and underground water. Buried concrete absorbs water as follows:

- From the soil
- In the presence of groundwater
- When immersed in groundwater

The difference in moisture content and its origin (soil or groundwater) can result in concrete with different areas of varying levels of chloride and sulfate contamination.

B.2.2. Zoning by different types of concrete

The quality of the concrete determines the number of coats and the quantity of inhibitor to be applied.

The distribution of pores in the concrete has an effect on the silane concentration. It is therefore recommended to determine whether the quality of the concrete is largely homonenous. If not, each type of concrete should be tested to determine whether it is suitable for inhibitor application.

In either case, the specifier must decide on the exhaustiveness, level and accuracy of testing which is appropriate for zoning.

C. Specification stage

In the previous stage (B. Prospecting Stage), all the information required for deciding whether or not the inhibitor can be specified for the building in question, and which areas should not be treated is collected.

In the specification stage, the first step is to determine whether it is feasible to use the inhibitor on the building concerned. Then, the specifier needs to consider the parts of the building which require protection and can in fact be protected by the inhibitor and the parts which do not need to be treated.

When it has been found that the product can be applied, the second step is to determine how intensively and under what conditions it should be applied in each area.

The third and fourth steps are the monitoring and inspection measures to be taken, and the criteria to be used for accepting or rejecting the work that has been performed.

In summary:

1. Possible use
2. Application conditions
3. Monitoring and inspection measures
4. Acceptance and rejection criteria

C.1. POSSIBLE USE

As a first step, the data on the building from the previous stage (B. Prospecting stage) must be checked on the basis of the limit system to determine whether or not the use of the inhibitor MasterProtect 8500 CI is feasible.

Tests may be carried out in one or more areas as required by the specifier. The number of tests will determine the accuracy of the data and, therefore, the confidence with which the product can be specified.

C.1.1. Corrosion indicators

The results of resistivity and corrosion rate measurements should be entered in the following tables with a view to analysing the corrosion risk in all areas of the concrete structure.

		Data zones				
Resistivity [kΩ·cm]	Corrosion risk	1	2	3	...	x
100–200	Very low					
50–100	Low to moderate					
10–50	Moderate to high					
< 10	Very high					

The results of the corrosion rate tests give an indication of the actual rate of corrosion in the concrete.

If the corrosion rate is than 0.2 μA/cm², the steel is considered to be passive. That is to say, either no corrosion is taking place or rather that the test indicates that the corrosion is taking place in different stages.

				Data zones				
Corrosion rate [μA/cm²]	Corrosion level	Cross-sectional loss of steel bars	Time until corrosion becomes visible	1	2	3	...	x
< 0.2	Passive	< 5.8	–					
0.2–0.5	Low tmoderate	5.8–58	> 10 years					
0.5–1.0	Moderate to high	58–174	3–10 years					
> 1.0	High	> 174	< 2 years					

We would recommend that the steel reinforcement be protected against corrosion if the data indicates that both the corrosion risk and the corrosion level are high.

C.1.2. Operating limits

The operating limits must then be checked to ensure that the application of the product 1s possible.

The limit data are collected and assessed.

			Data zones					
Test identification	Test	Limit	1		2		...	
			Data	OK	Data	OK	Data	OK
xx	Chloride content	2.5 %						
xx	Silane penetration	C						
xx	Cross-sectional loss	B						
xx	Sulfate content	C						
xx	Carbonation	C						
xx	Tensile strength							
xx	Service life							

A: Data obtained from in situ sample of coating thickness B: This information is documented and calculated on the basis of the diameter C: No limit registered

The next stage is to determine whether or not to use the inhibitor on the basis of the data obtained.

Different concrete zones were identified in stage B (Prospecting stage). The data on each of these zones must be compared with the data in the table.

This comparison may indicate areas where inhibition is not recommended because a usage limit is exceeded.

C.1.3. Scope

A sketch should be drawn, shwoing areas that are suitable for inhibition on the basis of to each limit and areas which are not suitable.

When sketches have been made showing areas not suitable for inhibitor application on the basis of each of the tests, these sketches can be superimposed, producing an overall diagram showing the areas which are not to be treated.

This way, a plan showing areas which can be treated because they do not exceed any of these usage limits can be produced.

C.2. SPECIFIC CONDITIONS OF APPLICATION

When the results of the previous stage have indicated that application of the inhibitor as possible, the objective of the next stage is to define the specifications for application, both for the substrate and for the inhibitor, taking the environmental and physical conditions of the project into account.

Detailed information on this section can be found in the Inspector Handbook.

C.2.1. Application mode

Type of application
In principle, the type of application to be used is determined, as indicated in the table below by the size of the surface to be protected.

1. Brush or roller	SMALL zones
2. Low-pressure spray equipment	LARGE zones
3. High-performance projection or other systems	VERY LARGE zones

Brush or roller application
This product is applied in the same way that paint is applied. The product should not be exposed to air for long periods of time as it is highly volatile (vapor pressure or evaporation temperature). It is recommended that only the amount of inhibitor to be applied immediately be poured into the tray.

Low-pressure spray application
In this case, the inhibitor is applied with low-pressure spray equipment, which spreads the product evenly onto the substrate. An operator is required to perform this task. This mode of application yields better results and requires more time per square meter than brush or roller application.

High-performance projection application
In the case of very large surface areas to be protected, the product may be applied by high-performance projection or other alternative procedures, depending on the specific details of the project. The manufacturer should be consulted to discuss possible solutions.

C.2.2. Application preparation

1. Substrate condition
Concrete surfaces must be dry and cleaned of all traces of mold and mold oil, curing compounds, dirt, dust, efflorescence, algae, grease, asphalt oil, paint, lacquers or other coatings, and any other materials that prevent penetration. Acceptable cleaning methods include shot blasting, high-pressure water blasting, or grinding. All delaminated, loose, or spalled concrete must be removed and repaired with an approved product from the MasterEmaco or other approved Concrete Repair range.

Section D of this handbook includes detailed specifications to be included in the specification for the project.

2. Protection of adjacent elements
- All non-mineral parts of the structure, such as gutters, wood, expansion joints, and windows need to be completely protected before using the inhibitor. If not, smearing may occur on these surfaces.
- To evaluate the final effect of other products, such as topcoat treatments, on the inhibitor and to check the adhesion of other products to the inhibitor, it is essential to perform a test in which the inhibitor is applied to a surface equivalent to that of the structure and then treated with the other products concerned.
- Gardens must be protected.
- Avoid generating dust during the application of the material. Dust on the surface may prevent the inhibitor from penetrating the concrete mass.
- Do not add water, solvents, or any other substance that may alter the characteristics of the product to the product. The silane concentration is crucial to its ability to penetrate the concrete.

3. Daily inspection of project
- The product will not inhibit corrosion if the moisture content of the concrete is above 4 %. It is important for the concrete to be dry. Otherwise, the capacity of the inhibitor to penetrate the concrete will be significantly reduced.
- Apply the product at temperatures between 5 °C and 40 °C.
- The product is considered to be dry and no longer affected by water or other products four hours after its application. The inhibitor must not be applied if rain is expected during the four hours following application as water will affect its chemical composition.
- The product must not be applied in bright sunlight as the time during which the inhibitor is absorbed by the substrate is key for it to penetrate the depth of the concrete. Exposure to direct sunlight can evaporate the product and prevent proper penetration.
- The product must not be applied with low-pressure spray equipment if the wind speed exceeds 15 km/h, since the minimum amount required cannot be guaranteed.
- Allow concrete surfaces to dry for between 24 and 72 hours after heavy rain or cleaning with water before applying MasterProtect 8500 CI.

4. Considerations after application
- Wait for four hours after applying the product for it to dry before applying any other product, such as epoxy coating or polyurethane.
- In the case of unexpected rain in the four hours following the application of the product, the surface must be protected, for example using plastic sheeting.

C.2.3. Application specifications

This section describes the details of the application of the material and the application limits. For more information on these items, see the Applicator Handbook.

Amount of inhibitor to apply
A total of 500 g/m² is usually required, applied in two or three separate coats. To promote absorption, layers are generally distributed as follows: three coats of approximately 170 g/m² on vertical surfaces and ceilings, and two coats of 250 g/m² on floors.

As the product is sold and stored in liters, the amount of inhibitor to be applied is calculated on the basis of a density of 0.9 g/cm³.

Conversion factors for the units are shown in the following table.

	g/m²	L/m²
g/m²	1	1.11
L/m²	0.9	1

Waiting time
The waiting time between coats is generally 15 minutes or until the surface is visibly dry. It is advisable to perform an aoolication test to confirm the waiting time.

Application test
It is advisable to perform an application test on the substrate to be protected. This test determines the amount of inhibitor required per coat and the number of coats needed in order to apply the minimum amount. Environmental conditions can cause a loss of material and must therefore be taken into account when determining the quantity of inhibitor to be applied. This test also indicates the waiting times required between coats which may differ from one substrate to another.

Penetration depth
The inhibitor must penetrate the concrete sufficiently to reach the steel reinforcement. The manufacturer states that the silane concentration must be 0.015 % based on the weight of the cement.

C.3. MONITORING AND INSPECTION

Procedures for monitoring inhibitor application and measurement of results must be specified in the specification stage. It is essential to have information on the monitoring procedures proposed by the contractor in order to define the work schedule.

Monitoring includes two approaches. Firstly, the entire process is recorded using control charts. These records are completed by the contractor. Secondly, the effectiveness of the product is verified by a test plan.

Detailed information on this section is given in the Inspector Handbook.

C.3.1. Control cards

All relevant information concerning the application of the product must be recorded. Firstly, the bottles must be labelled to allow tracking of the product from the warehouse to the point of application. Secondly, the application conditions must be recorded in a calendar, including an indication as to whether application was successful. Finally, the operator who applies the product must complete a control card with information including the number of coats applied and the duration of application. Application conditions, product quantities per coat, quantities per surface area and the names of the operators must be recorded. Sufficient data must be provided to allow the work to be monitored.

To summarise, the monitoring of application requires the following three tools:

1. Labeling of bottles
Once the mixture has been made up it is poured into bottles which must be labeled with at least the following information:

- Project identification
- Batch number
- Date of delivery
- Date of mixing
- Bottle code
- Person responsible for mixing
- Quantity of inhibitor in liters
- Area of application

Other information considered by the project manager to be necessary for the proper monitoring of application on site may also be included.

2. Application data
The ambient conditions during application must be recorded.

3. Application records
The application control cards must include the following information include the following information:

- Area of application
- Bottle code
- Number of liters
- Coat number
- Date of application
- Start time of application
- End time of application
- Operator responible for application (applicator)

Other information deemed necessary by the project manager for the proper control and monitoring of the application on site may also be included.

C.3.2. Tests

1. Silanes concentration
This test determines the percentage of silanes in the cement in weight at all depths of the workpiece. The reinforcement is effectively protected if the minimum silane concentration is reached at the depth of the reinforcement.

The minimum concentration of silanes considered to be effective is 0.15 % of the total weight of cement in the sample.

2. Corrosion rate

The corrosion rate is used to determine the state of passivation of the steel reinforcement bars and therefore the risk of corrosion or the effectiveness of corrosion protection.

The corrosion rate enables us to calculate the approximate service life of the reinforcement and therefore of the concrete.

Corrosion rate [µA/cm²]	Corrosion level	Cross-sectional loss of steel bars [µm/year]	Time until corrosion becomes visible
< 0.1	Passive	< 5.8	–
0.1–0.5	Low	5.8–58	> 10 years
0.5–1.0	Moderate	58–174	3–10 years
> 1.0	High	> 174	< 2 years

Once the inhibitor has been applied, the steel reinforcement should be in a passive condition. The corrosion rate should be lower than 0.2 µA/cm², indicating that the product is effective.

3. Electrical resistivity of concrete

Electrical resistivity is a material property of concrete that indicates its resistance to the flow of electric charges. It is a very influential parameter regarding the corrosion rate of steel reinforcement bars. The resistivity depends mainly on the moisture contained in the concrete pores: the higher the humidity, the lower the resistivity.

Resistivity [kΩ·cm]	Risk of corrosion
100–200	Very low
50–100	Low
10–50	Moderate to high
< 10	Very high

Since the inhibitor stops water ingress to the concrete, it considerably reduces the moisture contained in the pores. Therefore, when the inhibitor has been applied, the electrical resistivity of the concrete will increase. This can be used to test the effectiveness of the corrosion inhibitor.

C.4. CONDITIONS OF ACCEPTANCE AND REJECTION

Application of the inhibitor can be rejected if the project manager determines that any of the following conditions apply:

- The substrate has not been properly prepared to allow penetration of the various coats of inhibitor.
- The dye has been mixed with the inhibitor in an area that does not guarantee that the solution will not be contaminated.
- The inhibitor is applied to concrete with a moisture content of 4 % humidity or higher in heavy rain, or to a substrate which has been cleaned with water in the last 24 to 72 hours.
- The inhibitor is applied at temperatures outside the range of 5 °C to 38 °C or in bright sunlight.
- The inhibitor is applied with low-pressure spray equipment at a wind speed that exceeds 15 km/h, as the minimum quantity required cannot be guaranteed.
- The inhibitor is not applied in the number of coats or using the minimum quantity required as specified for the project.
- The corrosion inhibitor is not applied as specified by the manufacturer.
- The inhibitor is applied without respecting the waiting time required between the coats.
- The material used is not specified for the project.
- The instructions of the project manager and those given in the drawings and measurements have not been complied with.

Checklists and tests allow product application errors to be detected.

Section D of this handbook discusses specifications to be included in the project documentation.

D. Documentation stage

The purpose of this section is to inform the specifier of the necessary documentation concerning the corrosion inhibitor and correct application to be included in the project documentation. The information is presented as a partial project documentation and is, as far as possible, structured using the established Technical Building Code (Spanish Standard, Part I, Annex 1, "Project content"). However, the application of the inhibitor is outside the scope of the code. Therefore, it is the responsibility of the specifier to include information as partial project documentation or incorporate it into the overall project documentation.

Over the next few pages, information regarding each of the sections of the project is detailed: the technical report, drawings, specifications, and measurements, excluding the budget as it is not possible to evaluate prices, which may vary. It also includes information to be included for the evaluation of health and safety.

This document is intended for use in cases where the application of the product is required as a result of visible damage. If the inhibitor is to be applied for preventive purposes and no corrosion damage is visible, it is the responsibility of the specifier to remove sections and paragraphs that are not applicable or irrelevant.

D.1. REPORT

The purpose of the report is to justify the choice of material. The concrete element that requires protection, the data collection activities completed any corrosion damage and the solution adopted must be described.

D.1.1. Report

This section describes the background and the reinforced concrete elements that need to be protected against corrosion.

The following information is included:

- Information on the presence of corrosive substances such as chlorides
- Design, structural, and functional descriptions of the reinforced concrete elements in question

All information that could be relevant to the application of the product is included in this section. Such information may also include aesthetic considerations.

D.1.2. Data collection

Data is acquired during the prospecting stage – which is briefly described in this section – in order to document the existing damage and to develop a solution.

1. Visits for data collection
Depending on the location of the concrete elements in question, the approach to data collection may vary. For example, an inspection of floor slabs can be performed in person, whereas facade cladding may require other means to facilitate a proper examination.

This section briefly describes the methods that have been used to examine reinforced concrete elements.

2. Sampling
Sampling is the process of removing a specimen from the element for testing. The purpose of sampling must be documented. Possible purposes may include.

- Determining the diameter, cross-sectional loss and depth of the steel bars.
- Measuring the corrosion rate and electrical resistance of the concrete.
- Laboratory analysis.

3. Specimens
A specimen is a piece of the element that is extracted in order to perform tests.

It is necessary to state whether a metal detector was used for sampling and whether the specimens contain steel reinforcements.

4. In situ samples
In order to check the suitability of the proposed solutions, in situ samples of the surface preparation and samples of the application of the corrosion inhibitor are recommended. This section describes the samples taken, objectives proposed, results obtained, and conclusions drawn.

5. Laboratory tests
This section describes the tests performed by a competent laboratory to diagnose the level of corrosion. The tests are:
- Chloride content on the surface and at the depth of the reinforcements
- Corrosion rate and electrical resistance of the concrete before and after application of the inhibitor
- Depth of concrete carbonation

D.1.3. Damage description

Details of the damage identified in the reinforced concrete element are necessary in order to propose action for the repair of existing damage.

Damage is classified according to its severity. Possible examples of such classification are as follows:
stain, fissure, crack, detachment

Similarly, non-visible damage, which can only be detected by chemical analysis must be described. Possible examples of such tests are as follows:
chloride content, concrete carbonation, content of other corrosive substances

D.1.4. Proposal for action

The proposal for action describes the criteria that determine the scope of inhibitor application. It states the reasons why inhibitor or application is necessary as each project has its own criteria based on such characteristics as damage, chloride content, moisture in the facades, or wind. Criteria for the location of corrosion control registers are also defined.

This section should also describe the process of damage repair if necessary.

D.2. DRAWINGS

The drawings needed to document the application of the corrosion inhibitor define the scope and details regarding construction monitoring registers, if included in the project requirements. Information on the location of samples and specimens taken during the prospecting stage may also be included. This data supports the solution adopted.
In cases where damage caused by corrosion needs to be repaired before the inhibitor can be applied, the details of such repairs should also be included.

D.2.1. Area of application

The areas for inhibitor application must be approximately defined, also indicating the point where application of the product is to stop, if applicable.

D.2.2. Monitoring details

This section includes details of the proposed procedure for corrosion monitoring.

D.2.3. Location of data collection

As mentioned above, the drawings are not strictly necessary. It is up to the specifier to decide whether or not to incorporate them in the project documentation.

The location of samples and specimens are indicated on the drawings, as well as the means used for collection. Any additional information that the specifier considers to be of interest may also be included.

D.2.4. Damage repair

The damage repair process is shown graphically line with the specification documents.

D.3. TECHNICAL SPECIFICATIONS

The purpose of the technical specifications is to define how the solution is to be implemented as well as the conditions of acceptance and rejection. The following information is documented:

- Material specifications for the inhibitor and the dye, allowing application to be monitored
- Specifications for the performance of key work units, which define the application process
- Specifications concerning checks on the finished work to ensure that the inhibitor was applied and functions correctly

D.3.1. Material specifications

Information regarding the corrosion inhibitor and the dye that makes it temporarily visible in order to verify application is provided below.

1. Surface-applied corrosion inhibitor

Definition
MasterProtect 8500 CI from BASF is used as a surface-applied corrosion inhibitor. It is a colorless, organofunctional, silane-based liquid with low viscosity. It is intended for the protection against and the prevention of corrosion in reinforced concrete in marine structures, facades, and balconies.

MasterProtect 8500 CI is used to protect reinforced concrete elements as defined in the project documentation.

Features
Essential features of this material include the following:

- Significantly reduces the corrosion rate
- Has a density of 0.9 g/cm³ or 0.9 kg/l
- Does not change the water vapor permeability of concrete
- Chemically bonds to steel, cement paste, and other siliceous material – will not wash out or leach during wet/dry cycles
- Prevents water and chloride from penetrating the concrete
- Does not change the appearance of the concrete
- Reduces corrosion caused by carbonation
- Complies with the requirements of EN 1504-2

Supply and storage
The inhibitor is supplied in airtight packaging bearing information on the features and description of the product, as well as details of the manufacturer.

It must be stored in a dry, well-ventilated place at temperatures between 15 °C and 50 °C. Shield from weather, sunlight, and possible impact. Also keep away from strong acids, bases, oxidizing agents, and metals, as well as food, drink, and animal food. The quality of the inhibitor will be maintained at the required level until the expiry date recommended by the manufacturer if stored under these conditions.

The inhibitor is supplied with the dye Rhodamine B, which must be mixed in a space that prevents contamination of the final product.

Inspection and criteria for acceptance and rejection
The following circumstances are grounds for rejecting the product if so deemed by the project manager:

- The quality mark or AENOR seal is missing.
- There is a discrepancy between the delivery notes and the product.
- The actual product does not have the features defined in the project documentation.
- The package is open and the project manager determines that the contents have been manipulated.
- The application limits specified in the manufacturer's manual are not met.
- The product manager reserves the right to request tests to check the purity of the material.
- All factors required for obtaining the joint warranty of the manufacturer and the applicator must be considered.

In all cases, the limits of use as described in the technical specifications of the manufacturer must be taken into consideration.

Measurement and application
The Iquantity of inhibitor applied must be calculated on the basis of the area in square meters (m^2) of the plane of projection of the reinforced concrete element.

2. Dye

Definition
Rhodamine B, a photodegradable indicator commonly used as a laboratory reagent, is used as the dye for the application of the corrosion inhibitor.

This material is dissolved in the corrosion inhibitor MasterProtect 8500 CI to make it temporarily visible so application can be monitored.

The dilution ratio is 0.1 g of Rhodamine B per liter of inhibitor applied.

Features
MasterProtect 8500 CI is a reddish-violet powder. Its molecular weight is around 479 g/mol and its melting point is 483 °F (210 °C). Its water solubility is around 50 g/l.
Fine dust dispersed in the air in sufficient concentrations and in the presence of an ignition source is a potential dust explosion hazard.

Supply and storage
The inhibitor must be supplied and stored in a sealed package protected from physical damage. Store in a cool, dry, well-ventilated area away from heat, moisture, and incompatible products. Empty containers of the material may be hazardous as they may contain product residues (i.e., dust or solids). Product residues that cannot be recycled must be disposed of at an appropriate waste disposal facility.
The dye will be supplied to the site ready-mixed with the corrosion inhibitor in the ratio specified in the technical data sheet.

Monitoring and criteria for acceptance and rejection
The following circumstances are grounds for rejecting the product if so deemed by the project manager:

- The project manager reserves the right to require tests to check the quality and chemical composition of the mixture.
- The material is not photodegradable.
- The material stains the concrete.

Measurement and application
The quantity of dye required is calculated on the basis of the area of the projection plane in square meters (m^2). It is used in solution form with the inhibitor in proportions of 0.1 g/l and is supplied ready-mixed with the inhibitor to be applied.

D.3.2. Application instructions

The application of the corrosion inhibitor and all the processes it triggers are described in a single unit of work, "Protection of reinforced concrete", against corrosion which is described below. Text in italics indicates data identified during the specification stage, which will vary from project to project.

Protection of reinforced concrete against corrosion
Definition
This section defines the tasks required for protecting the steel reinforcement bars of the concrete against corrosion, including organizing the application in batches, dissolving the dye in the corrosion inhibitor, preparing the surface, and applying the migrating corrosion inhibitor MasterProtect 8500 CI, as well as compiling corrosion measurement registers.

Materials to be used
The following materials will be used to carry out these tasks:

- Surface-applied corrosion inhibitor MasterProtect 8500 CI
- Dye
- Materials needed to prepare the concrete surface to be protected
- Materials needed to compile maintenance records

1. Description of application process

Preparation
Firstly, the concrete surface to be treated must be mechanically cleaned, removing all existing coating. This process must be carried out mechanically in accordance with the

instructions of the project manager in order to remove any substance that may hinder the penetration of the inhibitor into the concrete elements.

Elements that are likely to suffer damage during this work be protected. Durable plastic or cardboard can be used for this purpose as they can be removed once the work has been completed. Any elements that could prevent or obstruct the proper performance of the work described must be removed and properly stored until the work has been carried out, at which they must be replaced as they were found.

Any elements likely to be damaged during the application of the inhibitor must also be protected, extending the protective measures taken at the cleaning stage. Special care should be taken to protect non-mineral elements of the surface (e.g., gutters, wood, and expansion joints) and gardens.

The processes that take place after application and that are intended to verify the correct application of the inhibitor on site are discussed below.

First, the area to be treated must be divided into sections that can each be covered in one working day. The project manager must be informed of the sections so that he or she can perform statistical tests to ensure the proper application of the inhibitor. The whole application process is organized in accordance with these areas.

In cases where a dye is needed to verify application, Rhodamine B should be used to temporarily dye the MasterProtect 8500 CI. The dye (Rhodamine B) must be dissolved in the corrosion inhibitor in accordance with the results of the tests described in the dye specifications. The dye must be added in a clean place where the inhibitor cannot be contaminated with substances other than the dye. After mixing the solution must be poured into bottles and labeled with at least the following information:

- Project identification
- Batch number
- Date of delivery
- Date of mixing
- Bottle code
- Person responsible for mixing
- Quantity of inhibitor in liters
- Area of application

All the information considered by the project manager to be necessary for the proper monitoring of application on site should also be included.

Application of the inhibitor
When the concrete element is totally clean and free from any other coating, and its surface is dry, the next stages the application of the dyed corrosion inhibitor.

The MasterProtect inhibitor 8500 CI by BASF Construction Chemicals is applied using a brush for smaller surfaces or low-pressure spray equipment (not powder spray equipment) for large surfaces.

A minimum quantity of 500 g/m² must be applied in three coats of approximately 170 g/m² on vertical surfaces and ceilings, and in two coats of 250 g/m² on floors. A waiting time of 15 minutes or until the cladding surface dries must be allowed between coats. The sequential application of the coast is important. The waiting time cannot be extended, all the coast required for an area must be applied in one working day.

No water, solvent, or any other substance (other than the dye), including dust, should be allowed onto the surface during the application of the material so that the inhibitor can penetrate the correct depth of the element.

Special care must be taken to verify that the surface remains completely dry. The inhibitor must not be applied if rain is expected within four hours. In the case of unexpected rain following application, the cladding will need to be protected with plastic. If the surface is wet for any reason, it must be left to dry for between 24 and 72 hours. In all cases, the relative humidity of the cladding must be measured prior to application as the inhibitor cannot be applied to concrete with a moisture content above 4%. The project manager may request a schedule showing rainy days and whether or not the concrete element can be inhibited.

Measures must be taken to protect the surface against wind and strong sunlight during application as it is necessary to reduce the material losses. The inhibitor must be applied at temperatures between 5 °C and 40 °C.

The application is recorded by means of forms including the following information:

- Area of application
- Bottle code
- Number of liters
- Number of layers
- Date of application
- Start time of application
- End time of application
- Operator responsible for application (applicator)

Other information deemed necessary by the project manager for the proper control and monitoring of the application on site may also be included.

Tests are performed to check that the amount of inhibitor applied is appropriate. These tests are described in more detail below (point 3. Testing, page 20).

Finally, registers to measure corrosion at the points indicated by the architect are compiled.

Measurement and application
The quantity of surface-, applied corrosion inhibitor is calculated on the basis of the surface area of the reinforced concrete in square meters (m^2). Proper certification is therefore necessary to verify the amount applied; corresponding purchase invoices may be presented.

The quantity of dye is also calculated on the basis of the area of reinforced concrete in square meters (m^2).

The quantities of materials needed for the substrate are calculated on the basis of the area of reinforced concrete in square meters (m^2).

The quantities of materials needed for implementing records are calculated on the basis of the number of records required.

Monitoring and criteria for acceptance and rejection
Application of the inhibitor can be rejected if the project manager determines that the following conditions apply:

- The substrate has not been properly prepared to allow penetration of the various coats of the inhibitor.
- The dye has been mixed in the inhibitor in an area that does not guarantee that the solution will not be contaminated.
- The inhibitor is applied to concrete of the moisture content of 4 % humidity or higher, in heavy rain, or to substrate that has been cleaned with water in the last 24 to 72 hours.
- The inhibitor is applied at temperatures outside the range of 5 °C to 40 °C or in bright sunlight.
- The inhibitor is applied with low-pressure spray equipment at a wind speed that exceeds 15 km/h, as the minimum quantity required cannot be guaranteed.
- The inhibitor is not applied in the number of coats and the minimum quantity specified for the project.
- The corrosion inhibitor has not been applied as specified by the manufacturer.
- The inhibitor has been applied without respecting the waiting time required between the coat.
- The material used is not specified for the project.
- The instructions of the project manager and those given in the drawings and measurements have not been complied with.

2. Samples
Work must be carried out on sample areas of the construction elements with a view to establishing the characteristics of the solution required and solving any unexpected problems. Further adjustments may be needed in order to achieve the required quality levels.

In line with the sampling schedule, the procedure to be followed is as follows: First, the project manager proposes the solutions and quality of topcoats to be achieved with the sample. The manufacturer then provides the instructions that it considers necessary.

With this information, the project manager establishes the processes to follow, detailing checkpoints and tests with precise stops for this inspection so that the sampling can be carried out properly. The project manager may request changes in order to adequately assess further procedure.

A solution is determined on the basis of the sample. This provides information on the following:

- **Cleaning and surface preparation**
  The sample should indicate the degree of cleaning required for the concrete element. This will help determine the appropriateness of the materials used for cleaning to eliminate any remaining coating without damaging the concrete.

  The location of the samples must be determined by the project manager and samples must be processed in line with to the project specifications and the instructions given by project manager.

- **Supply, mixing and application of the corrosion inhibitor**
  The corrosion inhibitor must be applied to the section of cladding selected by the project manager.

  This sample provides information regarding the amount of inhibitor required, the effectiveness of the material, and the photodegradability of the dye dissolved in the inhibitor. In order to determine the amount of the inhibitor required, and avoid loss of material due to wind or strong sunlight, the inhibitor must be applied to the sample in the number of coats and quantities laid down in the project specification. Later, tests must be performed to check whether the content of silanes at the depth of the reinforcement is in accordance with the manufacturer's instructions. The corrosion rate must be measured before and after application in order to prove the effectiveness of the product.

  Similarly, we have to check whether or not the dye has completely degraded under exposure to sunlight in an acceptable period of time.

- **Corrosion measurement registers**
  A number of sample points are selected for the measurement of in situ parameters characterizing the status and corrosion activity of the steel reinforcement bars.

  These maintenance measurements can be made easily whenever required over an extended period of time. The specific locations of the sample points are selected by the project manager and shown to the builder.

3. Testing
The tests carried out during the project aim to monitor the proper performance of the procedures outlined in the project specification. They must be distinguished from the inspection of the finished work as they are not intended to test the success of the entire project but only of part of the project. For this purpose the following tests must be conducted on the construction elements:

- **Supply and mixing of the dye and corrosion inhibitor**
  A check must be carried out in accordance with the project manager‘s requirements to ensure that the correct quantity of dye is dissolved inhibitor and that the inhibitor is not contaminated by other materials.

- **Application of the corrosion inhibitor**
  Samples are taken and laboratory tests performed to check the minimum concentration of silanes at the depth of the reinforcement, which must not be lower than 0.15 % of the weight of the concrete. The distribution of the samples to be tested must be representative of the application areas.

D.3.3. Requirements for inspection of the finished work

The corrosion rate must be measured and entered into all records in order to guarantee that the application of the product to the building will be successful. Values below 0.2 μA/cm² must be obtained as this indicates that the reinforcements are in a passive state. The true corrosion rate is determined by measuring the electrical resistivity of the concrete, which indicates the level of electrolytes and therefore the effectiveness of the inhibitor.

Finally, a maintenance plan is put in place to monitor the progression of corrosion and to check whether or not the reinforcement needs more protection against corrosion.

D.4. MEASUREMENTS

Measurements: protection of steel bars and quality control.

D.4.1. Protection of steel bars

- **Cleaning and surface preparation**
  Any existing coating must be completely removed from the entire surface of the reinforced concrete before proceeding with the application of the inhibitor. The of work performed in square meters (m²) in accordance with project drawings and specification documents. The samples must be kept (not thrown away) until the quality of the application is approvaed by the project manager or any other person in charge.

- **Supply, mixing and implementation of the protection**
  Rhodamine B dye solution is supplied ready-mixed with the surface-applied corrosion inhibitor MasterProtect 8500 CI by BASF Construction Chemicals in cases where a dye is needed to verify application. Dyed inhibitor is applied to the reinforced concrete according to the application areas in the amounts and number of coats described in the specification documents.

  Application is measured in square meters (m²) in accordance with the manufacturer's instructions, including quantities required to reduce loss of the material when being applied in strong wind or sunlight.

  Special attention must be paid to the average consumption of the material. It is not possible to certify the quantity of the material if there are no delivery or purchase notes. Similarly, a few inspections must be conducted as per the project manager's criteria to ensure that the correct amount is being applied.

D.4.2. Quality control

- **Measurement of the corrosion rate and electrical resistivity**
  Measurements of the corrosion rate and the electrical resistivity must be conducted on in situ samples of the concrete selected upon visual inspection.

- **Monitoring the effectiveness of the inhibitor**
  Tests to ensure that the corrosion rate has decreased are conducted after the application of the surface-applied corrosion inhibitor until the values obtained are within the acceptable range.

- **Test of the coating thickness**
  Tests must be conducted to determine that the reinforcement in the concrete has been sufficiently coated.

- **Measurement of resistance to chloride penetration**
  Tests must be conducted to ensure that the concrete resists the penetration of chlorides.

- **Test silane content at the depth of the reinforcements**
  Silane content at the depth of the reinforcements must be tested to ensure that the minimum levels required have been reached.

- **Measurement of moisture content in concrete**
  Moisture content in the concrete must be measured after the application of the inhibitor.

- **Implementation of corrosion control registers**
  Corrosion control registers must be implemented in the concrete by installing white anodized 40 × 40 cm aluminum plates. Forecasts of the electrical resistivity in the reinforcement to measure the corrosion rate and control of its progression over time, including forecasts for measuring moisture in the concrete, are conducted.

D.5. HEALTH AND SAFETY STUDY

The structure of the health and safety study depends on the relevant authorities. However, the health and safety information for the on the inhibitor and the dye, as well as the materials involved in the construction processes should be reviewed. Some essential information to be included in the health and safety study is given below.

Chemical products
Both the inhibitor and the dye are toxic chemicals. The instructions given by the manufacturer in the safety data sheet with regard to the storage, handling, transportation, and application of the product must be followed.

Both the inhibitor and the dye must be stored in their original containers and be protected from contact with other products or water until mixed.

Personnel must be warned to handle such materials with care and to wash hands and face thoroughly after using the product.

Personal protective equipment
The personal protective equipment required when handling and applying the corrosion inhibitor and dye powder are detailed below. However, other equipment may be required depending on the working environment, such as hard hats or harnesses.

- Gloves for protection against aggressive chemicals
- Masks for protection against chemicals
- Protective eyewear for protection against chemicals
- In the absence of masks and protective eyewear, masks which simultaneously protect the airways and eyes for protection against chemical agents should be used
- Coveralls

ANNEX 1. Corrosion concepts

The durability of reinforced concrete depends on protecting the concrete surrounding the steel bars. This protection is twofold. Firstly, the coating is a physical barrier against corrosion. Secondly, the high alkalinity of the concrete develops a passivation layer on the steel bars that can remain unchanged for an indefinite period. Passivation is the coating of the steel with a layer of transparent oxide that acts as a barrier preventing further oxidation.

A corrosion risk occurs when the passivation layer disappears as a result of carbonation and chloride attack.

Carbonation is the reaction of alkaline (or basic) compounds in the concrete with carbon dioxide (CO_2) from the atmosphere, which reduces the alkalinity of the concrete. Reduced alkalinity causes widespread depassivation of the steel bars.

Chloride attack is the erosion of various points in the passivation layer by chloride ions, which causes “pitting” corrosion. Chlorides occur in the concrete for two reasons: either they are added with components of the concrete (additives, water, etc.) or they penetrate the pore network. Penetration of the pores occurs in marine environments or areas where deicing salts are used. Cracks in reinforced concrete also provide quick access for aggressive chlorides. Once the steel bars are corroded, they expand, creating more cracks through which contaminants enter.

When they are unprotected, the steel bars are vulnerable to factors that cause corrosion, such as the simultaneous presence of moisture and oxygen. Moisture provides the aqueous medium in which the oxidation reaction occurs. The higher the level of humidity, the lower the electrical resistivity, or opposition to the movement of electrons. Thus, if the pores contain very little moisture, the electrical resistivity is very high and corrosion is unlikely to occur. However, if the pores are fully saturated with water and the resistivity is low, oxygen still has to be dissolved in the water to reach the steel bars. In such a situation, it is said that corrosion is controlled by the oxygen supply. Maximum corrosion occurs when the moisture content is high but the pores are not saturated. In this case, the electrical resistivity is low and the oxygen content is sufficient to cause corrosion.

ANNEX 2. Test descriptions

All the information necessary for the proper performance of the tests in the prospecting stage is given in the pages that follow.

2.1. In situ

1. Electrical resistivity of concrete

The electrical resistivity indicates the resistance of the concrete to the flow of electric charges. It provides information on the risk of corrosion of the steel reinforcement and serves as an indicator for the effectiveness of the corrosion inhibitor.

- **Name of the test**
  Electrical resistivity of concrete
- **Unit of measurement**
  kΩ·cm
- **Interpretation of results**
  In the first instance, the risk of corrosion can be estimated on the basis of the resistivity using the table below.

Resistivity [kΩ·cm]	Risk of corrosion
100–200	Very low
50–100	Low
10–50	Moderate to high
< 10	Very high

The test is performed again when the product has been applied. In addition to the value provided in the table, the results can be compared with the original test to assess the improvement produced.

- **Necessary device**
  In situ measurement using devices such as Gecor 6 or Gecor 10.
- **Completion time**
  The test results are obtained immediately.
- **Precision**
  The accuracy of the test is acceptable.
- **Destructive or nondestructive**
  This is a destructive test since it is necessary to chip away some of the concrete to access the reinforcement.
  Once the work has been completed and all the necessary registers have been implemented, it is no longer destructive since we can access the reinforcement without chipping off concrete.

2. Corrosion rate

As with the test above, the corrosion rate test is an indicator of the effectiveness of the inhibitor.

- **Name of the test**
  Corrosion rate
- **Unit of measurement**
  μA/cm²
- **Interpretation of results**
  Steel reinforcement is considered to be in a passive state when the corrosion rate is less than 0.2 μA/cm².
  The corrosion rate is also useful for estimating the annual cross-sectional loss of steel bars and thus the time remaining until corrosion becomes visible. This information is reflected in the table below:

Corrosion rate [μA/cm²]	Corrosion level	Cross-sectional loss of steel bars [μm/year]	Time until corrosion becomes visible
< 0.1	Passive	< 5.8	–
0.1–0.5	Low	5.8–58	> 10 years
0.5–1.0	Moderate	58–174	3–10 years
> 1.0	High	> 174	< 2 years

The test is performed again when the product has been applied. In addition to the value provided in the table, the results can be compared with the original test to assess the improvement produced.

- **Necessary device**
The test is performed with linear polarization techniques and can be measured with devices like Gecor 6, Gecor 10, or GalvaPulse.

- **Completion time**
The test results are obtained immediately.

- **Precision**
The accuracy of the test is acceptable.

- **Destructive or nondestructive**
This is a destructive test since it is necessary to chip away some of the concrete to access the reinforcement. Once the work has been completed, it is no longer destructive since the reinforcement can be accessed without chipping off concrete.

3. Depth of concrete carbonation
This test measures the depth of concrete carbonation. The test involves removing a concrete sample and applying phenolphthalein. Staining indicates the progress of carbonation inside the concrete.

- **Name of the test**
Depth of concrete carbonation

- **Unit of measurement**
mm

- **Interpretation of results**
Fuchsia-colored areas are desired and should not be considered carbonated.

- **Necessary device**
Results are determined by applying phenolphthalein – a liquid indicator that changes its color from transparent to fuchsia when coming into contact with uncarbonated concrete.

- **Completion time**
The test results are obtained immediately.

- **Precision**
The accuracy of the test is acceptable.

- **Destructive or nondestructive**
This is a destructive test as samples are necessary.

4. Tensile strength
The inhibitor can be applied if the tensile strength of the substrate reaches a certain minimum limit.

- **Name of the test**
Tensile strength

- **Unit of measurement**
N/mm^2

- **Interpretation of results**
The tensile strength of the concrete surface must be over 1 N/mm^2 on average (individual measurements must be over 0.5 N/mm^2) if the substrate is to be considered suitable for the application of the inhibitor.

- **Necessary device**
Digital dynamometer

- **Completion time**
The test results are obtained immediately.

- **Precision**
The accuracy of the test is acceptable.

- **Destructive or nondestructive**
The test is destructive as the dynamometer is applied until a disk is broken.

5. Sectional loss of steel bars
Sectional loss is one of the limits of application.

- **Name of the test**
Sectional loss of steel bars

- **Unit of measurement**
mm

- **Interpretation of results**

- **Necessary device**
A caliper is used to take the measurements.

- **Completion time**
The test takes only as much time as is needed to chip away the concrete to access the steel bars and clean the corroded areas with a wire brush to expose the resistant sections. (Do this in an area with corroded steel bars and in another area in original condition, if possible.) Measurements of the bars are then taken.

- **Precision**
The accuracy depends on whether measurements of unoxidized steel bars can be taken or whether the original diameter must be estimated.

- **Destructive or nondestructive**
The test is destructive as it is necessary to expose the reinforcement in order to take the measurement.

6. Concrete temperature
The temperature of the concrete is a condition for application.

- **Name of the test**
Concrete temperature

- **Unit of measurement**
°C

- **Interpretation of results**
  The range of temperatures obtained is compared with the range of temperature allowed for the application. This indicates whether the product may be applied under normal conditions without taking special precautions.

- **Necessary device**
  The concrete temperature is measured with a digital thermometer or an electronic thermohygrograph with a surface probe.

- **Completion time**
  The test results are obtained immediately.

- **Precision**
  The accuracy of the test is acceptable.

- **Destructive or nondestructive**
  This is a nondestructive test.

7. Concrete moisture

The percentage of moisture in the surface of the concrete is measured with specialized equipment. The test is nondestructive and the results are immediate.

- **Name of the test**
  Concrete moisture

- **Unit of measurement**
  % (humidity)

- **Interpretation of results**
  Concrete moisture must be less than 4 %.

- **Necessary device**
  A hygrometer is used.

- **Completion time**
  The test results are obtained immediately.

- **Precision**
  The accuracy of the test is acceptable.

- **Destructive or nondestructive**
  This is a nondestructive test.

8. Thickness of concrete cover

The steel bars are located and a sample is taken to measure the thickness of the concrete cover.

- **Name of the test**
  Thickness of concrete cover

- **Unit of measurement**
  mm (distance to access the steel bars)

- **Interpretation of results**
  The depth of the steel bars is needed to determine the quantity of inhibitor to be used to penetrate and protect them.

- **Necessary device**
  Metal detector

- **Completion time**
  The test requires no timeouts.

- **Precision**
  The accuracy of the test depends on the proper placement of the concrete reinforcement.

- **Destructive or nondestructive**
  The test is destructive as it is necessary to expose the reinforcement in order to make the measurement.

2.2. Laboratory

1. Chloride content

Chlorides in the concrete may make it impossible to use of the corrosion inhibitor. That is why it is very important to know the chloride content of areas planned for protection. Concrete samples at different depths are taken for laboratory analysis and subsequent preparation of a chloride contamination profile.

- **Name of the test**
  Chloride content

- **Unit of measurement**
  % (of the weight of the cement)

- **Interpretation of results**
  The test results are compared with the maximum chloride limit that BASF indicates in order to establish whether or not the areas measured are suitable for application.

- **Necessary device**
  It is a standard test and therefore easy to find a laboratory to perform it.

- **Completion time**
  The test includes no waiting times, and can be done quickly. It can be assumed that the results are obtained within a week, depending on the laboratory's workload.

- **Precision**
  The accuracy of the test is acceptable.

- **Destructive or nondestructive**
  This is a destructive test as samples are necessary.

2. Silane concentration

Silanes are the compound responsible for inhibiting corrosion of the reinforcement. If the concentration of silanes at the depth of the steel bars is below the minimum limit, the inhibitor cannot be applied as its effectiveness cannot be guaranteed. For this reason, it is essential to determine the concentration of silanes especially at the depth of steel bars.

The purpose of the test is to find chemicals derived from the application of the inhibitor in the concrete. To do this, several samples of powdered concrete are taken at different depths of the treated surface.

- **Name of the test**
  The analysis is performed using the following processes:
  – Pyrolysis
  – Gas chromatography
  – Mass spectrometry

- **Interpretation of results**
  The minimum concentration of silanes considered to be effective protection is 0.15 % of the weight of the cement at the depth of the reinforcements (coating thickness).

  Therefore, it is necessary to know:
  – The percentage of cement in the concrete
  – Coating thickness of the reinforcement

- **Necessary device**
  This is an unusual test and therefore difficult to find a laboratory to perform it.

- **Completion time**
  The test involves some complexity. It can be assumed that the results take between two and three times longer than the other laboratory tests requested.

- **Precision**
  The accuracy of the tests is very high.

- **Destructive or nondestructive**
  This is a destructive test as samples are necessary.

- **Potential errors**
  It has been noted during analysis that the pure product can only be detected within hours following application. It cannot be detected after longer periods. It is for this reason that the analysis is not intended to determine the content of the product in its original composition but rather the concentration of silanes.

3. Sulfate content

The sulfate content is tested in the laboratory from concrete samples taken from the site. The time it takes to obtain the results depends on the laboratory.

- **Name of the test**
  Sulfate content

- **Unit of measurement**
  % (of the weight of the sample)

- **Interpretation of results**
  The test results are compared with the maximum limit that BASF indicates in order to establish whether or not the areas measured are suitable for application.

- **Necessary device**
  This is a standard test and it is therefore easy to find a laboratory to perform it.

- **Completion time**
  The test includes no waiting times and can therefore be carried out quickly. It can be assumed that the results are obtained within a week, depending on the laboratory's workload.

- **Precision**
  The accuracy of the test is acceptable.

- **Destructive or nondestructive**
  This is a destructive test as samples are necessary.

4. Cement content

The cement content is tested in a laboratory from a concrete sample. The time it takes to obtain the results depends on the laboratory's workload.

- **Name of the test**
  Cement content

- **Unit of measurement**
  % (of the weight of the concrete)

- **Interpretation of results**
  The cement content is needed to determine the acceptable maximum limit of chlorides in the concrete.

- **Necessary device**
  This is a standard test and it is therefore easy to find a laboratory to perform it.

- **Completion time**
  The test includes no waiting times and can therefore be performed quickly. It can be assumed that the results are obtained within a week, depending on the laboratory's workload.

- **Precision**
  The accuracy of the test is acceptable.

- **Destructive or nondestructive**
  This is a destructive test as samples are necessary.

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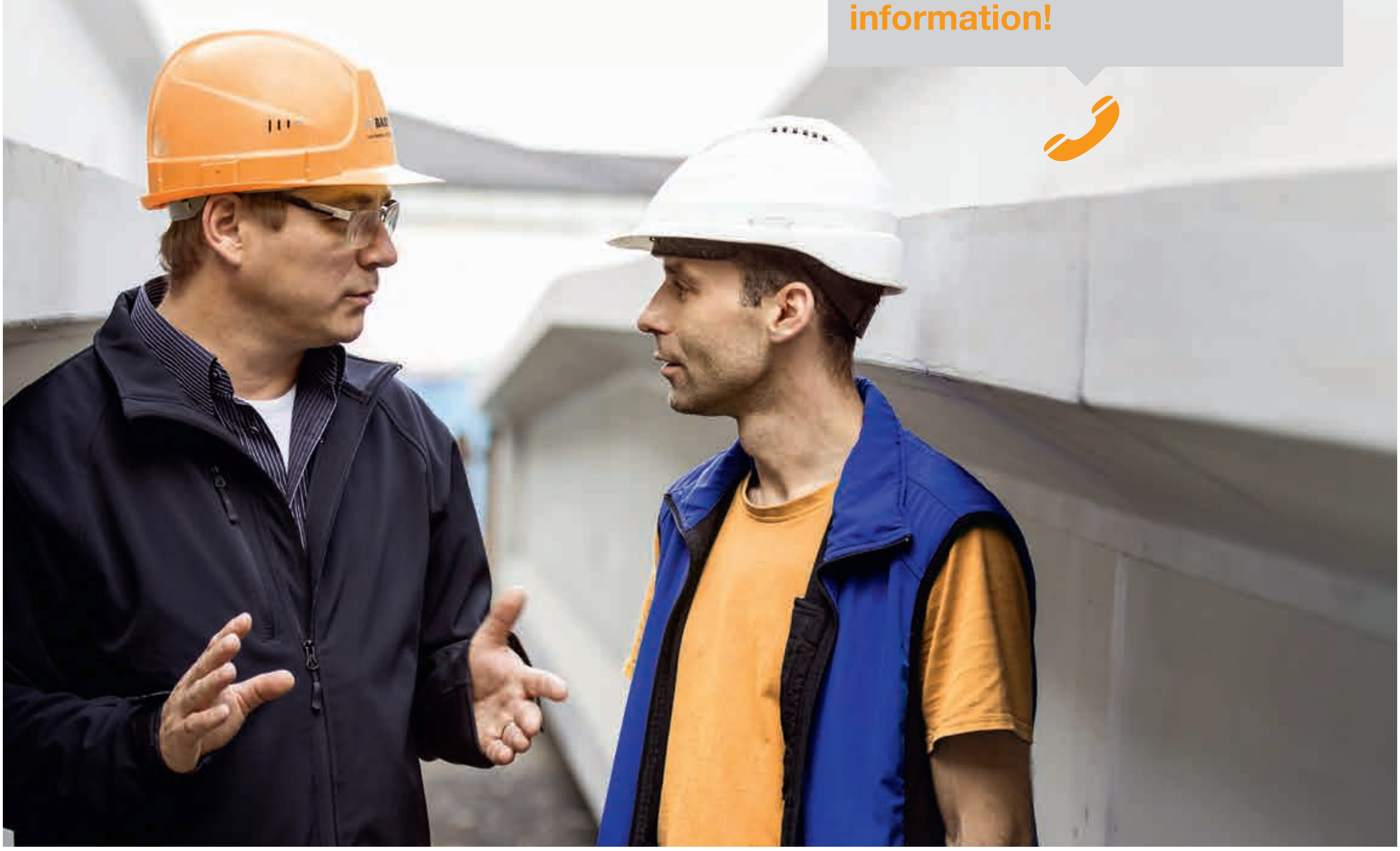

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