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MAPEI

Galvanic cathodic protection

# *Galvanic cathodic* protection

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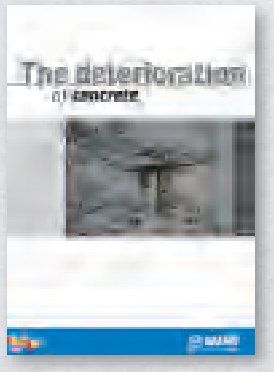
Mapei produces a series of technical manuals so that the subject of the deterioration of concrete may be analysed in depth, and to offer a professional approach to the problems regarding repair work.

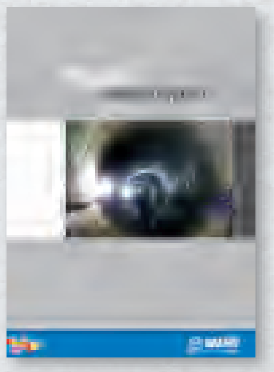
The subject of this manual is:
**Galvanic cathodic protection**


The other manuals available in the series are:









*The manuals are available upon request.*

# Galvanic cathodic protection

## Index





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## 1| Cathodic protection

Cathodic protection is a technique based on electrochemical principles to prevent corrosion on metal structures or protect metal structures erected in aggressive environments from corrosion. This effect may be obtained by inducing a continuous current between an electrode, known as the anode, and the metal which requires protection, known as the cathode. This circuit lowers the electrical potential of the metallic element thus reducing the speed at which it corrodes. The cathodic process may be initiated in two different conditions:

- If corrosion on the metal element has already started, there is a condition of cathodic protection; condition which acts to reduce the corrosion activity until it stops;
- If there is no corrosion on the element, it may be defined as preventive cathodic protection in that it impedes corrosion from the start.

Cathodic protection may be achieved in two ways:

- Impressed current system
- Galvanic anode system

The **impressed current system** relies on an external transformer to develop the current required. The positive pole is connected to an anodic disperser which is usually an insoluble anode (for example: high silicon iron, graphite, activated titanium, etc.) while the negative pole is connected to the structure requiring protection.
The main advantage of the **galvanic anode system** is that it does not require any external energy source. When two different types of metal are connected together and embedded in a suitable electrolyte the metal with the most negative electric potential will oxidise and protect the metal with the least negative potential. Aluminium and zinc are generally used to protect steel if the electrolyte is sea-water or concrete, magnesium is used for elements embedded in the ground and fresh water, while iron is used for copper alloys and stainless steel.

## 2| Corrosion

Metals may be classified according to their nobility, that is, according to their property of releasing electrons. The higher the nobility of a metal, more difficult is the release of electrons and, therefore, oxidation. Below: a list of metals in order of nobility (descending from the highest):

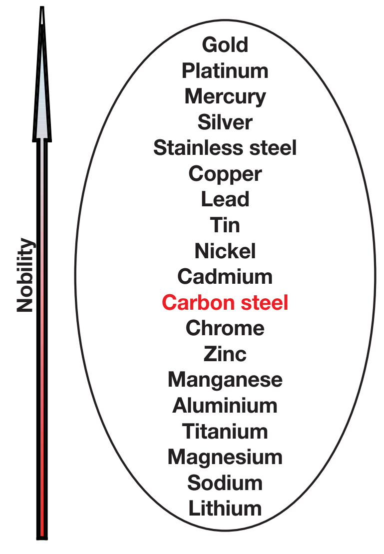



***Diagram C***
Scale of the nobility of metals starting with the most noble (gold: practically corrosion-proof). Carbon steel is the metal used to reinforce concrete. If this metal is connected to a less noble metal, such as zinc, it is protected from corrosion.

With reference to the above scale, the way galvanic cells or batteries work is easier to understand. If two different metals are connected together in an electrolyte, a circuit will be created between the two metals. This principle may be exploited to protect a metal from corrosion. The metal requiring protection (which becomes the cathode in the circuit) is connected to a different metal with a lower electric potential (less noble), which automatically becomes a sacrificial anode to free the cathode from the products of corrosion. In time, the sacrificial anode will be gradually consumed. A typical application is on metal hulls in ships.

***Diagram A***
A typical cathodic protection set-up: impressed current system

***Diagram B***
A typical cathodic protection set-up: galvanic anode system

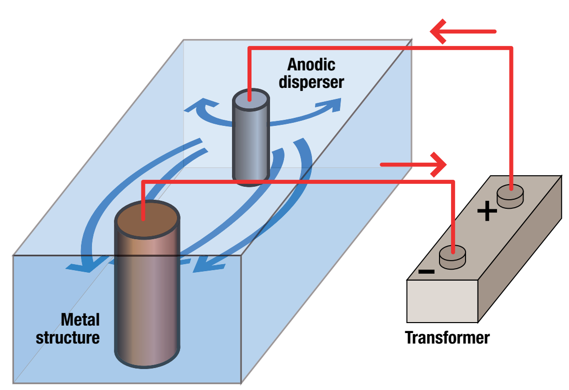



*diagram A*

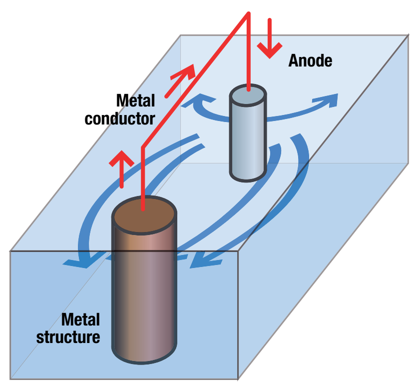



*diagram B*

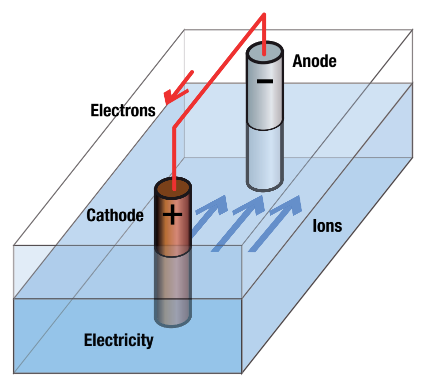


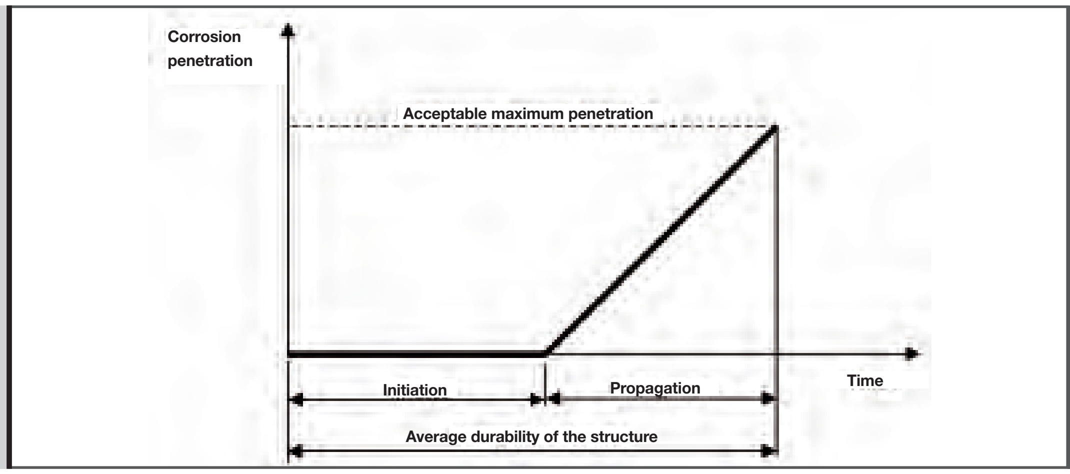

***Diagram D***
Simplified lay-out of a galvanic cell

## 3| Cathodic protection in reinforced concrete

In aggressive environments, the service life of reinforced concrete structures is highly dependent on the corrosion of the steel reinforcement.
In new concrete or in concrete without contaminants, the reinforcement is in a solution with pH > 11.5. In such conditions, a thin oxide film will form on the surface of the steel which protects it from corrosion. This condition is called passivity. Over the years, concrete may lose its alkalinity and, therefore, its capacity to protect the reinforcement. This occurs due to:

- Carbonatation: carbon dioxide in the atmosphere penetrates into the concrete and reduces its pH level from around 13 to approximately 9. At such a pH level, the film of oxide on the reinforcement steel may break up and so the steel will lose its passivity;
- Contamination by chlorides: as with carbon dioxide, chlorides penetrate the surface of the concrete and provoke localised fractures in the film of passivity on the reinforcement steel;
- Interference from dispersed currents; the film of passivity may also fracture in the anodic areas from where the current is released.

***Diagram E***
Tuutti Corrosion Model
Corrosion initiation and propagation in a reinforced concrete structure




The graph represents corrosion phenomenon on a concrete structure over time and may be divided into two distinct phases:

- Initiation phase: time for diffusion of polluting agents inside the concrete;
- Propagation phase: follows the initiation phase and continues until the maximum accepted level of corrosion is reached.

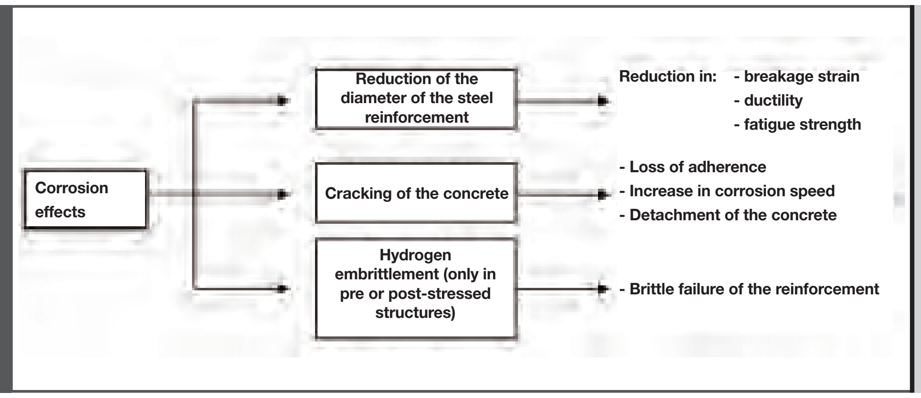



***Diagram F***
Effect of corrosion on a reinforced concrete structure

## 3.1| Corrosion due to carbonatation

The mere presence of carbon dioxide in concrete does not create any problem, in that it does not have a negative impact on the mechanical characteristics of the concrete. Its presence only becomes negative if it reaches the reinforcement steel and breaks up the film of passivity. Therefore, corrosion due to carbonatation depends on:

- The presence of carbon dioxide in the atmosphere, which may vary from 0.04% in rural areas to 0.2% in city environments;
- Concrete: the thicker the concrete, the longer the time required for the carbon dioxide to reach the reinforcement steel;
- Properties of the concrete: water/cement ratio, porosity, presence of cracks, etc.;
- Relative humidity in the environment. To trigger off corrosion, both oxygen and moisture must come into contact with the reinforcement steel. This is why the most critical environments for carbonatated reinforced concrete are those where the relative humidity is around 60-70%, thus permitting both factors to co-exist.

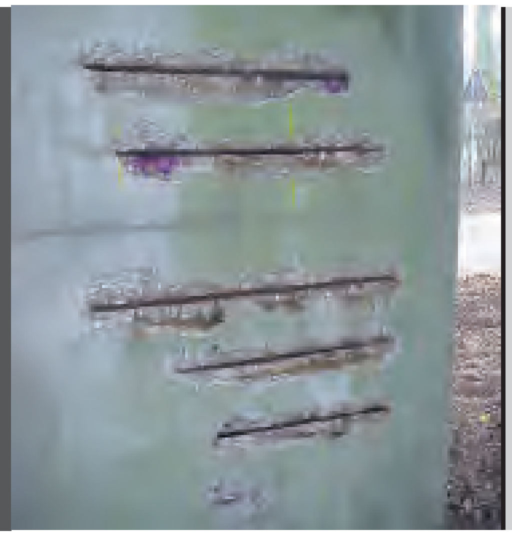


***Photo 1***
Deterioration of a reinforced concrete structure. Concrete detached following corrosion of the reinforcement steel due to carbonatation

### 3.2| Corrosion by chlorides

Corrosion induced by chlorides may be observed mainly in reinforced concrete structures in marine environments or on structures in road networks where high quantities of de-icing salts are used during the winter. Once a critical level of chlorides has been reached at the steel/concrete interface the film of passivity breaks up and, if there are water and oxygen present, corrosion starts. The areas where the chlorides break up the film of passivity act as anodes, while the areas where the chlorides have not reached such a level remain passive and act as cathodes. The corrosion which starts in this way is localised in the anodic areas and is defined as corrosion by pitting.

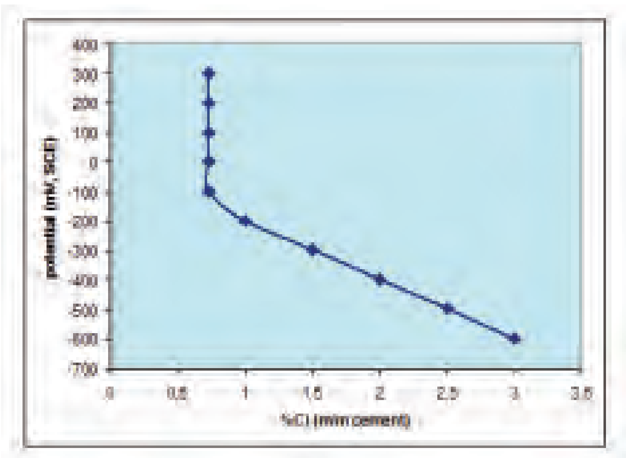
***Photo 2***
Deterioration of a reinforced concrete structure. Corrosion of the steel reinforcement induced by the presence of chlorides

The time required to initiate corrosion due to the presence of chlorides depends on:

- The concentration of chlorides on the external surface of the concrete;
- The characteristics of the cementitious matrix;
- The thickness of the concrete;
- The moisture level in the concrete.

In airborne structures, which have an electrical potential in the steel reinforcement close to 0 V (SCE*), corrosion initiates when the level of chlorides exceeds a level of between 0.4 and 1% of the weight of the cement, or for convenience purposes, 0.06-0.15% of the concrete.

***Diagram G***
C. Andrade's relationship between the chloride content in concrete and its value of potential




### 3.3| Electrical potential of corrosion

In a structure which has not been contaminated by external agents, therefore with no carbonatation or chlorides, the cementitious matrix maintains an alkali environment around the steel and, as a result, forms an oxide film on the steel which keeps the reinforcement protected from corrosion. In such structures, the values of electrical potential are in an ascending range from -0.150÷0.200 V (SCE) to +0.200 according to the level of moisture in the concrete.
In structures where carbonatation has lowered the pH value of the concrete and the passivity film has been broken up, corrosion may initiate and values of potential between – 0.150 and -0.300 V (SCE) according to the level of moisture present may be found.
In structures contaminated by chlorides, the values of electrical potential of reinforcement steel may be as low as -0.300 V (SCE), depending on the level of moisture and chloride content.
Once the process initiates, the attack continues even if the values of electrical potential are lower than the value E of the corrosion. To block the occurence, the electrical potential must be reduced to a value even more negative, known as potential of re-passivation, which also depends on the chloride content, the pH level and the temperature.
For example, if the value of electrical potential is measured on a structure as in Diagram H, a corrosion cell forms between the area with the lower value of electrical potential (for example, due to localised attack by chlorides) and the adjacent area with a higher value. If a zinc anode is applied (Figure 2), which has a much more negative electrical potential (approximately -1 V SCE), all the steel reinforcement will have a lower value and will be protected from corrosion.

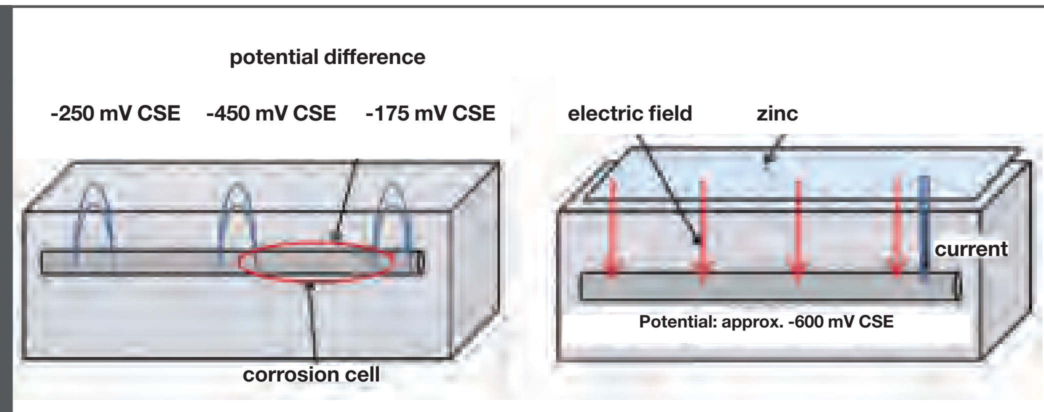



*Fig. 1* *Fig. 2*

***Diagram H***
Diagram of the formation of a corrosion cell in reinforced concrete and protection with a galvanic anode

* SCE means that the values of electrical potential are expressed using a calomel electrode as a reference.



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## 3.4| Galvanic cathodic protection

The phenomenon described above may be used to protect reinforced concrete structures. Electrochemical techniques are employed to annul or prevent corrosion or to limit it to within certain acceptable limits. To reach this target the reinforcement must be polarised using cathodes. Cathodic protection/prevention may be achieved by connecting the steel reinforcement to sacrificial zinc anodes which, thanks to their more negative electrical potential, protect the steel reinforcement rods and keeps them free from corrosion.

The aim of protection in the concrete is to bring the reinforcement to a passive state or reduce activity on its surface. In structures polluted by chlorides, the current also provokes an increase in the pH level and keeps the chlorides away from the steel, and both occurances promote the formation of a film of passivity. In carbonatated structures, on the other hand, the current only promotes an increase in the pH level, which may be increased from 9 (carbonatation condition) to 12-13, values which take the steel reinforcement from an active state to a passive state.

Cathodic prevention is based on the fact that corrosion of the steel reinforcement is not initiated as long as its electrical potential is kept lower than the electrical potential of corrosion. By connecting the two metals (carbon steel-zinc), the reinforcement is kept passive and initiation of the phenomenon is impeded, even if there are high levels of chlorides present.

Another aspect which must be considered is the density of current required for cathodic protection/prevention.

In old, deteriorated structures this value is between 5 and 20 $mA/m^2$, while for prevention on new structures the value is between 0.2 and 2 $mA/m^2$. In the first case, since the reinforcement is highly active, the initial demand for current will be very high (in the order of 15/20 $mA/m^2$), which will then gradually reduce to a lower level (in the order of 4-5 $mA/m^2$) as soon as a passive state has been reached (generally 6 to 12 months after installation).

This means that an important advantage of galvanic cathodic protection is that it is self-regulating according to the real demand for current which the reinforcement requires as time goes by.

The two tables on the following pages simplify the concept of the duration of galvanic protection, according to the amount of current distributed.

## 3.5| Galvanic cathodic protection on compromised structures

The theoretical consumption of zinc required for cathodic protection is approximately 12 kg/A•year (kg per ampere/year). On the basis of this figure, and setting the current distributed in the first year at 20 mA and 5 mA in the following years (the second column in the table), we may calculate the duration of a given mass of zinc used to protect the structure from corrosion. The first column in the table indicates the life in years of the anode, the third column the progressive weight of the zinc as time passes, the fourth column indicates the annual loss in weight calculated according to a theoretical consumption rate (12 kg/A•year) and the current distributed, which is equal to 220 g in the first year and approximately 60 g in the following years. We may thus calculate that a mass of 1350 g of zinc employed for galvanic cathodic protection may last for up to 20 years before it is completely consumed.

*Table 1*

| DURATION years | CURRENT mAmps | AMOUNT Zn / Mq g | LOSS IN WEIGHT g / year | RESIDUAL WEIGHT g |
|---|---|---|---|---|
| 1 | 20 | 1350 | -220 | 1130 |
| 2 | 5 | 1130 | -59 | 1071 |
| 3 | 5 | 1071 | -59 | 1012 |
| 4 | 5 | 1012 | -59 | 953 |
| 5 | 5 | 953 | -59 | 894 |
| 6 | 5 | 894 | -59 | 835 |
| 7 | 5 | 835 | -59 | 776 |
| 8 | 5 | 776 | -59 | 717 |
| 9 | 5 | 717 | -59 | 658 |
| 10 | 5 | 658 | -59 | 599 |
| 11 | 5 | 599 | -59 | 540 |
| 12 | 5 | 540 | -59 | 481 |
| 13 | 5 | 481 | -59 | 422 |
| 14 | 5 | 422 | -59 | 363 |
| 15 | 5 | 363 | -59 | 304 |
| 16 | 5 | 304 | -59 | 245 |
| 17 | 5 | 245 | -59 | 186 |
| 18 | 5 | 186 | -59 | 127 |
| 19 | 5 | 127 | -59 | 68 |
| 20 | 5 | 68 | -59 | 9 |

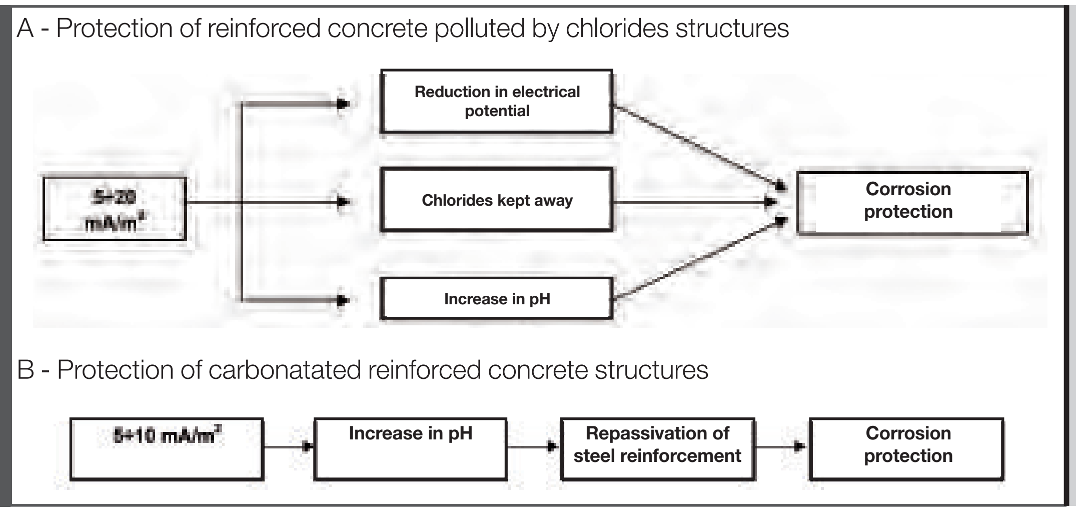


*Diagram I*
A – Effects of protection in reinforced concrete polluted by chlorides

B – Effects of protection in carbonatated reinforced concrete

## 3.6| Galvanic cathodic protection on new structures

Unlike the previous example, if galvanic cathodic protection is installed on new structures, the reinforcement is in an unpolluted, alkali environment and so will be protected from aggressive phenomenon. High currents are not required in these conditions (which are required in galvanic protection to passivate steel reinforcement) because the anodes are only required to maintain the passivity of the reinforcement which is already present. As in the previous table, we may note that if a stable current of 1 mA is distributed over a period of time (according to the second column in the table), we may calculate the duration of a given mass of zinc used, in this case, to prevent the formation of corrosion on a structure. The yearly loss in weight, calculated using the theoretical consumption rate (12 kg/A•year) and the current distributed (1 mA), will be 12 g/year. We may thus calculate that a mass of 460 g of zinc employed for galvanic cathodic prevention may last almost 40 years before it is completely consumed.

*Table 2*

| DURATION years | CURRENT mAmps | AMOUNT Zn / Mq g | LOSS IN WEIGHT g / year | RESIDUAL WEIGHT g |
|---|---|---|---|---|
| 1 | 1 | 460 | -12 | 448 |
| 2 | 1 | 448 | -12 | 436 |
| 3 | 1 | 436 | -12 | 424 |
| 4 | 1 | 424 | -12 | 412 |
| 5 | 1 | 412 | -12 | 400 |
| 6 | 1 | 400 | -12 | 388 |
| 7 | 1 | 388 | -12 | 376 |
| 8 | 1 | 376 | -12 | 364 |
| 9 | 1 | 364 | -12 | 352 |
| 10 | 1 | 352 | -12 | 340 |
| 11 | 1 | 340 | -12 | 328 |
| 12 | 1 | 328 | -12 | 316 |
| 13 | 1 | 316 | -12 | 304 |
| 14 | 1 | 304 | -12 | 292 |
| 15 | 1 | 292 | -12 | 280 |
| 16 | 1 | 280 | -12 | 268 |
| 17 | 1 | 268 | -12 | 256 |
| 18 | 1 | 256 | -12 | 244 |
| 19 | 1 | 244 | -12 | 232 |
| 20 | 1 | 232 | -12 | 220 |
| 21 | 1 | 220 | -12 | 208 |
| 22 | 1 | 208 | -12 | 196 |
| 23 | 1 | 196 | -12 | 184 |
| 24 | 1 | 184 | -12 | 172 |
| 25 | 1 | 172 | -12 | 160 |
| 26 | 1 | 160 | -12 | 148 |
| 27 | 1 | 148 | -12 | 136 |
| 28 | 1 | 136 | -12 | 124 |
| 29 | 1 | 124 | -12 | 112 |
| 30 | 1 | 112 | -12 | 100 |
| 31 | 1 | 100 | -12 | 88 |
| 32 | 1 | 88 | -12 | 76 |
| 33 | 1 | 76 | -12 | 64 |
| 34 | 1 | 64 | -12 | 52 |
| 35 | 1 | 52 | -12 | 40 |
| 36 | 1 | 40 | -12 | 28 |
| 37 | 1 | 28 | -12 | 16 |
| 38 | 1 | 4 | -12 | 4 |

If a concrete structure is studied and designed correctly and prudently with:

- Galvanic cathodic prevention applied on the steel reinforcement;
- Design, preparation and application of the concrete according to the requirements of EN 206-1:2006 Standards for the exposition class in which it will be built;
- Protection of the concrete surface according to EN 1504-2 Standards;

a long service for such a structure will then be guaranteed.

Galvanic prevention alone, as illustrated previously, will offer tens of years of protection against deterioration due to corrosion, which means the moment the protection is completely consumed, corrosion phenomenon will still not have been initiated.

Going back to the concepts of “initiation phase” and “propagation phase” discussed in the previous section, if the prescriptions defined in the Standards above are strictly adhered to when designing the concrete, it is clear that the service life of a structure will be further increased by a number of years.

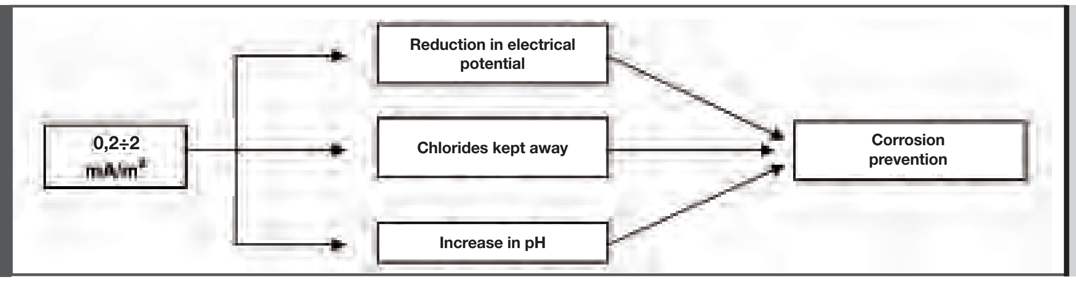


*Figure L*
The effects of prevention on reinforced concrete

## 4| Mapei products for galvanic cathodic protection and prevention

MAPEI has developed a range of products especially for galvanic cathodic protection/ prevention:

**MAPESHIELD I**:
four different types of internal galvanic anodes in various sizes and masses of zinc to guarantee protection for most types of reinforced concrete structures. The very shape of **MAPESHIELD I** gives it a large anodic surface, a characteristic which, together with the special conductive paste, makes the product extremely efficient and long-lasting.
**MAPESHIELD I** anodes ensure that the steel reinforcement is depolarised in compliance with the prescriptions in the EN 12696 European standard "Cathodic protection of steel in concrete".

**MAPESHIELD E 25**:
adhesive zinc plates applied directly on the surface of new and repaired concrete. Apart from its simple application procedure, this type of galvanic anode allows the steel reinforcement to be protected without having to remove the concrete unless necessary. This leads to a considerable saving in time and costs. **MAPESHIELD E 25** ensures that the steel reinforcement is depolarised in compliance with the prescriptions in the EN 12696 European standard "Cathodic protection of steel in concrete".

**MAPESHIELD S**:
a product developed for galvanic cathodic protection of steel structures exposed to atmospheric conditions. This type of anode is also comprised of a thin auto-adhesive zinc plate applied directly on the surface requiring protection. **MAPESHIELD S** conforms to the prescriptions in the UNI 10781 Standard "Requirements of self-adhesive zinc tape, application methods and checking the coating".

The next pages contain the Technical Data Sheets of the products mentioned above.

## 5| MAPESHIELD I Technical Data Sheet

Pure zinc anodes coated with a special conductive paste, for galvanic cathodic protection against corrosion of reinforcement rods in new structures and in structures requiring repair.

### 5.1| Where to use

**MAPESHIELD I** is particularly recommended for protecting reinforcement rods against corrosion in structures requiring repair work and also offers a number of advantages if applied on new reinforced structures for protection against corrosion, especially if they come into contact with aggressive agents.

Application examples
- Piles and abutments on bridges and viaducts
- Floor slabs
- Pre-fabricated reinforced concrete structures
- Front edges of balconies
- Concrete floors (such as car-parks)
- Foundations
- Basins
- Pre-fabricated structures (buffer panels, beams, etc.)

*Photo 3*
**MAPESHIELD I** anodes in their vacuum-packed wrapping

## 5.2| Technical characteristics

**MAPESHIELD I** is composed of a zinc core with a large surface area covered by special conductive paste which keeps the system active over the years.

After connecting **MAPESHIELD I** to the reinforcement rods with metal stays, a difference in electrical potential is created between the steel and the zinc which stops corrosion and impedes its formation, even if the surrounding environment is particularly aggressive due to the presence of chlorides, for example. In fact, when two different metals are connected together in a suitable electrolyte (in this case the concrete), the metal with the most negative potential (the zinc) will corrode, while the metal with the least negative potential (steel reinforcement rods) remains protected against corrosion. Also, the current generated provokes an increase in the pH level which leads to a slow re-alkalisation of the concrete and, if chloride ions are present, pushes them away. The degree of protection depends on the density of the reinforcement in the structure. The number of anodes applied varies according to whether the structure is highly reinforced or with only a small amount of reinforcement, or whether the structure is new or an old structure requiring repair. This calculation must be carried out using the attached graphs which indicate the reinforcement/concrete ratio and the pitch between each anode.

**MAPESHIELD I** is available in 2 different lengths and 4 different masses so the system may be used in most structures. The surface which the anode is capable of protecting depends on its size (the bigger the anode, the larger the area it protects) while the mass, which is proportional to the amount of metal it contains, effects its duration.

**MAPESHIELD I** ensures that the steel reinforcement is depolarised in compliance with the prescriptions in the EN 12696 European Standard “Cathodic protection of steel in concrete”.

## 5.3| Recommendations

- **MAPESHIELD I** may not be applied where there is structural damage to the reinforcement. In such cases, the reinforcement must be integrated or replaced according to calculations carried out by a specialised technician.
- When the use of **MAPESHIELD I** is planned, do not apply **MAPEFER**, **MAPEFER 1K** or any other type of anti-rust protection on the reinforcement rods.
- Do not use epoxy or polyurethane mortar for repair work.
- If repair work is required, we recommend the use of a compensated-shrinkage mortar according to EN 1504-3 Standards with a maximum resistivity of 100 kΩ.

## 5.4| Application procedure

**Structures which require repair**

*Preparation of the substrate*

Prepare the substrate by removing the deteriorated and detached concrete, including from below the reinforcement rods, until a solid, strong substrate with a rough surface is obtained. Any areas previously repaired and which are not perfectly bonded must also be removed. All corrosion and loose particles must be removed from the reinforcement rods to guarantee that there is good contact between the steel and the repair mortar or concrete. The continuity of the reinforcement rods must be checked with an ohmmeter before installing the protection. Resistance up to 1 ohm is acceptable.

***Photo 4***
Application of **MAPESHIELD I** on a structure under repair

*Choice and pitch of the anodes*

Three main factors must be considered when choosing the most suitable anode:

- The shape of the structure;
- The size of the structure;
- Duration of the passivity of the reinforcement rods to be guaranteed under all conditions, including in the presence of chlorides or cracks.

**MAPESHIELD I** is available in 4 different configurations:

- **MAPESHIELD I 10/10**
- **MAPESHIELD I 10/20**
- **MAPESHIELD I 30/10**
- **MAPESHIELD I 30/20**

Where the first number indicates its length (10 and 30 cm) and the second number its duration (10 and 20 years) according to the mass of the anode.

For example, on a heavily-reinforced structure requiring repair (steel/concrete ratio = 0.8-1) with 30 cm long anodes and a service life of 20 years (**MAPESHIELD I 30/20**), according to graph 2 the number of anodes required to protect the surface is 3 per square metre.



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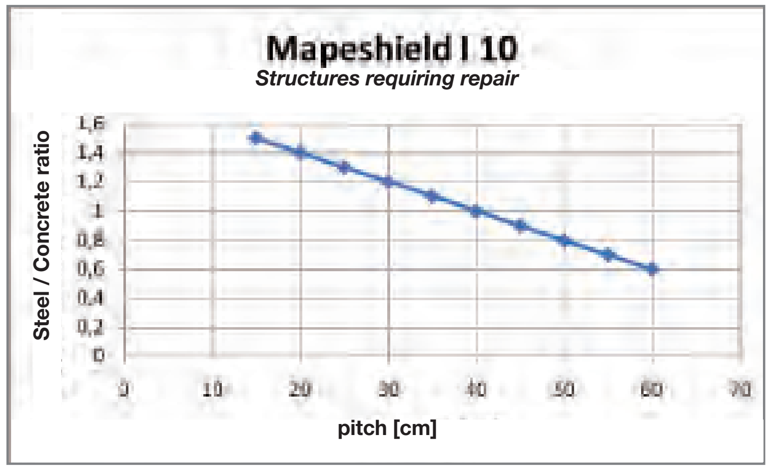
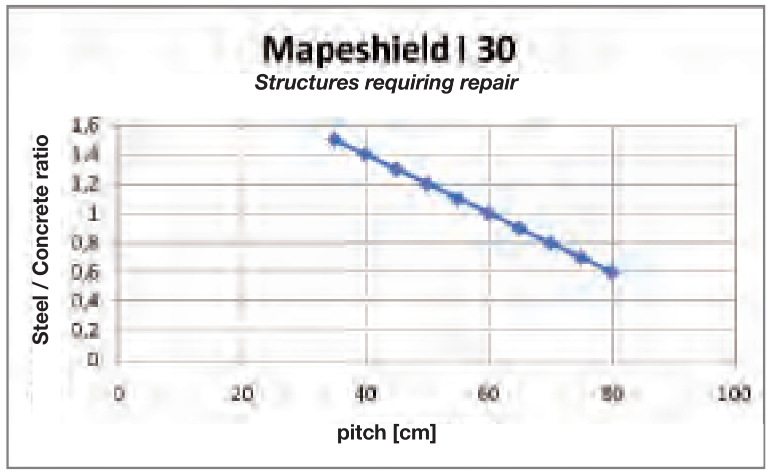
***Graph 1***
Graph to illustrate the pitch of the anodes according to the density of the reinforcement: Repairs using MAPESHIELD I 10




***Graph 2***
Graph to illustrate the pitch of the anodes according to the density of the reinforcement: Repairs using MAPESHIELD I 30




*Application of the anodes*

The anodes must be positioned and fastened firmly in place to the reinforcement rods so that they do not move during repair and casting operations. They must be attached to the reinforcement rods with the metal fasteners on the anodes using the special clips.

Enough space must be left under the anodes to allow the mortar to penetrate when repairs are carried out. This space must never be less than 2-3 times the size of the largest aggregate in the repair mortar. Once installed, the continuity between the anodes and reinforcement rods must be checked with an ohmmeter. Resistance up to 1 ohm is acceptable.

*Application of the repair mortar*

The electrical resistance of the repair mortar must be in a range of between 50% and 200% of the original concrete, and up to a maximum of 100 kΩ according to the prescriptions in the EN 12696 Standards. Mortar from the **MAPEGROUT** and **PLANITOP** ranges comply with the requirements and are therefore recommended for repairing structures protected with galvanic cathodic systems. Carry out repairs following normal application guidelines, according to the product chosen and the indications on the data sheet of the mortar used for the repairs.

When applying the mortar, do not leave any gaps or voids around the anodes.

**New structures**

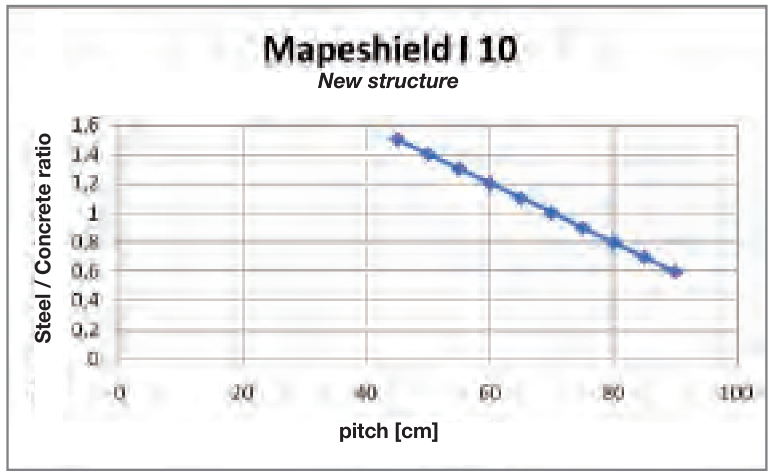
**MAPESHIELD I** may be used on new structures even if they are located in particularly aggressive environments. If the system is placed on the reinforcement rods, complete passivity is guaranteed. Even if the concrete used has been made according to EN 206, UNI 11104 or Eurocodice 2 Standards, cracks may appear over the years due to shrinkage following incorrect curing procedures or the continuous external stresses to which it is subject (vibration, dynamic loads, impact etc.).

Water, oxygen, carbon dioxide and chlorides may then easily penetrate into the cracks and corrode the reinforcement rods. A galvanic cathodic protection system installed correctly on the concrete considerably increases the duration of the structure, by delaying problems caused by unforeseen defects for a number of years. To protect new structures, fewer anodes are required compared with repaired structures and they have a much higher duration.

This is due to the fact that, on new structures, the reinforcement rods are passive and so the current required to keep them protected is minimum. For example, in a new highly-reinforced structure (steel/concrete ratio = 0.8-1) two **MAPESHIELD I 10/20** anodes every square metre (see Graph 3) offer protection against corrosion for approximately 40 years, and when the anodes are completely consumed the reinforcement rods will still be passive.

***Photo 5***
Application of
**MAPESHIELD I**
on a new structure

*Graph 3*
Graph of the pitch between each MAPESHIELD I 10 anode applied on new structures according to the density of the reinforcement




**Functional checks**

In order to check the system, several reference electrodes (in Ag/AgCl for example) must be embedded in the concrete when it is cast or applied in the area protected by the anodes which are to be monitored. The anodes are installed in critical areas and connected to cables with an on/off switch and then connected with the cables from the reference anodes to an external switch box.

The procedure for the functional checks is described in the EN 12696 Standard which states:

- Depolarisation during the 24 hours after switching off of at least 100 mV compared to the potential measured between 0.1 and 1 second after disconnecting the anode (instant off);
- Depolarisation over a longer period (> 24 hours) of at least 150 mV after instant off.

**MAPESHIELD I** complies with the above criteria.

## 5.5| Precautions to be taken during and after application

No special precautions need to be taken if the temperature is between +5°C and +35°C.

## 5.6| MAPESHIELD I: Technical data

*Table 3*

| MAPESHIELD I 10 | U.M. | 10/10 | 10/20 |
|---|---|---|---|
| External surface: | mm | 100 x 55 ± 10% | 100 x 55 ± 10% |
| Height: | mm | 12 ± 10% | 15 ± 10% |
| Weight: | g | 230 ± 10% | 320 ± 10% |
| Storage conditions: | / | Dry, cool area in sealed packaging | Dry, cool area in sealed packaging |
| Storage time: | months | 12 in sealed packaging | 12 in sealed packaging |
| Outside colour: | / | Blue | Blue |
| Packaging: | / | Vacuum-packed | Vacuum-packed |

*Table 4*

| MAPESHIELD I 30 | U.M. | 10/10 | 10/20 |
|---|---|---|---|
| External surface: | mm | 300 x 50 ± 10% | 300 x 50 ± 10% |
| Height: | mm | 10 ± 10% | 12 ± 10% |
| Weight: | g | 450 ± 10% | 570 ± 10% |
| Storage conditions: | / | Dry, cool area in sealed packaging | Dry, cool area in sealed packaging |
| Storage time: | months | 12 in sealed packaging | 12 in sealed packaging |
| Outside colour: | / | Blue | Blue |
| Packaging: | / | Vacuum-packed | Vacuum-packed |



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## 6| MAPESHIELD E 25
## Technical data sheet

Adhesive zinc plates applied directly on the surface of structures for galvanic cathodic protection against the corrosion of reinforcement rods in concrete.

*Photo 6*
Roll of
MAPESHIELD E25


### 6.1| Where to use

**MAPESHIELD E 25** is particularly recommended for protecting reinforcement rods against corrosion in structures which do not require repair work and to reduce or block oxidation in structures requiring repair.

Application examples
- Piles and abutments on bridges and viaducts
- Floor slabs
- Car parks
- Pre-fabricated reinforced concrete structures
- Beams and columns
- Front edges of balconies

### 6.2| Technical characteristics

**MAPESHIELD E 25** is composed of a 250 µm thick plate of 99.9% pure zinc coupled with an adhesive gel which is also an excellent ionic conductor. After connecting **MAPESHIELD E 25** to the reinforcement rods with metal stays, a difference in potential is created between the steel and the zinc which stops corrosion and impedes its formation, even if the surrounding environment is particularly aggressive due to the presence of chlorides, for example. In fact, when two different metals are connected together in a suitable electrolyte (in this case the concrete), the metal with the most negative potential (the zinc) will corrode, while the metal with the least negative potential (steel reinforcement rods) remains protected against corrosion. Also, the current generated provokes an increase in the pH level which leads to a slow re-alkalisation of the concrete and, if chloride ions are present, pushes them away. The degree of protection depends on the density of the reinforcement in the structure. On heavily reinforced structures, **MAPESHIELD E 25** must be applied on all the surface requiring protection. If the density of the reinforcement is low, on the other hand, the distance between the plates may be increased up to a maximum of 50 cm. This calculation may be carried out using the pitch table on page 24.

**MAPESHIELD E 25** ensures that the steel reinforcement is depolarised in compliance with the prescriptions in the EN 12696 European Standard “Cathodic protection of steel in concrete”.

### 6.3| Recommendations

- **MAPESHIELD E 25** may not be applied where there is structural damage to the reinforcement. In such cases, the reinforcement must be integrated or replaced according to calculations carried out by a specialised technician.
- When the use of **MAPESHIELD E 25** is planned, do not apply **MAPEFER**, **MAPEFER 1K** or any other type of anti-rust protection on the reinforcement rods.
- Do not use epoxy or polyurethane mortar for repair work.
- If repair work is required, we recommend the use of a compensated-shrinkage mortar according to EN 1504-3 Standards with a maximum resistivity of 100 kΩ.
- Do not use the product if water percolates inside the structure. In such cases, use **MAPESHIELD I**.

### 6.4| Application procedure

**Preparation of the substrate**

*Structures which require repair*

The substrate must be prepared correctly, by removing the deteriorated and detached concrete, including from below the reinforcement rods, until a solid, strong substrate with a rough surface is obtained. Any areas previously repaired and which are not perfectly bonded must also be removed. All corrosion and loose particles must be removed from the reinforcement rods to guarantee that there is good contact between the steel and the repair material. Once the concrete has been removed, attach pieces of electric cable to the reinforcement rods which will then be connected to the anodes after the repair work has been completed. Each structural element (column, beam, etc.) must have at least one connection. The continuity of the reinforcement rods must be checked with an ohmmeter before installing the protection. Resistance up to 1 ohm is acceptable.

*New structures and structures which do not require repairing*

Remove all dust, rust, cement laitance, grease, oil, old paint and any other contamination from the concrete. Attach pieces of electric cable to the surface of the structure which will then be used to connect the reinforcement rods to the anodes. Remove a small amount of concrete from around the reinforcement rods to connect the pieces of electric cable. Each structural element (column, beam, etc.) must have at least one connection. The continuity of the reinforcement rods must be checked with an ohmmeter before installing the protection. Resistance up to 1 ohm is acceptable.

***Photo 7***
Electric cable previously connected to the reinforcement rods

***Application of the repair mortar***

The electrical resistivity of the repair mortar must be in a range of between 50% and 200% of the original concrete, and up to a maximum of 100 kΩ according to the prescriptions in the EN 12696 Standards. Mortar from the **MAPEGROUT** and **PLANITOP** ranges comply with the requirements and are therefore recommended for repairing structures protected with galvanic cathodic systems. Carry out repairs following normal application guidelines, according to the product chosen and the indications on the data sheet of the mortar used for the repairs.

***Application of the anodes***

Apply **MAPESHIELD E 25** on the surface of the repaired or new structure or the structure which does not require repairing by removing the protective film from the conductive gel. Press the plate onto the substrate so that it forms a perfect bond. Apply the sheet of zinc along the structure. Make sure there are no gaps, which may cause weak spots in the whole system. Press the **MAPESHIELD E 25** firmly onto the surface using a rubber roller or similar instrument to guarantee a good bond. Connect the previously laid electric cables to the anode sheet by welding or with a mechanical fastener. Plates not inter-connected with other plates must have their own direct connection with the reinforcement rods, or a connection must be made between the other plates. If **MAPESHIELD E 25** is applied on the inner face of structures, such as beams or floor slabs for example, use also metal expansion rivets to fasten it to the structure to further guarantee a good bond.

***Photos 8 - 9*** Connecting the electric cable to **MAPESHIELD E25**:

***Photo 8***
by welding
***Photo 9***
with a fastener

***Sealing external plates***

After applying the anode, the exposed ends and joints must be sealed with **MAPEFLEX PU40** or **MAPEFLEX PU45** after treating the edges with **PRIMER M** to avoid the ingress of water between the plate and substrate.

***Smoothing and finishing layer***

Smooth over the plates and even out the substrate with **MAPELASTIC** or **MAPELASTIC SMART** without applying a primer beforehand. The protection system may then be completed by applying a coat of **ELASTOCOLOR PAINT** resin-based paint in water dispersion, available in a wide range of colours using the **ColorMap®** automatic colouring system.

***Photos 10 - 11 - 12***
Smoothing over and protecting **MAPESHIELD E25**:

***Photo 10***
**MAPELASTIC SMART**
applied with a roller
***Photo 11***
**MAPELASTIC SMART**
applied by brush
***Photo 12***
**MAPELASTIC**
applied by trowel

***Functional checks***

In order to check the system, several reference electrodes (in Ag/AgCl for example) must be installed in the area to be protected by the plates. The electric cables used for the connections between the anodes and the reinforcement rods must have an on/off switch and be connected to a switchbox together with the reference anodes.

The procedure for the functional checks is described in the EN 12696 Standard which states:

- Depolarisation during the 24 hours after switching off of at least 100 mV compared to the potential measured between 0.1 and 1 second after disconnecting the anode (instant off);
- Depolarisation over a longer period (> 24 hours) of at least 150 mV after instant off.

**MAPESHIELD E 25** complies with the above criteria.



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## 6.5| Precautions to be taken during and after application

No special precautions need to be taken if the temperature is between + 5°C and + 35°C.

## 6.6| MAPESHIELD E 2 : Technical data and pitch of anodes

*Table 5*

| TECHNICAL DATA (typical values) | |
|---|---|
| **COMPOSITION** | |
| Thickness of zinc plate: | 0,25 mm |
| Thickness of adhesive: | 0,8 mm ± 0,2 |
| Protective liner: | 0,1 mm |
| Total weight (kg/m²): | 3,15 ± 5% |
| **CHARACTERISTICS** | |
| Purity of zinc plate (%): | 99,9 |
| Colour: | metallic grey |
| Longitudinal yield strength (N/mm²): | > 130 |
| Transversal yield strength (N/mm²): | > 150 |
| **ADHESIVE** | |
| Colour: | transparent |
| Minimum application temperature: | +4°C |
| Ideal temperature for application: | > 4°C |
| In-service temperature range: | from -10°C to 60°C |
| Shelf life: | 12 months if stored in a cool, dry area in sealed packaging |

*Table 6*

**TABLE TO DETERMINE THE PITCH OF MAPESHIELD E 25**

| | DURATION (years) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 22 | 20 | 19 | 18 | 17 | 16 | 15 | 14 |
| | PITCH BETWEEN THE PLATES (cm) | | | | | | | |
| 0,1 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| 0,2 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| 0,3 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| 0,4 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| 0,5 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| 0,6 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| 0,7 | 20 | 20 | 50 | 50 | 50 | 50 | 50 | 50 |
| 0,8 | 15 | 15 | 20 | 20 | 20 | 50 | 50 | 50 |
| 0,9 | 10 | 15 | 15 | 15 | 20 | 20 | 20 | 50 |
| 1,0 | 5 | 5 | 10 | 15 | 15 | 15 | 20 | 20 |
| 1,1 | 0 | 5 | 5 | 5 | 10 | 15 | 15 | 15 |
| 1,2 | 0 | 0 | 0 | 5 | 5 | 10 | 10 | 15 |
| 1,3 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 10 |
| 1,4 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 |
| 1,5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| 1,6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1,7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# 7| MAPESHIELD S Technical data sheet

Zinc plate with adhesive backing for galvanic cathodic protection against the corrosion of steel structures exposed to atmospheric conditions.

## 7.1| Where to use

**MAPESHIELD S** is particularly recommended for protecting flat, round and complex shaped metal structures which have a surface to which zinc plates may be directly applied.

Application examples
- Beams
- Columns
- Piles
- Pipe-work
- General metal structures

## 7.2| Technical characteristics

**MAPESHIELD S** is composed of an 80 μm thick plate of 99.9% pure zinc with a 25 μm thick electrically-conductive adhesive backing. The matrix of the adhesive backing includes micro-granules of zinc. This composition makes the adhesive electrically conductive.

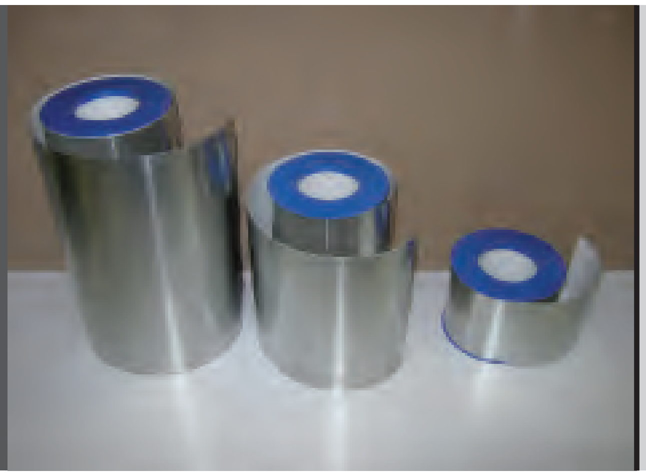

***Photo 13***
From left to right
**MAPESHIELD S 300**
**MAPESHIELD S 200**
**MAPESHIELD S 100**

When **MAPESHIELD S** is applied on a metal structure, it forms an electrical interface between the surface to be protected and the zinc, thus transforming it into a galvanic anode which protects the structure from corrosion, even if the surrounding atmosphere is particularly aggressive. In fact, two different metals connected together in the presence of an electrolyte form a corrosion cell. In such conditions, the metal with the most negative potential (the zinc)



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will corrode, while the metal with least negative potential (iron, steel, etc.) remains protected. The micro-structure of **MAPESHIELD S** is perfectly homogenous and isotropic in all directions. Thanks to these characteristics, oxidation is uniform with no pitting.

**MAPESHIELD S** is available in 50 metre long rolls at a width of 100, 200 or 300 mm. To guarantee protection, the zinc plate must be applied on the entire surface of the structure which requires protection. Once applied, no other operations need to be carried out because contact with the structure is guaranteed by the adhesive. **MAPESHIELD S** conforms to the prescriptions in the UNI 10781 Standard “Requirements of self-adhesive zinc tape, application methods and checking the coating”.

## 7.3| Recommendations

- **MAPESHIELD S** may not be applied where there is structural damage. In such cases, the structure must be checked by a specialist.
- Before applying **MAPESHIELD S** ensure the substrate has been prepared correctly.
- At the moment of applying **MAPESHIELD S**, the surface must be dry and the temperature must be higher than + 3°C.

## 7.4| Application procedure

**Preparation of the substrate**

It is extremely important that metal surfaces are prepared correctly to guarantee that the strip bonds perfectly to the structure to be protected and the best performance is obtained from **MAPESHIELD S**. The substrate must be prepared by removing all loose parts such as rust, old protective layers, etc. Prepare the surfaces with a mechanical brusher, a high-pressure cleaner or by sand-blasting. Remove all dust and fragments with compressed air.

When the product is applied, surfaces must be clean and dry to guarantee that the anode bonds well and that there is perfect contact with the structure to be protected.

**Application of the anodes**

The technique used to apply **MAPESHIELD S** on the surface of external metal structures depends mainly on the structure’s layout (horizontal, vertical or slanted) and shape.

The protective layer on flat surfaces or curved surfaces with a large radius (more than 3 metres) may be applied manually with strips of **MAPESHIELD S**. The strips must be applied by pulling them as tightly as possible with the longitudinal axis of the strips parallel to one of the main axes of the surface. When applying **MAPESHIELD S** on suspended tanks, start from the bottom of the tank using strips which are long enough to cover the bottom and at least 50 of the side of the tank at each end of the strip. Then continue application on the sides followed by the top of the tank. In the case of tanks on vertical or slanted supports, apply the coating by starting at the lowest point to avoid interrupting the flow of rainwater or condensation.

On round structures, such as pipe-work, the product may be applied in a continuous spiral with a special winding machine which guarantees quick, easy application without creases or folds. On round structures where it is not possible to apply the product in a continuous spiral, cut strips of the tape in lengths equal to the circumference of the pipe and apply manually.

Whichever application technique is employed, use the following procedure:

- Gradually strip off the protective backing film from the **MAPESHIELD S** just before the tape comes into contact with the metal surface;
- Welds on the surface must be covered with a strip of **MAPESHIELD S** so as to cover the weld and at least 2 cm each side of the weld before treating the whole of the surface;
- Overlap adjacent strips of **MAPESHIELD S** by at least 20 mm;
- In order to guarantee a perfect bond with the surface press the strips firmly immediately after application with a non-metal pallet knife or a magnetic press. Start from the centre and work towards the edges to remove all air bubbles;
- Take all necessary precautions to avoid damaging the protective coating during application.

## 7.5| Precautions to be taken during and after application

No special precautions need to be taken if the temperature is between +5°C and +35°C.

## 7.6| MAPESHIELD S: Technical data

| TECHNICAL DATA (typical values) | | |
|---|---|---|
| **COMPOSITION** | | |
| | Weight [g/m²] | Thickness [µm] |
| Zinc plate | 560 | 80 |
| Adhesive: | 50 | ≥ 25 |
| Liner: | 90 | 75 |
| **CHARACTERISTICS** | | |
| Bond with stainless steel (N/mm): | ≥ 0,65 | |
| Resistance to slip (hours): | ≥ 8 | |
| Electrical conductivity (Ohm·mm²): | ≤ 10 | |
| Minimum application temperature: | +3 | |
| In-service temperature range (°C): | from -10 to 80 | |
| Maximum temperature for short periods (1-2 hours) (°C): | +100 | |
| Shelf life: | 12 months if stored in a cool, dry area in sealed packaging | |

Notes:

Notes:



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