

**July 2009 Report On:****CHLORIDE AND BRIDGE STRUCTURES**

**Research & Development Department – Prepared by Zhonghe Waterproof Material Co., Ltd., manufacturer of CN2000**

**Abstract:** Chlorides are the "crime culprit" that causes corrosion damage to millions of bridges around the world, and cause major economic losses in all countries worldwide.

While chloride corrosion to the steel rebar is the main form of concrete structural damage, studying the mechanism of deterioration showed that waterproofing and anticorrosive treatments must be carried out on bridge structures to extend their service life. For this, the **CN2000®** series of waterproof materials have excellent waterproof and anti-corrosion properties and will play an important role in the rejuvenation and protection of these structures.

**Key words: Concrete Deterioration - Reinforcing Steel Oxidization – Waterproof – Anticorrosion - Service Life - CN2000 Series Waterproof Materials**

**Introduction**

**Bridges** – The solidification of art, which have distinct images and strong appeal, reflect the characteristics of the times, and records the course of the development of human civilization. Only the strong, solid and durable stability of the bridge building structure can really show their immortal vitality. However, over the past 20 years, on a worldwide scope, bridge damage caused by spreading ice melting salt and the major damages and economic losses resulting from these actions, are truly amazing.

In 1986, a group of experts were formed by Europe, North America, Australia, Japan etc. These 16 countries, conducted a detailed and overall survey as to the status of about 800,000 cement concrete road bridges (length of at least 5 meters) in these countries and transnational, the results showed that the reinforcing steel corrosion and freezing and thawing damage are the two most intrusive forms of damage and this damage becomes more serious with the use of de-icing salt.

If Governments want to repair or update these damaged bridges, the cost can be as high as \$500 - \$900 U.S. per square meter, far higher than the cost of the original structure. This developing trend is not really very optimistic.

According to earlier statistics, among the 575 thousand bridges in the United States, more than half have evident damage; 40 percent of the bridges have insufficient bearing capacity, and must be repaired and reinforced; and bridges with serious damage and that are in a critical state are numbered at about 90,000.

There are on average, several thousand bridges partially or completely damaged each year and their life expectancy is reduced to less than 20 years. In the 1990s, the maintenance costs in the United States for these bridges has been estimated to be as high as 155 billion U.S. dollars, and is four times as much as the cost of construction in those years; Canada is farther north, and the corrosion damage to its infrastructure is especially outstanding due to the use of de-icing salt in large areas. It is reported, that to completely repair North America's infrastructure it will cost more than 500 billion US Dollars.

In England the 11 main viaducts, were discovered to be seriously damaged after only being in use for 12 years. Two years after construction of the Viaducts, corrosion of the reinforcing steel was discovered and it was determined that this was the result of the use of deicing salt during the winter months. This corrosion resulted in serious damage to the structures and after years of repairs, the accumulated maintenance cost has reached as high as 120 million pounds, or 6 times as much as the cost of the original construction.

In Japan, a survey to 177 bridges and 672 housings in the Okinawa region showed that the damage rate of bridge floorings and concrete beams has exceeded 90 percent. In the Arab Gulf and the Red Sea, the Adriatic coast, Norway, Sharp in Australia, Bombay in India, Bangladesh etc. and in the rest of the regions of the world, the damage rate of Reinforced Concrete Bridges is extremely high.

In China, according to 1998 statistics, the disqualification rate of railway bridges was 19.39 percent; at present there are still several thousand "unsafe bridges", and "distress" bridges that are still being used. It is deduced, that the direct losses exceed 100 billion yuan per year as a result of this concrete corrosion. The chloride environment accounts for the major portion of these costs.

The Beijing Xizhimen overpass, due to salt deicing, after only 19 years of use, has revealed concrete cracking, scaling, reinforcing steel corrosion etc. This serious corrosion, due to the structures exposure to chlorides resulted in the demolition and reconstruction of this overpass. In addition, in the Beijing and Tianjin regions, there are many recently constructed overpasses, though relatively new, it is noted that there is serious corrosion damage to the reinforced steel due to the exposure of the structures to chlorides.

Many reinforced concrete bridges on the expressway in Shandong China, which mostly lies in the coastal or saline-alkali soil areas, although only put into use only about 10 years ago, are already showing serious damage. The damaged parts of these bridges are: the piers, girders, beams, flooring and railings, however, the most extensive damage is to the edge beams. The damage, for the most part has resulted in the concrete protective layer cracking and spalling and the corrosion of the reinforced

steel.

Within the attainability of salt damage, besides the bridges, there are still the ocean and coastal concrete structures, sea sand housings, salt lake, saline-alkali soil, and industrial salt environment.

It is confirmed by studies, the deicing salt environment is a far worse chloride environment than the sea.

We must make it clear that the occurrence of a single form of corrosion is rare. Apart from the deterioration damage and destruction caused by salt damage to the abovementioned concrete structures, there are still the effects of carbonization, corrosion, sulfate corrosion, dry and wet, freeze-thaw cycle, alkali aggregate reaction, microbial biochemical reactions as well as stress loading and water flowing etc. Integrated deterioration factors are to a considerable degree, the durability disease syndrome, which is considered the hot spot, in the current international concrete research fields.

In that the steel bar corrosion rate caused by the chlorine ion, is by far faster than the concrete carbonization, and in extreme circumstances, the steel bar corrosion rate caused by the chlorine ion in actual structure can reach 5 mm/annually, and the steel bar corrosion rate caused by carbonization is only 0.05 mm/annually, therefore, this article will focus on stating that one of the important factors that impact the concrete durability – is the corrosion problem of chloride on the reinforced concrete structures and the prevention and control measures that are necessary.

## **2. Mechanism**

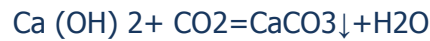
### **2.1 Damage to the concrete layer**

#### **2.1.1 Speed up the corrosion of $\text{Ca(OH)}_2$ in cement paste**

Concrete is a multiphase multi-component and porous system, its interfacial tension is larger than water, so it has hydrophilic Chloride in its environment and uses water as a transmission medium to infiltrate the concrete through the pores or cracks of the concrete. First, the water will have corrosion on cement paste that is the dissolution corrosion. In the process of cement paste hydration produces  $\text{Ca(OH)}_2$ , to the common silicon cement; its content can be as high as 10 to 15 percent.

Because of its lower solubility in water (is 0.165 g per 100g water in 20°C), it is therefore partly in a solid-phase crystallization state that exists in the cement paste, and part of the water dissolved in the cement paste, is in a saturated solution state: When infiltrated by water (moisture, water vapor),  $\text{Ca(OH)}_2$  will be diluted and/or dissolved, the solid, liquid phase balance relationship of  $\text{Ca(OH)}_2$  in the cement paste is destroyed, by fusing, and initiates the hydration and hydrolysis reaction in the cement paste; the constant dissolution of  $\text{Ca(OH)}_2$  made material is lost within the

cement structure, the Ca (OH)<sub>2</sub> concentration in the cement paste liquid phase drops constantly, which makes calcium silicate hydrate (CSH) and calcium aluminate hydrate which can stably exist only in a certain concentration of Ca (OH)<sub>2</sub> liquid phase and are constantly hydrolyzed and separated out, lead strength of concrete structures are lowered constantly, and lose the complete cementation performance in certain periods and sustain destruction. The Ca (OH)<sub>2</sub> digested reacts with CO<sub>2</sub> in the environment, produces calcium carbonate sediment:



This is the reason for the white precipitate on the surface of concrete.

From the above corrosion process we can see, that all concrete structures which have contact with water or that are in damp environments, such as hydraulic architectures (reservoirs, river dams), bridges, water storage tanks, water pipes, seepage (steam) channels, (cooling towers, chimneys) etc. These are all possible examples of such corrosion. The typical example is: the original Beijing Xizhimen overpass which had been demolished and reconstructed, on the lower part of the bridge floorings and joints, was noted the widespread existence of large areas of white exudates, which was determined through analysis, to be the products of corrosion.

The existence of Cl<sup>-</sup> etc. will greatly increase the solubility of Ca (OH)<sub>2</sub> in concrete, thus accelerating the corrosion of Ca (OH)<sub>2</sub>; and the dissolution of calcium made the surface of cement paste porous and loose, and enhanced the penetration and proliferation of the ion into the internal structure, which decreased the alkalinity of the cement paste and the reinforced steel bar lost its protection.

### **2.1.2** Crystallization expansion destruction

The infiltrated chloride will react very easily with the tricalcium aluminate (C3A) in the cement, and this produces the hydrous calcium aluminate chloride (3CaO·Al<sub>2</sub>O<sub>3</sub>·CaCl<sub>2</sub>·10H<sub>2</sub>O and 3CaO·Al<sub>2</sub>O<sub>3</sub>·CaCl<sub>2</sub>·3H<sub>2</sub>O), producing crystallization expansion, which destroys concrete structures.

### **2.1.3** Cl<sup>-</sup> free due to carbonization

Once concrete achieves "neutralization", that is when the concentration of CO<sub>3</sub><sup>2-</sup> is higher, this produces 3CaO·Al<sub>2</sub>O<sub>3</sub>·CaCO<sub>3</sub>·12H<sub>2</sub>O in priority and stability, therefore the Cl<sup>-</sup> in these complex salts, free up, and corrosion destroy the steel bars.

### **2.1.4** Other

Chloride permeating into the concrete can greatly accelerate its freeze-thaw destruction; when the environment temperature fluctuates around 0 °C, the hydrous chloride salt crystallization is infiltrated into the concrete which then produces a volume expansion of 130 percent, thus producing expansive destruction.

The potassium and sodium ions in chloride enter into the concrete, and initiates "alkali aggregate reaction"; the  $Mg^{2+}$  and  $NH_4^+$  ions in magnesium chloride and ammonium chloride; can replace the calcium in the cement hydrated products and will produce soluble or loose material and this will result in the concrete losing its strength and integrity.

## 2.2 Corrosion to steel bar

### 2.2.1 The protective function of concrete to steel bar

**a.** Physical protection: concrete covering and wrapping the steel reinforcing bar and isolates the steel from the outside environment. This provides the first protective shield for the steel bar, but because of the permeability of concrete on its own and its thickness limitations, it can only maintain the steel in the protected state for a short period of time.

**b.** Chemical Protection: Because of the cement hydration produces a great deal of  $Ca(OH)_2 \cdot 3CaO \cdot 2SiO_2 \cdot CaCO_3 \cdot 3H_2O$  and  $CaO \cdot Al_2O_3 \cdot 6H_2O$  etc. alkaline hydrates, as well as a small amount of  $K_2O$  and  $Na_2O$  in the cement, makes the cement paste high in alkalinity, its pH value can be as high as 12.5 to 13.5, in this environment, on the steel bar surface there is produced about 20 to 60 Å a compact and stable passive film composed by water oxides  $\square-Fe_2O_3 \cdot nH_2O$  or  $Fe_2O_3 \cdot nH_2O$ , which therefore effectively protects the steel bar and resists corrosion. The latest research shows that there still exists the Si-O bonds in the passive film, which is solid and compact and it also has a strong protective function.

However, it must be pointed out, that such protection can only be effective under certain conditions and for a certain period of time, and that this protection is limited. Once the concrete protective layer has deteriorated due to environmental factors, it will result in the decline of its alkalinity and the steel reinforcing bars will lose their protection.

Research indicates that when  $pH > 11.5$ , steel bars are in a completely passive state, or when the  $pH < 9.88$ , of the oxide film on the surface of steel bars has become unstable, and no longer has the protective effect, this will initiate the steel bar corrosion. In addition, as far as the chlorine ion is concerned, even in the high alkalinity, the chlorine ion has an extraordinary destructive capability to the passive film on the surface of the steel bars. Therefore, in the high chloride (salt) circumstances, the protective effect of concrete is further limited.

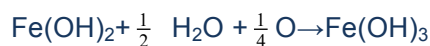
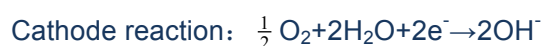
### 2.2.2 Steel bars corrosion mechanism and influence factors

**a.** electrochemical reaction— micro-battery effect:

The basic condition for generating micro-battery in the concrete is the existence of water, oxygen, electrolyte and two poles. Water (or Humidity) infiltrates from outside

and various harmful gases and salts dissolved in the water produce electrolytes. The formation of two poles is due to the different components in the steel bars or the different stress states and the incomplete oxide film on the surface of the steel bars or the same reinforced concrete structures is in different mediums. Thus, the various free ions in the water migrates due to the potential difference between the two poles, and they gain and lose electrons to the two poles respectively (stolen electrons) the electrons are transported by steel bar itself or by water.

The reaction of the corrosion battery is:



Ordinarily, the hydrate process of cement produces a great deal of calcium hydroxide, and makes the pores of concrete fill with a calcium hydroxide solution, the PH of the concrete can reach 12 to 13.5 and this kind of alkali medium has an excellent protective effect by producing an insoluble iron oxide passive film on the surface of the steel bars. But, as said above, when the acidic gases in the air, water as well as some ions diffuse (permeate) into the concrete, and react with these basic materials they produce salts and water, this kind of carbonization (or neutralization) action and makes the alkalinity of the concrete weaker and the quantity of hydrogen ion increases. When the concrete reaches a PH <11.5, the passive film of steel bars becomes unstable, and begins to gradually corrode. The aforesaid corrosion products are generally called "rust or oxidization" and this produces a volume expansion of 2 to 6 times.

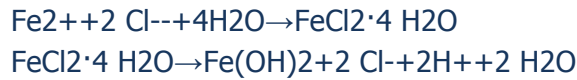
The action of rust and oxidization causes inner stress and micro-cracks of the substrate in the structure as a result of the concrete expansion. Water, harmful gases and aerosols intrude through these micro-cracks and further aggravate the corrosion process of the concrete and steel reinforcing bars.

The destructive effect of chlorine ion:

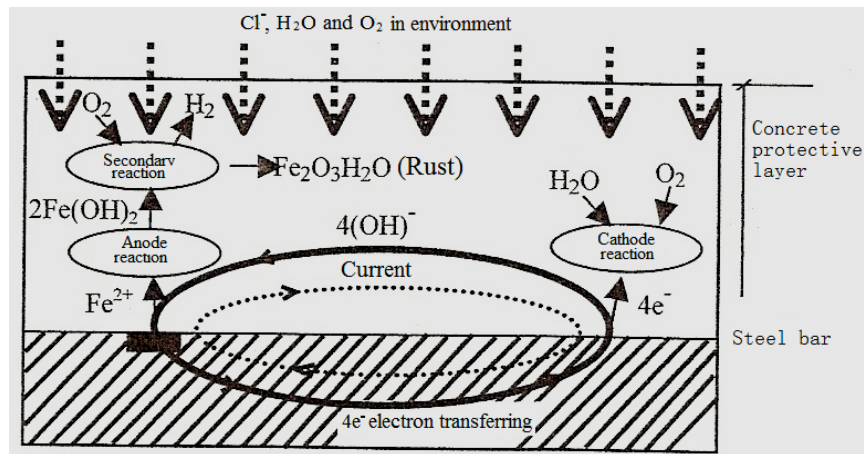
The infiltration of the chlorine ion generates an important effect on the corrosion of steel bars. Cl<sup>-</sup> has a small radius and great activity, it has a very strong penetration capability, and will infiltrate into the concrete. It reaches the surface of the steel bars, and is absorbed on the passive film. This makes the PH value drop quickly to below 4, resulting in partial passive damage. Then, because of the destructiveness of Cl<sup>-</sup> to the passive film, this makes the iron matrix (small anode) exposed on parts of the steel bars to form potential differences between the undestroyed passive film (big cathode),

and initiates a pitting corrosion very rapidly. The depth of pitting corrosion is about 10 times as much as the average corrosion depth, and is even more harmful than a uniform corrosion; Cl<sup>-</sup> encounters with the Fe<sup>2+</sup> generated FeCl<sub>2</sub> has accelerated the removal Fe<sup>2+</sup>, thus speeding up the process of the anode. In addition, due to the conductivity of Cl<sup>-</sup>, this has made the resistance between the cathode and anode drop.

The corrosion battery efficiency improves and the, electrochemical corrosion process speeds up. The reactions are as follows:



It is thus clear, that chlorine ion only takes the initiate, activate or "transporting" effects on the corrosion of the steel bars, and does not participate in or change the composition of corrosion products, and its content does not lower with the process of the corrosion reaction, thus its destructive capabilities are greater. See the following drawing.



**Figure 1 steel bars electrochemical corrosion diagram**

**2.2.3** Damage characteristics of steel bars corrosion

**a.** Concrete cracking

Concrete has excellent compression resistant performance, but its bending resistance and cracking resistance are poor. The corrosion product—rust generates 2 to 6 times volume expansion and this is sufficient to make the micro-cracks in the concrete develop into cracks. Because of this, the steel corrosion rate will be increased greatly.

**b.** Bonding performance degradation

Because of the structure of the corrosion products are loose, it forms an isolation layer between the steel bars and the concrete and decreases the bonding effect between the steel bars and the concrete. When the steel bars corrode to a certain extent, they lead to the concrete cracking. The bonding performance between the steel bars and the concrete drops, and the grip of concrete to the steel bars is weakened substantially.

The bonding force between the two, from decline to loss, from all the parts to the whole structure results in the entire component losing its integrity over time.

#### **c. Steel bars fracture**

Due to the combined effect of pitting corrosion, surface corrosion, stress corrosion, hydrogen brittleness and other corrosions, the bending strength, shear strength, yield strength and ultimate strength of steel bars within the structure is gradually decreased until the carrying capacity is lost and the components fracture. This results in the loss of the structural integrity and usefulness of the structure.

### **2.3 Brief summary**

From the above we can see that the existence of Cl<sup>-</sup> causes the deterioration of concrete and corrosion of steel bars, and this process must have the infiltration of dissolved oxygen in the containing water. Water as the transmission medium of Cl<sup>-</sup> and oxygen, are indispensable, and a necessary condition. Cl<sup>-</sup> destroys the concrete layer and the steel bars oxide film induce and activate steel bar corrosion. Oxygen promotes cathode reaction, which decides the corrosion rate. In addition, the aforesaid process is neither the single effect of Cl<sup>-</sup>, nor the simple superposition of effects of other factors. But it is the complicated comprehensive effects of multi environmental factors, and these factors existing together, interdependent, and promoting each other, eventually lead to the overall damage and destruction of the concrete structures.

## **3. Control Measures**

### **3.1 Methods**

#### **3.1.1 Overview**

Since the 1960s, institutions have made unremitting efforts to prevent concrete structures from corrosion damage by chlorides, and developed in succession, modified concrete formulas, concrete protective layers, and the application of epoxy coatings to the steel bars, rust prevention agents, waterproofing materials, and other new anti-corrosion technologies.

From the above mechanism analysis it is not difficult to see, that Cl<sup>-</sup> as one of the main factors that cause the concrete structure to produce corrosion damage. It is the same as all the other physical, chemical and biological corrosion damage factors in the environment. Water as a transmission and reaction medium, is indispensable and prerequisite condition; waterproof and anti-corrosion are inseparable.

To this, the world renowned concrete expert Mr. Mehta had an incisive exposition: "From a long-term point of view, the penetrability or water permeability is the sole feature that directly related to the concrete durability. A large number of facts have proven that if the concrete structure is completely impenetrable or completely water impermeable, then those diseases, including steel bar corrosion, alkali aggregate



reaction and the freeze-thaw damage will utterly, not happen."

Take this as a starting point, if by setting up a protective layer on the concrete surface, makes up for the porous structure shortcomings of the concrete, isolates it from the outside environment, and effectively blocks the infiltration of water and harmful media. It should be an effective, feasible and fundamental measure for controlling concrete structures from deterioration, and will increase a structure's durability.

Considered comprehensively from terms of cost effectiveness, research and the development status, as well as the negative effects and other various factors, experts and insiders agree to this statement unanimously.

The surface protection of concrete can generally be divided into five categories: penetrant, sealant, organic coating, coating isolation layer, and cement-based covering. It is worth indicating, that "cement-based infiltration crystalline waterproof material" of cement-based covering category by its excellent waterproof and anti-corrosion properties and environmental indexes had received positive feedback from all sources.

In 2001, with the publishing of the Chinese National Standards GB18445, which was developed with the participation of a number of well-known North American, Asian and European companies, and with the support of the other three Chinese National Standards, the "cement-based infiltration crystalline waterproof material" product has become the one, waterproof material that has the most promising future at present.

### **3.1.2 The anticorrosive properties of CN2000B (Cementitious Capillary Crystalline Waterproofing - CCCW)**

The top 10 waterproof properties of **CN2000B** of which details are described in another article. As mentioned above, this coating layer has excellent waterproof properties and forms a solid barrier over concrete. Water and its harmful media are inaccessible to the concrete foundation, so the corrosion damage will not occur. However, how about the corrosion resistance property of the coating layer itself? The following will focus on this discussion.

#### **a. Structure and composition**

Different from many other infiltration crystalline waterproof materials in domestic markets and those abroad, the **CN2000B** that has been researched and developed by ourselves has independent intellectual property rights with its unique composition and structure and is a material coating layer with prominent and unrivaled anti-corrosion properties.

- Coatings have hydrophobic properties. The special constituents of a coating can drop the liquid surface tension or surface free energy on the liquid-solid interface, made it difficult for liquid to infiltrate a solid surface, manifesting a "water repellent" effect.

- The special constituents of a coating, after hydration and infiltration crystallization action, make it form into a dense, solid and stable waterproof layer. Water and Cl-, SO42- that take water as transmission to the reaction medium, cannot enter.
- Free, corrodible materials and corrosion susceptible constituents in the material are reduced substantially;
- There is SO42- in the molecular structure of the hydration products of **CN2000B**, and it has ability to resist the erosion of sulfate;
- Can form crystal with Cl-, and in the complex salt that cause swelling damage, has been solidified priority by the special added other more stable ion, Cl- do not have the replacing ability and generating environmental conditions.

**b. Test results**

Using sample blocks that coating **CN2000B** on their surface and made water absorption rate, diluted hydrochloric acid, chloride and sulfate resistance test respectively, and compared with the blank sample.

The test results are on the table below.

**Table 1: Collection of CN2000®B corrosion resistance testing results**

| Items   | Results   |                                 |   |
|---|---|---------------------------------|---|
| Water absorption rate<br>/ % depth of<br>infiltration               | <b>Blank</b>  | Infiltration 30 to 35mm for15   |   |
|   | <b>Coating</b>  | Infiltration 0.2 mm for 1.03    |   |
| 5%NaCl solution<br>soaking test (20□60d)                            | <b>Appearance</b>                                       | <b>Water</b>                    | No spalling, no cracking and no atomizing |
|   |   | <b>Solution</b>                 | No spalling, no cracking and no atomizing |
|   | <b>Corrosion<br/>resistance<br/>coefficient<br/>/ %</b> | <b>Compression<br/>strength</b> | 1.12                                      |
|   |   | <b>Bending<br/>strength</b>     | 1.03                                      |
| 10%NaCl solution<br>soaking test (40□60d)                           | <b>Appearance</b>                                       | <b>Water</b>                    | No spalling, no cracking and no atomizing |
|   |   | <b>Solution</b>                 | No spalling, no cracking and no atomizing |
|   | <b>Corrosion<br/>resistance<br/>coefficient<br/>/ %</b> | <b>Compression<br/>strength</b> | 1.13                                      |
| <b>Bending<br/>strength</b>   |   | 1.02                            |   |
| 5%Na <sub>2</sub> SO <sub>4</sub> solution<br>soaking test (20□60d) | <b>Appearance</b>                                       | <b>Water</b>                    | No spalling, no cracking and no atomizing |
|   |   | <b>Solution</b>                 | No spalling, no cracking and no atomizing |

|   |                                      |                         |   |
|---|--------------------------------------|-------------------------|---|
|   | Corrosion resistance coefficient / % | Compression strength    | 1.14  |
|   |                                      | Bending strength        | 1.08  |
|   |                                      | Impermeability strength | 1.07  |
| 5% MgSO <sub>4</sub> solution soaking test (20□60d) | Appearance                           | Water                   | No spalling, no cracking and no atomizing   |
|   |                                      | Solution                | No spalling, no cracking and no atomizing   |
|   | Corrosion resistance coefficient / % | Compression strength    | 1.01  |
|   |                                      | Bending strength        | 0.99  |
|   |                                      | Impermeability strength | 0.93  |
| Diluted hydrochloric acid soaking test              | PH=1                                 | Rigid material          | Was corrode about 0.5mm in its surface, no cracking, scaling, spalling and atomizing  |
|   |                                      | Flexible material       | Surface corrosion can be neglected, no cracking, scaling, spalling and atomizing      |
|   | PH=2                                 | Rigid material          | There is a little tiny pitting on the surface, but no scaling, bubbling               |
|   |                                      | Flexible material       | There is very little small corroding pitting on the surface, but no scaling, bubbling |

From the above results we can see:

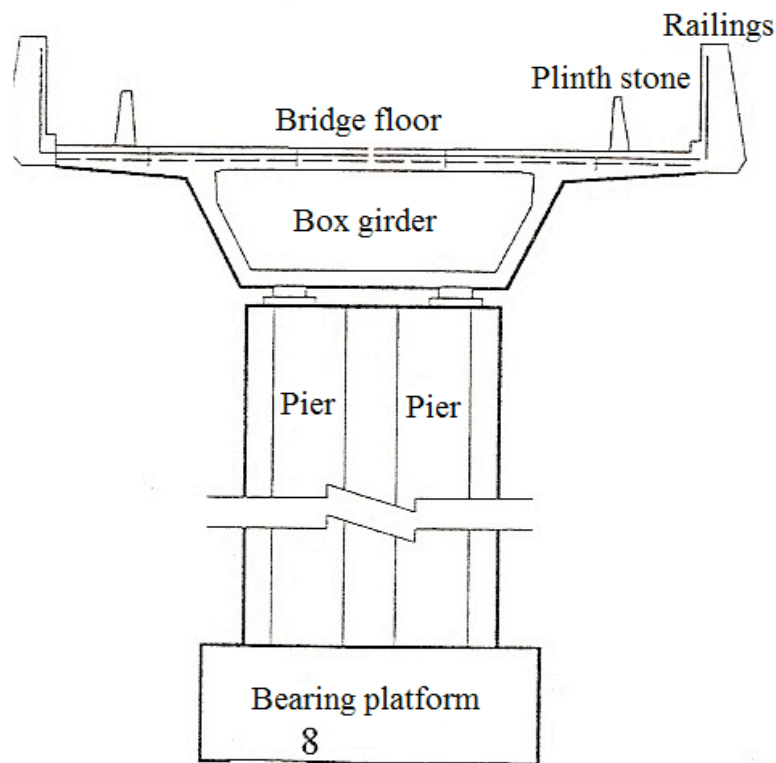
- For rigid material (**CN2000B**) in the acid medium of pH value from 2 to 2.5, can be used for a short term, but should be avoided in long term contacts. It is safe and reliable for the acid medium of pH value  $\geq 3$ ; the acid resistance ability of flexible material (**CN2000C + CN2000D**) is better than the rigid material, it is safe for the acid medium of pH value  $\geq 2$ ; expressing according to results of previous alkali resistant test and the acid resistant test this time, it is safe for rigid material used in the environment of PH value is 3 to 12 and flexible material used in PH value 2 to 12.
- For **CN2000B** waterproof material testing pieces, under the conditions of in 20°C 5% NaCl solution, 5% Na<sub>2</sub>SO<sub>4</sub> solution and 5% MgSO<sub>4</sub> solution, as well as in the strengthen condition of 40°C 10% NaCl solution, after eroding for two months, the surfaces coating are intact, there are no damage observed.
- **CN2000B** waterproof material testing pieces under the aforesaid conditions (4.1), after eroding for two months its corrosion resistance coefficient **K<sub>bend</sub>**, **K<sub>pressure</sub>** and **K<sub>permeability</sub>** are larger than or close to 1, indicating the material has good anti - sulfate, chloride and the magnesium salt corrosion properties.
- The durability of the concrete structure is closely related to the permeability of

concrete material itself, and particularly related to the permeability of the surface. After coating with the **CN2000B** infiltrated crystalline waterproof material, the concrete has a lower water absorbency and compact surface, and this greatly prevents the intrusion of water and corrosion media. This has blocked the root cause of the reinforced concrete corrosion and deterioration, and greatly enhances the durability of concrete. Therefore, **CN2000B** infiltrated crystalline waterproof material should be a first choice of material for reinforced concrete structure protective coatings.

**3.2 Waterproofing positions**

Bridge structures, dependant on its components, lie in the atmosphere, underwater and underground and are exposed to different environments respectively. For this, the erosion factors and degrees of damage it receives are varied, but all suffer a certain degree of environmental, physical, chemical and biological erosion damage. Accordingly the structures different components, corrosion and anti-corrosion measures are briefly described below.

For the diagram of bridge structure see figure 2.



**Figure 2: Diagram of reinforced concrete bridge diseases**

**3.2.1 Bridge floor.**

The waterproof coating layer of a bridges concrete road-bed structure is very important for the designed life of the bridge. It is clearly stipulated in the "Technical specification for bridge floor waterproofing engineering" of Beijing city local standards

(which Zhonghe assisted in compiling) the bridge floor components require several waterproofing treatments and, and one of the waterproof materials, "cement-based infiltrated crystalline waterproof material" is prominently required. See figure 3 for bridge floor waterproofing.

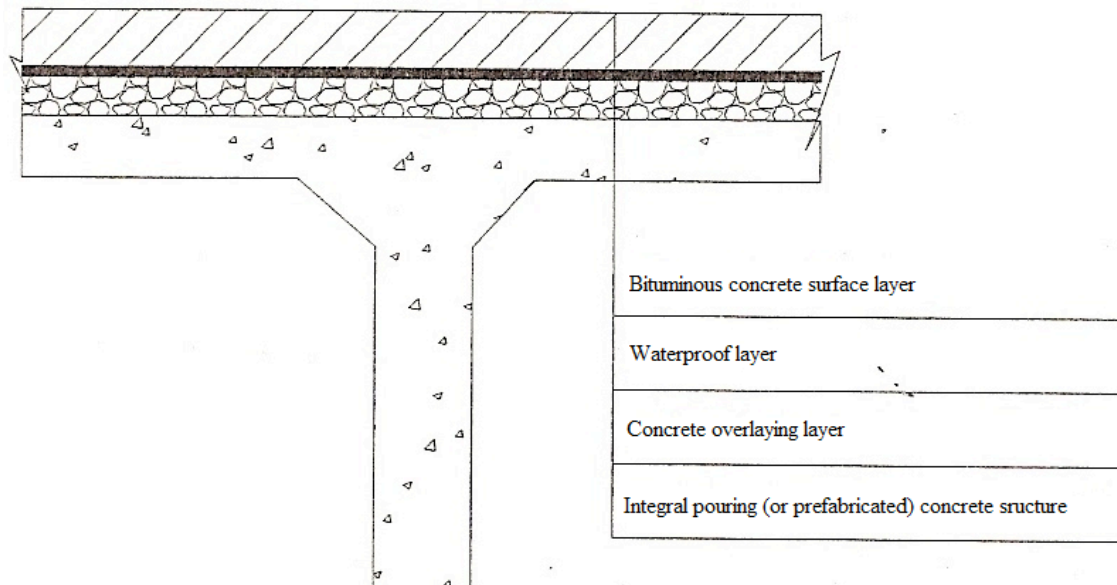
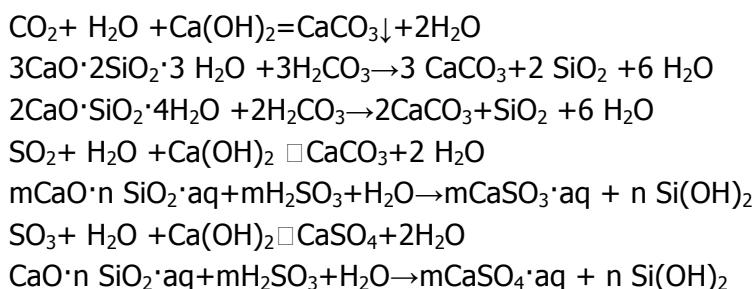


Figure 3: Diagram of bituminous reinforced concrete bridge floor waterproofing layer

**3.2.2** Railings, plinth stone, girders, support, as well as the components of the pier above the water surface.

The reinforced concrete structure in these components of the bridge, that are exposed to the atmosphere perennially; in addition to temperature, wet and dry, freezing and thawing physically damages the structures, and they are also highly susceptible to erosion by the CO<sub>2</sub> in the atmosphere and other pollutants such as SO<sub>2</sub>, SO<sub>3</sub>, acid rain, and cause "carbonization" in the concrete layer. The so-called concrete carbonization, is when there is the existence of water, after the CO<sub>2</sub> and acidic gases dissolved in the water or dispersed in the aqueous phase producing an aerosol will react with the Ca(OH)<sub>2</sub> or unhydrated C<sub>3</sub>S and C<sub>2</sub>S in cement paste and the basic reactions are as follows:



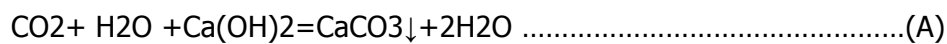
Clearly, the above reaction destroys the structure of the cement paste and decreases

the alkalinity of the cement paste, making the steel bars lose their protection and promotes the oxidization of the steel bars. Therefore, a coating of **CN2000B** in these components, can effectively prevent the intrusion of water and CO<sub>2</sub> etc., and prevent the deterioration of concrete caused by freeze-thaw and carbonation effects.

### 3.2.3 Pier

Parts of pier above the water surface which lie in the atmosphere environment are vulnerable to carbonation, the reaction agent; its mechanism is same as the aforesaid.

The soaking parts of pier will be subjected to the erosion of water, especially when the water quality is soft:



While CaCO<sub>3</sub> meet with CO<sub>2</sub> and H<sub>2</sub>O will produce the following reversible reaction:  
 $\text{CaCO}_3 + 2 \text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{Ca}(\text{HCO}_3)_2 \dots\dots\dots (\text{B})$

When the reaction (B) reaches balance, the amount of CaCO<sub>3</sub>, CO<sub>2</sub> and Ca (HCO<sub>3</sub>)<sub>2</sub> dissolved in water remaining unchanged. If the content of Ca(HCO<sub>3</sub>)<sub>2</sub> in water is too small, that is the water is on the soft side, the balance is destroyed, the reaction (B) going on toward the right, thus consumed CaCO<sub>3</sub>, made the reaction (A) going on continually, consuming the CO<sub>2</sub> dissolved in water constantly, and the alkali in the cement paste dissolution constantly, and the structure was destroyed.

It is needed to point out specially, the pier position in the interface of water and air that is the "water level changing area" or "waves splashing zone", due to suffering the erosion damage of above ground (atmosphere), underwater (complete soaking area) environment concurrently, makes this position, the position of the pier that has suffered the most serious corrosion damage. The wet and dry cycle and freeze-thaw cycle physical damages are particularly notable in this position, and that, due to the concrete in this position is relatively "oxygen-rich", so promoting the oxidization of the steel bars.

The excellent waterproof property of **CN2000B** will effectively resist the corrosion damage to the pier produced by the harsh environment where the piers lie.

### 3.2.4 Pier foundation

Bridge pier foundations go deep into the soil and rock layer, forming the external environment of the foundation (is known as the underground area or soil area). Due to the gas phase in the soil and the underground water, all containing CO<sub>2</sub>, causes the concrete pier foundation to produce the same carbonization as the concrete structures in the air, and causes the concrete layer deterioration (see the rear part); secondly, in the salt lake or high salinity soil zone, due to high salt content underground, this

produces serious corrosion to the pier foundations, including sulfate and chloride corrosion. The corrosion of sulfate causes the structure to produce expansion, loosing or decomposition and other various damages, to this, is expounded in another special topic. In addition, the sulfate-reducing bacteria and various microbes in soil will generate organic acids or inorganic acid due to biochemical action, and produce corrosion to pile foundation.

**CN2000B** is a superior waterproofing product, used in providing an anti-corrosive waterproof treatment to the 4400 pile heads of the main foundation of the Chinese National Aquatics center in Beijing "The Water Cube" and other major infrastructure assets in Asia and Canada. This shows the successful application of the **CN2000** line of products in a project that is recognized worldwide.

## **CN2000® a Revolutionary Concrete Solution**

**Exclusively Provided by**



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