# CN2000®

## Durability of Marine and Coastal Concrete Construction

Dubai is a place of dreams built in concrete. Tourists from around the world are attracted by the Burj Al Arab, a 7 Star Hotel, and many other world class attractions.

2 Palm islands recently built from rock from the desert and sand from the seabed have increased Dubai's coastline by 820 kilometers. A group of Islands shaped as a map of the word is near completion and a third Palm Island, larger than the first 2 combined is now under construction in Dubai's sea.

Many new luxury homes, resorts and hotels will be built on these artificial islands over the next decade. As well as these surface structures, there will be many structures built, that will be immersed in the sea. Boat docks, sea walls, piers and even bridges with pylons driven deep into the sea bed, all these structures and the required infrastructures will be primarily constructed from concrete.

The world's oceans and seas bring many resources and benefits to mankind; however there is a price to pay in durability of structures that are in close proximity to this environment.

Dubai's environment consists of very high summertime temperatures (April to October 40- 45 degrees centigrade) combined with a relative humidity of 90%. As well, sea breezes and the soil are very high in salinity.

The combination of heat, humidity, high salinity, tidal and wave erosion, impact damage from floating objects, halobios, sea life and sea bed bacteria have had serious negative effects on concrete construction in this part of the world.

Experts in engineering and construction as well as owners and investors of these mega-projects are seriously concerned about concrete's durability in this type of environment.

To this, the manufacturer of **CN2000®** Concrete Waterproof Material provides the following discussion:

# 1 The Mechanism of Corrosion Destruction

## 1.1 Sulphates Erosion

There are high concentrations of sulphates contained in seawater. The following reactions are generated when concrete structures, especially in the foundation piles immersed in seawater come into contact with the dissolved sulphates:

(1) If the actions are $Na^+$ and $K^+$, when they react with concrete stone, ettringite (AFt) will be produced.

$$Na_2SO_4 \cdot 10H_2O + Ca(OH)_2 = CaSO_4 \cdot 2H_2O + 2NaOH + 8H_2O$$

$$4CaO \cdot Al_2O_3 \cdot 12H_2O + 3(CaSO_4 \cdot 2H_2O) + 14H_2O = 3CaO \cdot Al_2O_3 \cdot CaSO_4 \cdot 31H_2O + Ca(OH)_2$$

The volume of product AFt is 1.5 times larger than the volume of substances before the reaction. This forms great internal stresses within the concrete structure resulting in the expansion and contraction of the concrete, and over time, the structures strength will be lost. This can be considered a kind of chronic and stubborn disease to concrete.

(2) If the action is $Mg^{+2}$, the reaction is

$$Ca(OH)_2 + MgSO_4 + 2H_2O = CaSO_4 \cdot 2H_2O + Mg(OH)_2$$

The solubility of $Mg(OH)_2$ in water is very low, the pH value of its saturated solution is only 10.5. In such acid-base value, C-S-H gelatin takes on an unstable state.

Moreover, the valence states of $Mg^{+2}$ and $Ca^{+2}$ are same and the radii of them are almost equal each other, so it is very easy for the following reaction to happen

$$C\text{-}S\text{-}H + MgSO_4 + H_2O \rightarrow CaSO_4 + Mg(OH)_2 + mSiO_2 \cdot nH_2O$$

The produced $Mg(OH)_2$ goes on to react with silica gel and forms hydrated magnesium silicate M-S-H

$$Mg(OH)_2 + mSiO_2 \cdot nH_2O \rightarrow M\text{-}S\text{-}H + H_2O$$

Moreover, M-S-H has no adhesion, and will result in loss of concrete strength.

### 1.1a: Carbon-Sulfur-Silicon-Calcium-Stone Type Erosion

Experts didn't pay much attention to this kind of erosion for many years. When calcium ion, silicate, carbonate and water exist at the same time in concrete structures and the invading sulfate can react with them, they will produce a carbon-sulfur-silicon-calcium-stone.

$$Ca_3Si_2O_3 \cdot 3H_2O + 2CaSO_4 \cdot 2H_2O + 2CaCO_3 + 24H_2O \rightarrow$$

$$Ca_6[Si(OH)_6]_2 \cdot 24H_2O \cdot [(SO_4)_2 \cdot (CO_3)_2] + Ca(OH)_2$$

The produced $Ca(OH)_2$ will change to $CaCO_3$ through a carbonizing reaction; and the new $CaCO_3$ will participate in the above reacting process and keep it ongoing again and again. Therefore, carbon-sulfur-silicon-calcium-stone type eroding consumes C-S-H gel and hydrated compounds such as $C_3AC_4AF$ continuously. This makes the structure of the concrete stone lose its cohesion. This kind of eroding is more serious than general simple sulfates; and generic anti-sulfate-eroding concrete and unprotected concrete cannot resist this kind of eroding.

### 1.2 Eroding by Chlorides

Sea water is the main source of the chlorine ion. Usually, seawater contains 3% salts and most of them are chlorides. Sea breeze and sea fog contain the chlorine ion as well, and sea sand contains various quantities of chlorine ion. Chlorine can erode concrete structures as follows

(1) The eroding destruction to the layer of concrete

The existence of $Cl^-$ can enhance the solubility of $Ca(OH)_2$ in concrete markedly. It can speed the dissolving attack to $Ca(OH)_2$ ; invasive chlorine can react with tri-calcium aluminates $C_3A$) in concrete and produce aqueous chloridized calcium aluminates ($3CaO \cdot Al_2O_3 \cdot CaCl_2 \cdot 10H_2O$ and $3CaO \cdot Al_2O_3 \cdot CaCl_2 \cdot 3H_2O$), which can result in a crystalline expansion, however when concrete comes across neutralization $Cl^-$ will dissociate from these complex salts and produce an eroding destruction to the reinforcing steel bar.

(2) The eroding destruction to reinforcing steel bar

The infiltration of the chlorine ion makes a significant impact to the corrosion of the reinforcing steel bar. With a small radius and higher activity, $Cl^-$ has very strong penetrating ability to permeate concrete, and penetrates to the surface of the reinforcing steel bar, this is absorbed as a passive film, and reduces the pH value to less than 4 very rapidly, bringing about destruction of the local passive resistance to corrosion; thereafter, the potential difference will be formed between $Cl^-$ and those passive films which haven't been destroyed. Then the point eroding is induced to develop quickly; and when point eroding develops rapidly its harm is more serious than the one of uniform eroding; due to the formation of $FeCl_2$ transit of $Fe^{2+}$ is intensified, thus the corrosion process of anode is intensified; besides this, due to electrical conductivity of $Cl^-$ it decreases the resistance between the cathode and anode and enhances the efficiency of the eroding battery; thus the destruction of electrochemistry eroding is intensified. Reaction equations are as follows:

$$Fe^{2+} + 2Cl^- + 4H_2O \rightarrow Fe\,Cl_2 \bullet 4H_2O$$

$$Fe\,Cl_2 \bullet 4H_2O \rightarrow Fe(OH)_2 + 2Cl^- + 2H^+ + 2H_2O$$

It is obvious that for the corrosion of a reinforcing steel bar, the chlorine ion action is only to induce, activate or act as a porter. It doesn't participate or change the composition of the eroding product. Its content will not be reduced with eroding and thus its harm is more serious.

## 1.3 The Eroding of the Atmospheric Environment

The part of concrete structure above the ground will not only be similarly eroded by the bittern in air, in sea breezes or in the rain, but it is also affected and destroyed by other physical, chemical and biological factors in the atmosphere. Physical factors include dry-damp change, temperature difference between daytime and night, etc.

According to some information, the temperature of the concrete surface may be higher than 50°C and the dry and hot, windy daytime conditions deposits salts on the surfaces and is then dissolved when dew condenses on the surfaces at night. The difference in temperature is notable. All of these make up a rigorous eroding circumstance.

Together with less concrete grade and less thickness of a protective concrete layer and construction that may be of an inferior quality, a lot of maritime concrete structures, reinforcing steel bar is corroded badly, sometimes within the first year, in the Arab gulf and Red Sea areas.

Chemical factors include carbonization and acid rain etc.

### 1.4 Dynamic Eroding and Stress Eroding

The eroding of sea water (or coastal soil) to concrete is not a single effect of a certain medium, it is a composite effect of multi- mediums; the flow of sea water (the abrasion and scour of attack force of running water and waves may strengthen the invading force of eroding mediums) and the inner & external stresses to the structure make this kind of eroding appear in the form of dynamic eroding and stress eroding.

### 1.5 The Corrosion at Different Parts of Structure

At some special parts of the structure, such as the transition zone or vaporizing zone (which is at a height of about 0.3 to 0.5m above the ground or water surface), splash zone, these zones suffer the most severe corrosion of the whole structure, because of the environmental eroding destruction above ground (salt fog zone), underground or under water (full-dip zone). Splash zone and tide difference area is located at the changing environment for dry and damp, the tidal affect twice each day makes the splash zone and tide difference area to suffer from freeze-thaw cycles twice each day (such a situation can appear in the days between fall and winter or between winter and spring).

The corrosion of concrete and reinforcing steel bar is severe due to the colligation affect of physical and chemical destruction.

The Australian Sharp investigated 62 coastal concrete structures. They found that the durability problems were all related to the abnormal and severe corrosion of the reinforcing steel bar at the splash zone; In China the concrete structure destruction caused by corrosion of the reinforcing steel bar is quite common and severe in seaport docks at the splash zone area.

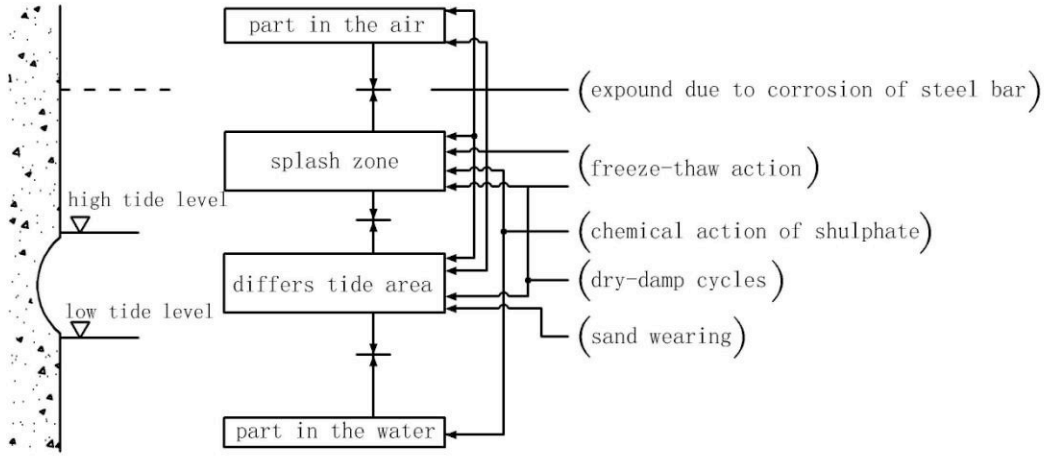


Fig 1 different positions suffer different corrosion for the reinforced concrete structure under marine environment

Summarized above, the durability problem of the marine and coastal concrete constructions have been become the most notable hotspot in the concrete research domain worldwide.

## 2. The Counter Measure of Prevention and Cure

The eroding destruction mechanism of the environment to concrete structures, whether physical or chemical factors, whether in the atmosphere, underground or in the water, the common and most important precondition is that the water plays a role of a transport or reacting medium, whereas, the porous characteristics of concrete itself and the existence of crannies in the concrete provides channels for water and other harmful mediums. So, concrete can be protected from the eroding destruction of the harmful environmental mediums if the water can be blocked so as to not infiltrate into the concrete. This opinion has become commonly recognized throughout academic and engineering circles worldwide and is supported by several decades of research.

Just as the famous American concrete expert Mr. Metha indicated: for the long-range point of view, concrete penetrability or infiltration characteristic is the one and only characteristic relating to the durability of concrete. It has been shown time and time again, if a concrete structure could not be penetrated or infiltrated completely then the

disease, including the corrosion of reinforcing steel bar, alkali-aggregate reaction and destruction of freeze-thaw won't take place at all.

There is a manifold waterproof measure for concrete structures. Through analysis and comparison, it can be said: if on the surface of a concrete structure, we apply a protective coating, which forms a waterproof layer, and if the layer itself has an ability to resist corrosion, then it can resolve the concrete structure degradation due to the defect of the concrete structure itself and to the influence of environmental factors.

Thus, waterproofing can improve the concretes durability and prolong the service life of a concrete structure.

According to the Life Cycle Cost Analysis (LCCA) concept released in America, if waterproofing design were taken into account at the time of infrastructure designing, it would markedly save later maintenance costs (about 70%) and maximize the long term benefits, although the initial cost may be increased a little.

## 3. The Introduction of CN2000® Series of Waterproofing Materials

### 3.1 Three Technical Innovations

（1）Innovations of Material Structure

In the development of **CN2000B®** (Cementitious Capillary Crystalline Waterproofing Material CCCW), Zhonghe Waterproof Material Corporation relied on the proprietary techniques of the nuclear industry, proceeding with molecular physics, research forces between molecules and moving regularity, we introduced the Eka-molecular sieve matter and activating substance, to make the main body of a waterproofing material having an Eka-molecular sieve structure. Eka-molecular sieve matter has certain and even apertures, a very high specific surface; after another activating substance is absorbed on the Eka-molecular sieve surface and holes at the molecular level, it will form dispersion in an atomic level spontaneously, so, active matter was activated—ionization, it creates conditions for its diffuse migration into the concrete substrate.

The Cementitious Capillary Crystalline Waterproofing Material (CCCW) with Eka-molecular sieve structure developed by our company is an innovation in the composition of the CCCW structure. To this, the conclusion of an innovation search report was given by the Nuclear Industry Patent Center in 2006 as follows: this kind of

researching content is innovative. To diffusing law and acting mechanism of active substances, ZHONGHE Waterproof Company contributes useful researching outcome.

(2) Innovation of a Preparation Technology (Patent: Fully Automatic Powder Preparation System)

Matching accurately and homogeneousness of various materials of CCCW is very important to the performance and stability of the product, especially, for those important accessorial materials in which their quantity is only minimal, however exact proportions in every cubic centimeter of a batch have a great influence on the performance of the product. Up to now, in China and in other Countries, the powder preparation industries still use a conventional fitful batching method and general mixing machine. In this way, there are many problems in proportion accuracy and mixing uniformly.

Our company patent, the Fully Automatic Powder Preparation System, mostly includes a System of Mixing in many Fine Streams"and a Servo Affixation System of Auxiliary Materials". This System realizes a continuous and automatic production of multi-powder matching and mixing, and that the matching ratios are accurate and the mixing was homogeneous. It has enhanced the production capacity from one hundred tons per year to a ten-thousand-ton level per year. The conclusion of an innovation searching report in 2006 shows this system as being unique.

The characteristics of The Fully Automatic Powder Preparation System is that: it can adjust the accessorial material adding quantities accurately in one millisecond at the time of examining the main materiel flux; the mixing homogeneity can be in accordance with the requirement of each powder materiel for every cubic centimeter. Thus it ensures an exact matching ratio, and ensure stability and conformity.

This system uses special software developed and designed by ourselves. It can be utilized to function by long-range control by computer.

## 3.2 Ten Main Characteristics of the Performance of **CN2000B®:**

The system has been improved continuously these past few years. We have applied for 7 national patents, in which 2 of the patents for invention have been qualified at the first review, and the certificates for the other 5 patents have been issued already.

(1) Waterproofing and anti-exudation performance is notable

For the capillary crystalline characteristic of this material, its waterproofing effect will be better and better with age.

(2) Anti-Corrosion is Very Good

This product can resist or endure high or low temperatures, dry-wet alternating and freeze-thaw cycles. It can restrain alkali-aggregate reaction; can resist aging and eroding from other acid gas, acid water, chloride, sulfates etc.

(3) High Strength

For the effect of capillary crystalline, the coating layer molecularly bonds and becomes a part of the concrete, and can resist a high pressure water head.

(4) High Stability

The crystalline structure produced in the coating and the substrate concrete is very stable and does not decompose, therefore it can resist aging and resist ultraviolet radiation.

(5) Long Life

CCCW coatings have the same life as the concrete structure itself. It can improve the durability of a concrete structure greatly.

(6) Normal Breathing Ability

Crystalline products of CCCW do not affect the aspiratory function of a concrete structure; it can breathe, eliminate dampness and keep concrete dry freely.

(7) Self-Rehabilitation Ability

Tiny cracks less than 0.4 mm can be self-healing once exposed to water. This is indicative of the durability of this product in its performance.

(8) Environmentally Friendly

This product is non-toxic and tasteless. It will not cause secondary pollution; it can be used in projects for drinking water, food-processing and natatorium. Proved by testing,

the content of its formaldehyde, VOC's, heavy metals, deleterious matter is lower than the normal instrumental detection limit.

(9) Construction Efficiency

**CN2000®** can be applied on damp surfaces of the concrete substrate at normal temperatures; by trowel coating, brush coating or spray coating. These methods all can be used, and the application method is simple and efficient. The setting time is very short; labor is saved, time is saved; and the product is suitable for diversified substrate surfaces (new, old, or surfaces or with complicated forms).

(10) Economical and Efficient

The price of this product is lower than similar products from other manufacturers; the construction period is only one sixth of the time of others. Its cost and construction is much lower than similar products from other manufacturers.

## 4. Application of CN2000® Series of Waterproofing Materials

**CN2000®** series of waterproofing materials were appraised and it was determined The synthesized performance and technical data of this series of products have reached an internationally advanced level by National Defense Science Technology Committee of China as early as 2001. As uninterrupted innovation of our company at material developing, manufacturing techniques, application technologies and so forth; in recent years, Tianjin Technology Committee and China Science Technology Office authorized a scientific research developing fund to The Fully automatic clean production of Cementitious Capillary Crystalline Waterproofing with Eka-Molecular Sieve construction of our company by the checkup of locality and country. It incarnated the authorization, recognition and sustainment of the country to our company; furthermore, in 2002 our company passed the ISO 9000 QUALITY MANAGEMENT SYSTEM CERTIFICATION, it insures production quality in management. In 2006 our company passed (MSDS), it insures the products passes safety certification throughout North America, Europe and around the world.

**CN2000®** series of waterproofing materials has undertaken hundreds of important projects of waterproofing and anti-corrosion in Chinese energy sources, traffic engineering, environment protection, military affairs, industrial and civil constructions

and others with excellent performance and results. In recent years, our products have been exported to Taiwan, Mozambique, Algeria, America, Canada and many other countries and regions throughout the world.

We do our best to resolve the waterproofing and anti-corrosion problems related to concrete structures, especially in regard to the durability problems of marine and coastal concrete construction projects and we offer our expertise to build resource – efficient and sustainable development of communities.

## CN2000® a Revolutionary Concrete Solution