This is

（無機質セメント結晶増殖材）

XYPEX

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Translated from Japanese Text of Japan Xypex

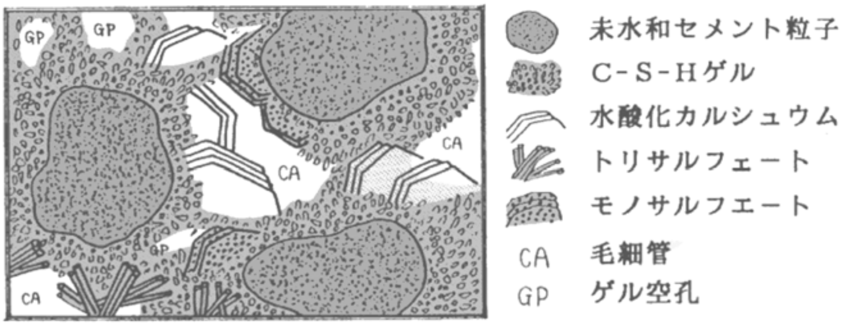
CONTENT

1. The Basic Factors that Cause Concrete Deterioration (Porous Property)

1.1 Forms and Structure of Pores present in Concrete

The most important factor that causes concrete to deteriorate is the presence of many pores of varied sizes inside the concrete during its formation.

Constituents of Concrete



- Unhydrated cement particles
- C-S-H gel
- Calcium Hydroxide $Ca(OH)_2$
- Tri-Sulphate
- Mono-Sulphate
- Capillary CA
- Gel pores GP

The above shows a microscopic view of the sheared surface of normal concrete.

- Cement, Gel pores(Change of state from free water to crystal water (ice), gel water, contraction and expansion of volume are essential characteristics of the cement hydration process.)

  Between 10 - 30 Å O

- Capillary pores (Loss of free water etc.)

  Between 0.1-100 µm Ø

- Water breathing way (By evaporation)

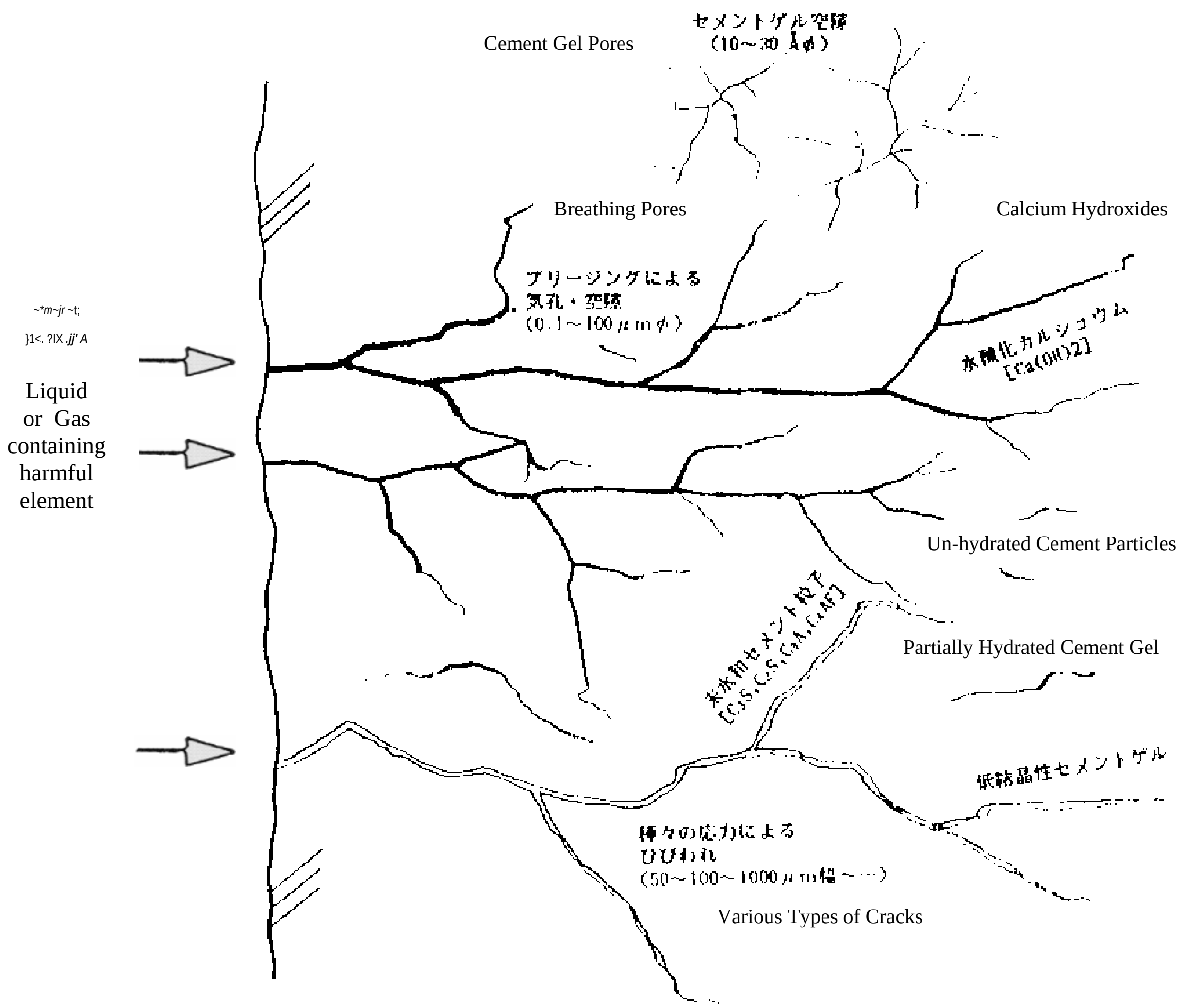
  Between 50 -100 - 1000 µm Ø

- Various stress cracks (Cracks due to internal and external stress forces)

  Between 50 - 1000 µm wide or more

The various types of pores present in the concrete allow the movement or spread of free water internally, and the penetration of gases and liquids externally, thus inducing various chemical and physical changes that regress the durability of the concrete.

1.2 Pores that Cause Deterioration of Concrete



From the above, you can see the effect of pores on the regression process of the concrete. Among the various types of pores, only OPEN-PORES (versus CLOSED-PORES) lead to the external surface. The Gel Pores, due to their size, are not alarming

Concrete deterioration occurs in the many OPEN-PORE paths around the Ca $(OH)_2$, un-hydrated or partially hydrated cement gel and it also provokes subsequent chemical reaction that lead to rusting/damage of the steel reinforcement.

2. The Basic Theory of Xypex Products (Crystalline Growth Mechanism)

The Xypex crystal reacted to a depth of more than 30 cm in the Xypex treated concrete sample.

The Xypex crystal growth mechanism consists of the following three reaction process:

Reaction I
Xypex Concentrate (XC) mixed with water to form slurry, applied firstly to the surface of the concrete:

→ Calcium Compound Crystal + Water Soluble Silicate

→ Catalytic Calcium Compound

→ Catalytic Magnesium Compound are formed.

Reaction II
Water Soluble Silicate + $Ca(OH)_2$ → C-S-H Series of Crystal

Reaction III

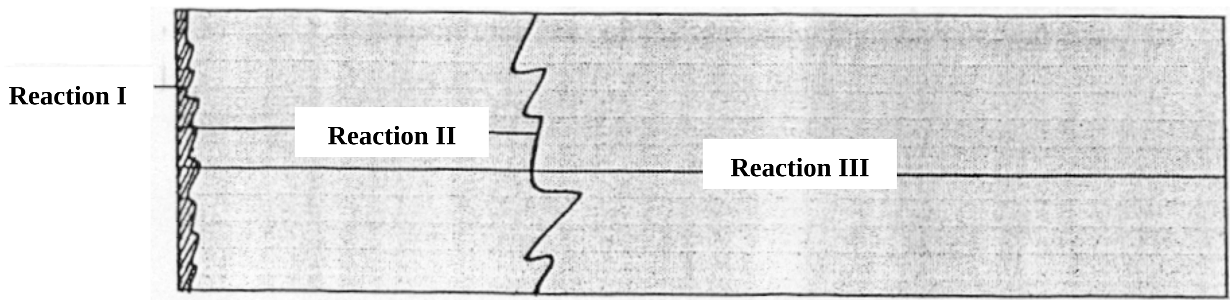
- Catalytic Calcium Compound + Water Soluble Silicate

  → C-S-H Series of Crystal + Catalytic Chemical Compound

- Catalytic Magnesium Compound + Water Soluble Silicate

  M-S-(H) series of Crystal + Catalytic Chemical Compound

← Repeated Reaction

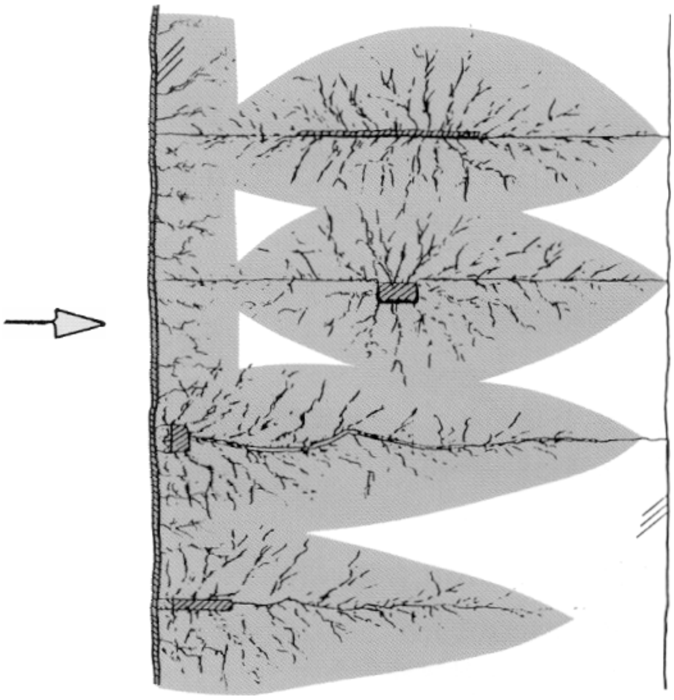


3. The Basic waterproofing Capability of Xypex

3.1 Methods of Application

As previously explained, the multiple crystallization process in Xypex treated concrete makes it impermeable to water. The following lists two basic methods of application.

- Brush-on (Spray-on) method
- Filling (Sealing) method

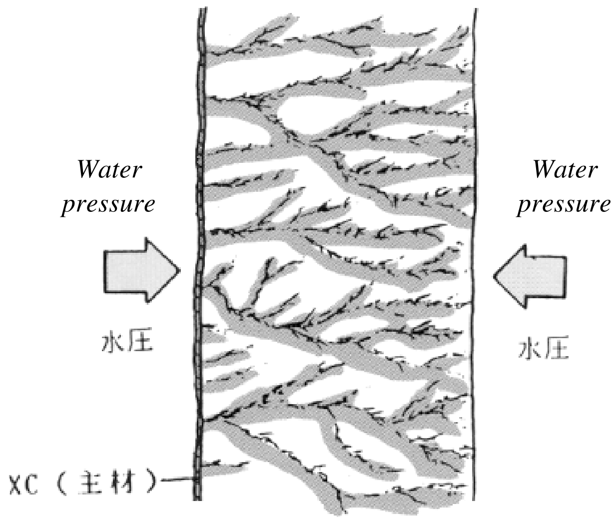


Note: Selection of method depends on the width of cracks, magnitude of leakage and site conditions..

The above two basic methods of application, if properly executed, can make all concrete 100% impermeable to water.

3.2 Easy and Flexible Application

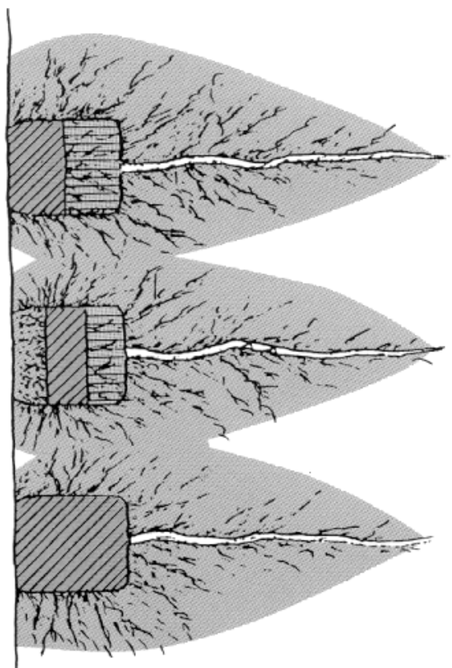
The currently used paint-on membrane waterproofing material presents a fundamental restriction in application where the concrete surface is wet. Xypex, however, uses water as a catalyst to form crystals in the deepest parts of the concrete. Xypex can be applied to either side of the structure depending on the construction sequence and circumstances.



XC – Xypex Concentrate (main product)

3.3 Width of Cracks and Quantity of Water Leakage

A brush-on / spray-on method is able to waterproof concrete with hairline cracks. However, the filling method is necessary if water is seeping out through the cracks. Depending on the width of the crack and the quantity of water leakage (water pressure), additional layers of Xypex can be applied to arrest the seepage.



Packing Method

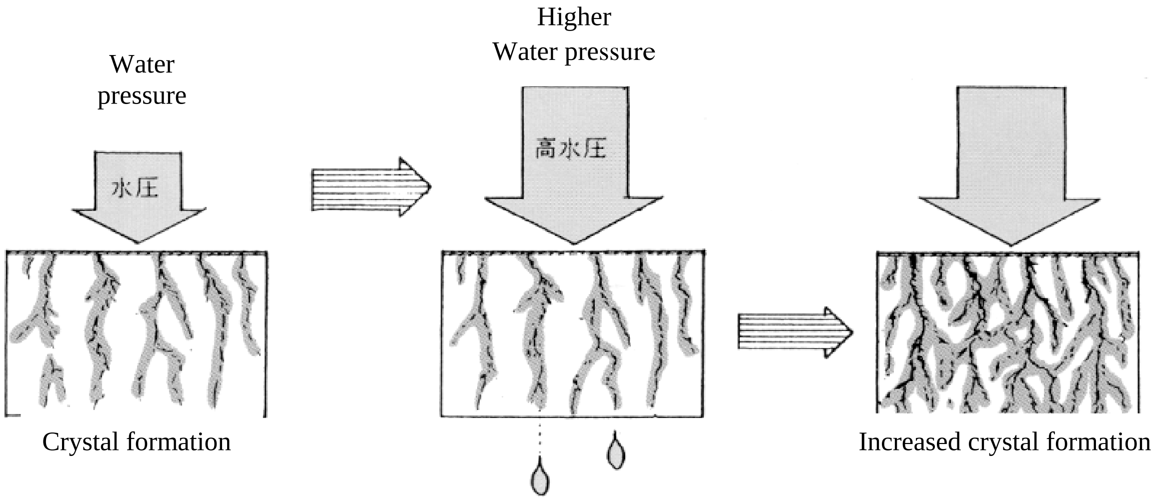
Indicates the Xypex Concentrate (XC main product) and the picture on the left shows the progress of crystallization using XC as a reference point.

The cracks widen and the leak worsens when the time and the amount of XC applied are not sufficient for normal crystallization.

The aim in application is therefore to use the larger cracks as contact facets between the filling material (XC) and concrete, thus speeding up the crystalline growth at these points.

3.4 Water Tightness Under Water Pressure

The multiple growth of crystals in the concrete when Xypex has been applied makes the concrete more dense and thus more water tight due to its ability to withstand water pressure.



In addition, the Xypex treated concrete can feel and react automatically to any change in water pressure, and continue to produce crystals until water tightness is achieved provided the water pressure is maintained at a point.

For example, a concrete sample treated with Xypex appropriately could withstand 5 kg/m^2 of water pressure with zero water penetration. If the water pressure increases to 10 kgf/m^2, the immediate effect may be that of initial emergence of water at the surface due to its temporary incapacity to contain the excess pressure. However, if the 10 kgf/m^2 water pressure is maintained for 1-2 days, total waterproofing can be achieved.

3.5 Conditions for Attaining the Waterproofing Effect

The $Ca(OH)_2$ (acidic calcium) component reacts with un-hydrated cement, multiplies partially hydrated cement gel to form crystal clusters, and thereby achieving a waterproofing effect.

For ideal results, the following 3 conditions are required:

- Moisture (Xypex material relies on this factor to grow and react)
- Temperature (reaction temperature)
- Time (reaction time)

In other words, if the necessary water, temperature (at 10^oC up, reaction speed almost doubles) and long reaction time is provided, a high amount of crystallization will occur and vice versa.

These reaction conditions, together with the number of pores, have critical speed implications to the waterproofing result.

3.6 Waterproofing the Roof and Basement Area

As long as the construction is in concrete, the effect of using Xypex products will not differ between civil engineering structures and building structures.

Conventional waterproofing materials face the problems of durability in the case of roof waterproofing and the necessity of double wall construction in the case of basement waterproofing. Xypex succeeded in where others have failed.

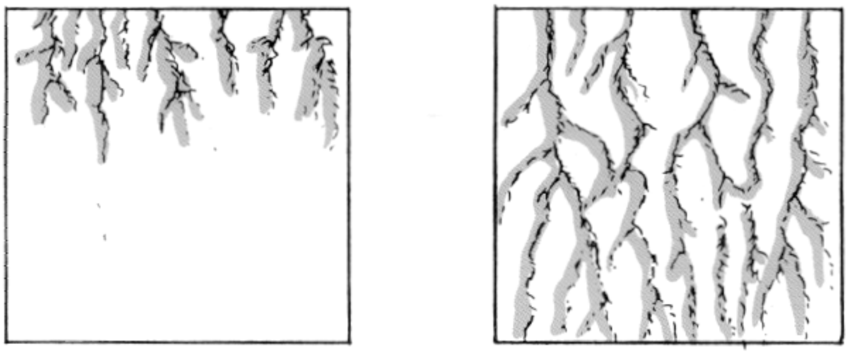
Xypex’s strong merit points are as follows:

- Double wall construction is not necessary for basement area (refer to job references).
- If it is a new construction, brush or spray application on the concrete surface is sufficient but the maximum slump of the concrete should be at 12 cm.

3.7 The Effect of Applying Xypex to Concrete

As explained in section 3.5, the presence of water inside the concrete is a necessity for spreading the Xypex catalytic ingredient and to induce crystallization. The atmospheric temperature also helps to speed up the reaction.

Therefore, the greener the concrete, the higher the efficiency of crystallization.



The effect of Xypex on normal 300-700 kgf/cm^2 concrete differs as shown below :

Concrete sample	**Depth of Xypex crystal penetration detected**
1-2 months old :	5-10cm / 2 -3 weeks
2-3 hours old :	25-36cm / 2 -3 weeks

Therefore, in order to achieve faster crystallization, the concrete should be treated within 2-3 hours after casting. The younger the concrete, the more effective the Xypex product.

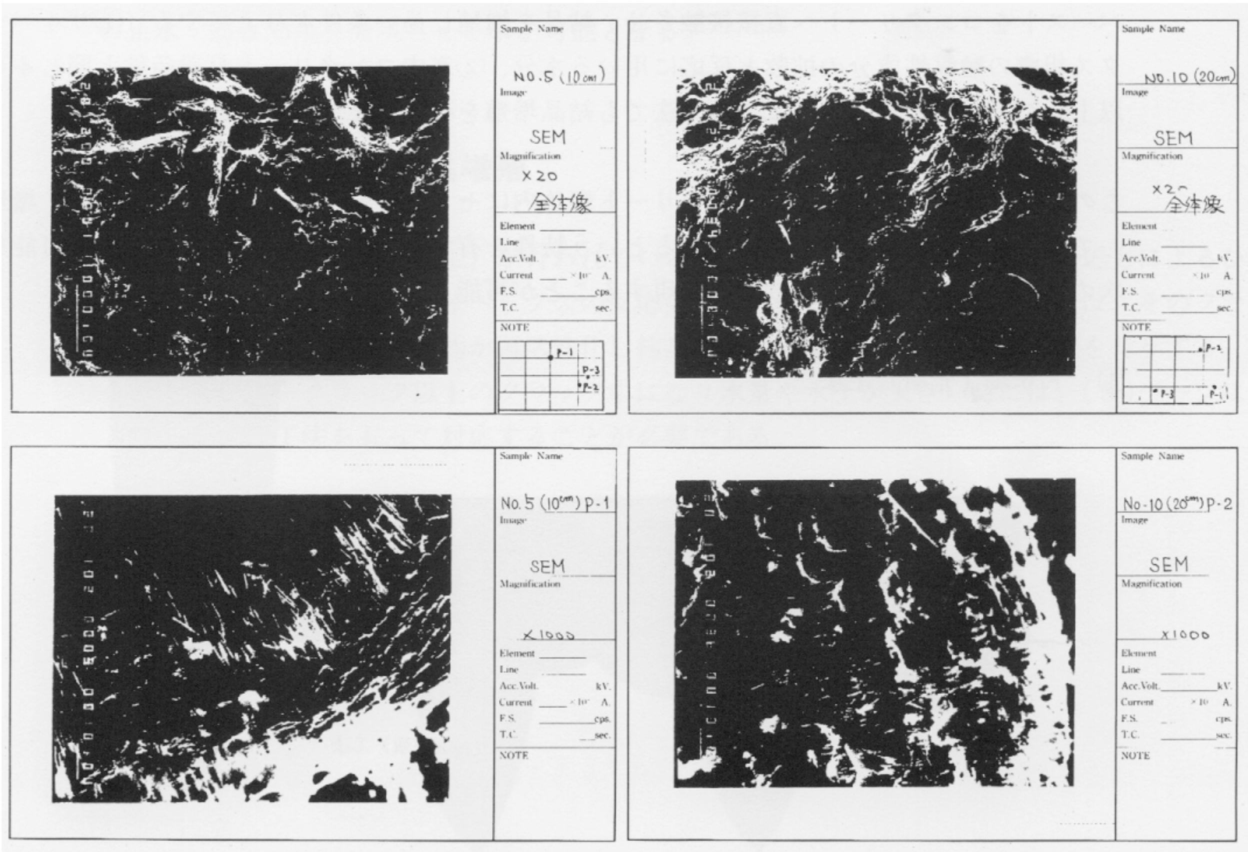
Note: However, it is recommended to apply the Xypex product at least 24 hours after the concrete is cast to prevent premature absorption of the concrete moisture during the initial curing period.

4. The Distinguishing Features of Xypex

4.1 Xypex Multiple Crystalline Growth and Penetration Feature

As explained previously (in section 1), concrete contains pores of various sizes, all connected by a network of tracks and the water inside is used by the Xypex catalytic ingredient for spreading. As explained in section 2, as long as the reaction conditions are suitable, the reiteration (repetition) reaction will be reactivated, and the multiplication reaction will be continued indefinitely.

Below are SEM (Scanning Electronic Microscope) photos shows a designed concrete sample 180kgf/cm^2, slump = 8cm, thickness = 40cm, top treated with Xypex concentrate (XC) slurry and the observed depth of crystal multiplication after leaving the sample outdoors for 3 years.



4.2 The Perpetual Crystal Multiplication Effect of Xypex in Concrete

Xypex reacts with chemical by-products of hydration in the presence of water to form inorganic crystals in the concrete.

$C_3C_2H_3$	about 75%
C_3AH_6	
$C_2(AF).3\ CaSO_4.32H_2O$	about 20%
$C_3A.CaSO_4.12H_2O$	

Xypex chemicals reacts with Ca $(OH)_2$ and C-S-H compounds to create a growth of crystal that becomes an integral component of the partial interlock. The crystals are hard and immovable thus physically they will exist as long as the concrete structure exists.

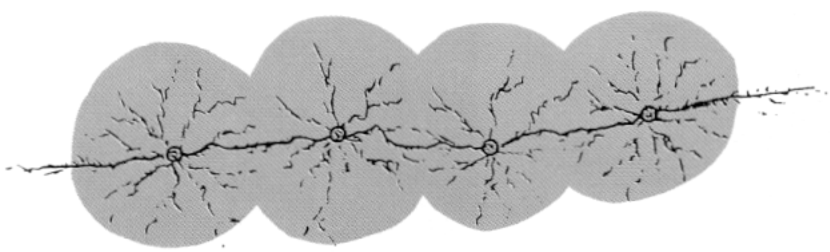
4.3 Area Specific Waterproofing

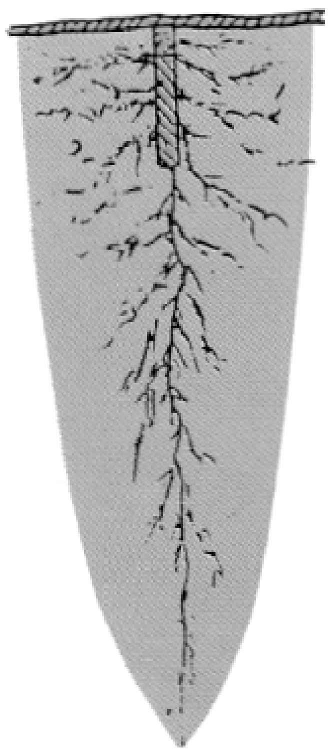
To observe the waterproofing effects of Xypex, we put it in direct contact with concrete and we also provide a optimum environment for crystallization:

1. Xypex catalyst and reaction water
2. Temperature above 4^oC

Xypex penetrates concrete, crystallizing within its pores, thereby waterproofing concrete in a way no other products can.

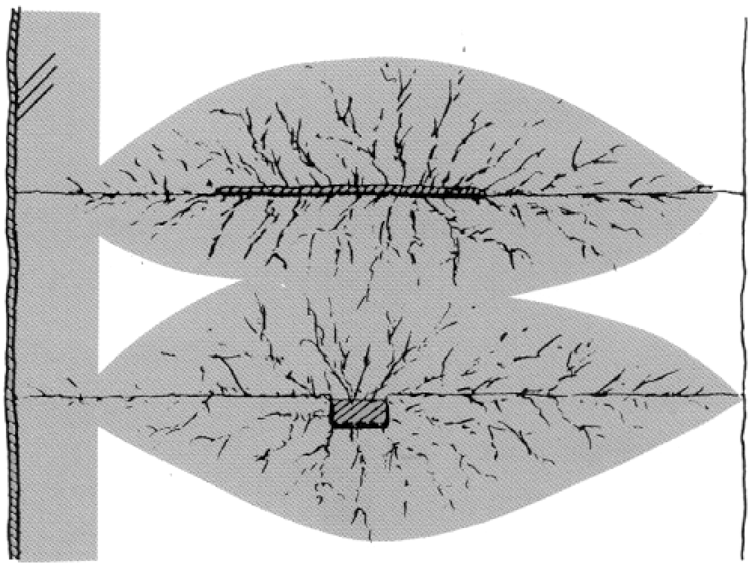
a) Drill & Pack method of application





Drill & Pack Method

b) Filling Joint method of application

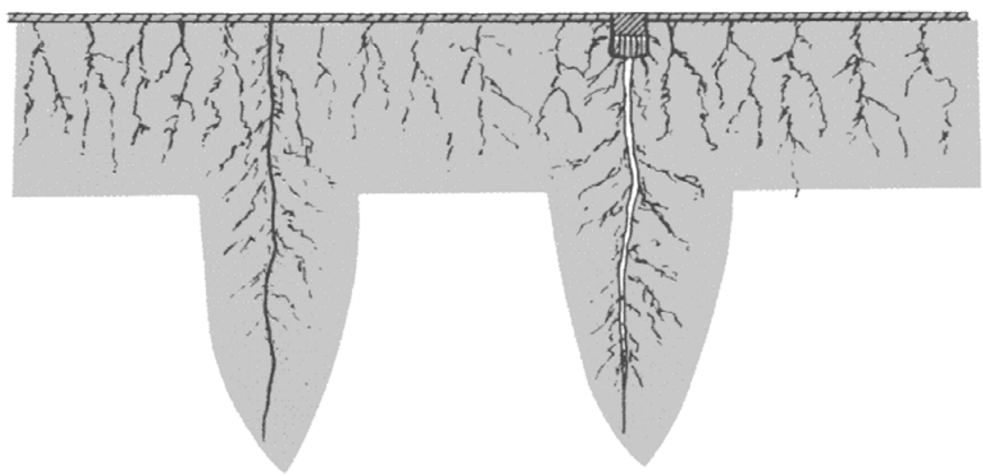


The catalytic components of Xypex takes the spread or filling points as a starting point from which crystallization spreads radially through the various air paths in the concrete. This forms a big spherical impervious zone around the starting point. It is therefore possible to waterproof specific areas by multiplying this effect.

4.4 Multiple Crystallization by Re-activation

In Xypex treated concrete, future cracks may be prevented by the catalyst given a suitable reaction condition (temperature and the presence of water). These conditions re-activate the crystallization process to waterproof the new cracks.

However, if the new crack’s width is more than a hairline crack, and if a large quantity of water is present, additional filling of the catalyst by means of the filling method is required to effectively waterproof the area.

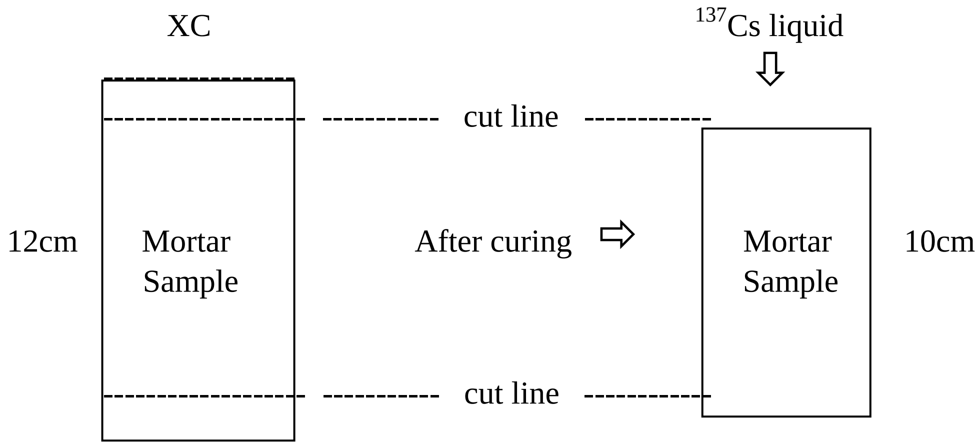


5. Special Characteristics of Xypex Treated Concrete Against Harsh Environmental Conditions

5.1 Nuclear Radioactive Diffusion Penetration Resistance

Xypex treated concrete dispersed radiation ^{137}Cs (an alkaline metal element which is much more powerful than ^{90}Sr^{50}Co spread etc.) in the deep part of the mortar. The density of radiation was reduced by one line compared to the untreated mortar.

Japan Atomic Energy Research Institute (JAERI)
Test Method:



Results and Comments :
From the test, it shows that the ^{137}Cs density in the Xypex treated mortar is one line lower than untreated mortar.

Also, exposure to (^{60}Co) 5.76 x 10^4 rads of gamma (g) radiation, the Xypex treated sample revealed no ill effects or damage.

(JAERI – Japan Atomic Energy Research Institute)

5.2 Freezing and Melting Resistance

AE treated concrete was subjected to consecutive freeze-melt cycles to test its elasticity coefficient. Xypex treated concrete deteriorated by 9 -10% compared to 25-30% of untreated concrete. (Material testing Centre - Japan)

5.3 Salt Resistance

Sea Water Shower (50^0C) - 12 hours
Accelerated Drying (60^0C) - 12 hours x 270 days
Salt penetration in neutral concrete, reinforcement rusting area ratio. Xypex treated sample penetration is 2/3 compared to untreated sample.

(The Ministry of Construction - Japan)

5.4 Neutrality Resistance

Neutralized progression condition.
30^0C - 60% R.H. CO_2 5% concentration.
Xypex treated concrete is 2/3 – ½ neutrality depth compared to untreated concrete.
(Material Testing Centre - Japan)

5.5 Increase in Compressive Strength

Xypex treated concrete cured for 4 weeks, the compressive strength increase by 10 – 15%.
(Electrical Power Research Centre - Japan)

5.6 Healing of Shrinkage Crack

Xypex treated concrete used for containing Atomic Energy Solution (agent) in the nuclear power station, shows the biggest ratio of shrinkage after curing for 8 weeks. It indicates a reduction of about 20% as compared to untreated concrete. (Material Testing Centre - Japan)

5.7 Resistance to Chemicals

Submerged the Xypex treated concrete sample in Sulphuric acid solution at pH 0.1 of 5% concentration for a period of 6 weeks and observed that 1/4 – 1/5 penetration damage compared to untreated concrete.
Also, Xypex withstands extreme high acidity, thus submergence for 8 weeks observed no change nor damage.

5.8 Resistance to Alkaline Base Material

a) In a railway bridge structure, AAR has carried out a core sample from the bottom part of the structure which Xypex had been applied. After 20 months, water pressure 5kgf/cm^2 x 100 hours was applied to the cored sample. It was recorded that the untreated sample had a water penetration of 500-800 ml and the Xypex treated cored sample had 0 ml water penetration.

b) Further AAR also found that the Na.K in the cored sample had been substituted and pushed out from the core body.

(Research with JR. Presented at the 9th AAR International Conference)

a) and b) are the bases of resistance for AAR.

5.9 Safe and Non-toxic

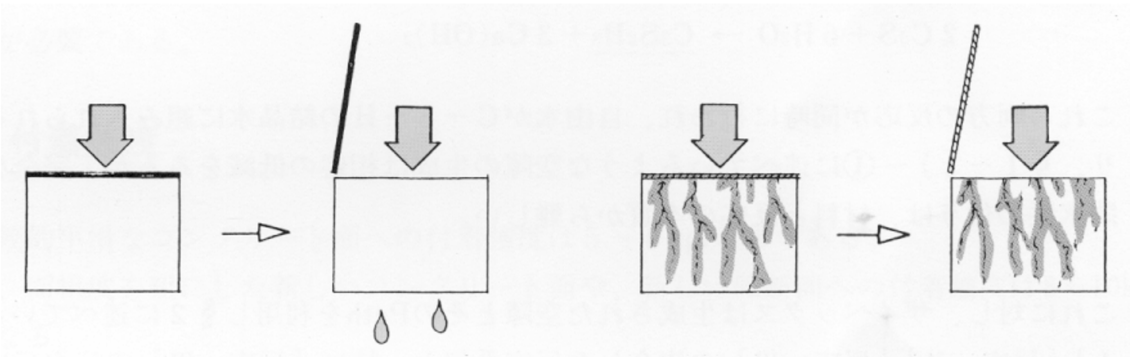
Xypex material is tested and approved fro use in potable water piping system and tanks. Xypex material is approved by JWWA-K-135 for use as a brush-on material to the water way, and also complied with food and hygiene regulations. (The Administrative Division of Japan)
(Japan Paint Examination Association)
(Japan Food & Hygiene Association)

6. Comparison of Xypex Material with Other Waterproofing Materials

6.1. Comprehensive Penetration vs Superficial Effect

Concrete has many various sizes of pores, micro or macro, and the pores' passage capillaies allow penetration and diffusion of matter which is the main factor that causes the concrete to deteriorate.

To prevent the deterioration process in general, the easiest way is to cover the outer face of the concrete physically with some kind of film or membrane material. These are mainly of organic-base materials like resin, neoprene, bituminous felt etc.



However, external coating materials adhering to the concrete physically is completely different from the Xypex material. When the film is damaged or delaminated, its waterproofing effect is lost, unlike Xypex treated structures where the multiple growth of crystals within the concrete structure increase the density of the concrete, thereby creating its waterproofing characteristic. Even if the (Xypex) brush-on layer is removed, there would be no change in its waterproofing effectiveness.

Tests had been carried out by applying water pressure to Xypex treated (brush-on) concrete with the brush-on coating layer removed.

Other type of penetrating waterproofing material claims only the outer layer penetration reaction, see only (Reaction I) or (Reaction II) (refer to section 2). In fact, their reaction remains at the shallow part which corresponded to (Reaction I) + slight (Reaction II), whereas Xypex penetrates right into the concrete (Reaction III).

Crystallization mechanism is necessary for the deep layer reaction.

6.2 Xypex Admix Material

Xypex Admix material is to combine or mix into the concrete at the beginning stage (premix stage) as concrete waterproofing material or concrete protection material. For example, representative inorganic substances which belong to pozzolanic susbstances that contain sislica. The purpose is to hydrate the cement in addition to supplement mixing reaction of water and pozzoline.

That is :

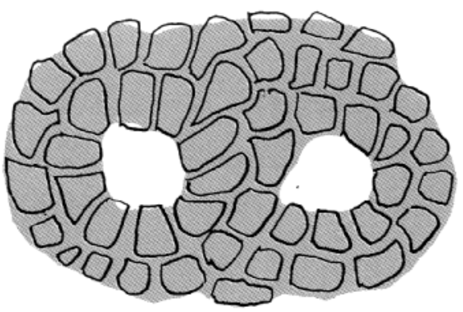
$$3Ca(OH)_2 \quad + \quad 2SiO_2 \quad \rightarrow \quad \boxed{C_3S_2H_2}$$

This is essentially the same as the cement hydration reaction :

$$2C_3S \quad + \quad 6H_2O \quad \rightarrow \quad \boxed{C_3S_2H_2} \quad + \quad 3Ca(OH)_2$$

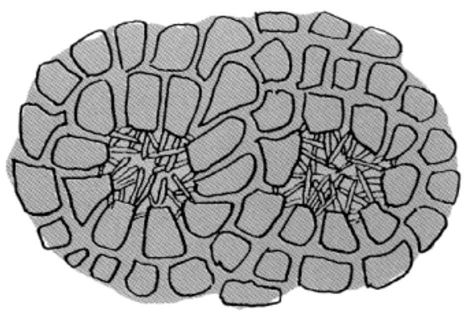
Both reactions occur at the same time and free water C-S-H and crystallized water are produced.

In comparison, Xypex utilizes the created pores space and caillary path by employing its unique mechanism, i.e., the series of (Reaction I, II, and III) (refer to section 2), in particular the repetition of (Reaction III), the multiple crystallization in the pore space.



水和反応によるポアー（空隙）

Pore Space created by the water mixing reaction



ポアー内への結晶増殖

Crystals multiply and formed inside Pore Space