



## **XYPEX TESTING SUMMARY**



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# **PREAMBLE TO XYPEX TESTING**

## **XYPEX TECHNOLOGY AND PRODUCTS**

The Xypex technology is a unique chemical treatment designed to waterproof, protect, and enhance new concrete, as well as restore and rehabilitate existing concrete structures. The active ingredients in Xypex cause catalytic reactions which generate crystalline formations within the pores and capillary tracts of concrete. These Xypex crystalline formations become an integral part of the concrete structure, thus enhancing the characteristics of the concrete itself. The chemistry in Xypex is totally compatible with the concrete itself. The treated concrete becomes totally impermeable, preventing the penetration of liquids from any direction.

The Xypex technology is available in various forms. The "Xypex Admix" can be introduced during the batching of the concrete, for use in either precast or poured-in-place structures. The "Xypex Dry-Shake" products and method is specifically designed for use during the placement of slabs. The "Xypex Coating" products are applied to hardened concrete structures, including both "green" concrete and existing structures. There are also various Xypex "Patching, Plugging and Repair" materials designed to rehabilitate defective or damaged concrete.

## **XYPEX PROJECTS**

Xypex has been used successfully in thousands of projects around the world - projects of all kinds. They range from construction of world-class hotels, sports stadiums, shopping centres, and office complexes - such as Mexico City's World Trade Centre, the largest building in Latin America....to the protective maintenance of water and waste-water treatment facilities, water reservoirs, swimming pools, nuclear stations, and dams. In Australia the Xypex treatment has added an estimated 30 years of life to a 50-year-old sewage treatment plant. In fact, we have even waterproofed the tomb of the first President of Ghana. Xypex has recently been extensively used on the Gatun Locks of the Panama Canal to provide chloride protection. Xypex was used to waterproof NASA's Neutral Buoyancy Tank in Texas for the training of astronauts and for testing of the Space Lab components. In Malaysia, Xypex Admix was utilized to enhance the concrete foundation of the largest continuous pour in Southeast Asia. Xypex Admix has been utilized to waterproof and protect a variety of precast components (eg. manholes, vaults, pilings, median barriers, pipes, wharves, box culverts, "u" beams, railroad ties, etc.). The results in the field are the ultimate determinant of the staying power of a technology or product. It becomes the real "laboratory" that determines success or failure of such a technology. The growth of our organization and the acceptance of our products has been governed mainly by the consistent satisfaction of our customers - the engineers, architects, public works officials, maintenance supervisors, contractors, plant managers and others with whom we have worked around the world.

## **XYPEX TESTING**

We appreciated the importance and value of testing the performance as well as the quality of the Xypex products and technology. Xypex products have been tested for both performance and for quality assurance by independent scientific laboratories throughout the world. Various performance characteristics have been evaluated, namely: water permeability, chemical permeability, petroleum permeability, air permeability, sealing cracks, chemical resistance, freeze-thaw durability, radiation resistance, compressive strength, tensile bond, abrasion resistance, potable water and public health testing. We have also evaluated related factors associated with crystalline growth, include porosity and scanning electron microscopy. Attached is copy of the "Summary of Xypex Independent Testing" which provides a listing and abstracts of the individual Xypex tests. We have also complete Test Reports available upon request.

It is important to note that the Xypex technology is unique and therefore with some of the performance characteristics, in particular permeability, require a distinct test methodology. The methodology or standard of testing for the Xypex technology and its products are detailed below. Copies of the most appropriate and available standards for testing the performance or effects of the Xypex treatment are also identified.

**Permeability Testing** of the Xypex technology must involve determining the amount of "output", "throughput" or "depth of penetration". Testing should include significant hydrostatic pressure and negative-side application. Acceptable test methods include tests based on US Corps of Engineers CRD C48-73 and DIN 1048. These are the two most appropriate permeability test methodologies and most other tests tend to be based on this methodology (eg. Onorm B 3303, Austrian Standard and GOST 12730.5-84 Russian Standard).

**Carbonation Resistance Testing** of Xypex treated concrete specimens and the ability of this treatment to suppress or limit the damage due to carbonation. Measurement of the penetration of CO<sub>2</sub>.

**Crack Sealing Testing** is based on ASTM C856-88 "Standard Practice for Petrographic Examination of Hardened Concrete". This methodology is used to evaluate the ability of the Xypex crystalline structure to self-heal hairline cracks when subjected to hydrostatic pressure.

**Depth of Penetration Evaluation** is essential to the Xypex technology. We want to demonstrate how the Xypex crystalline structure becomes an integral part of the concrete matrix, and that the Xypex crystalline formation grows throughout the concrete substrate. Typical test methodology involves scanning electron microscope photography.

**Chemical Resistance Testing** is most commonly based on the ASTM C266-77 methodology. The results must demonstrate that the protection to the concrete provided by the Xypex crystalline treatment is able to withstand a pH range of 3.0 - 11.0 in constant contact and 2.0 - 12.0 in periodic contact. The concrete treated with Xypex must also be able to withstand sulphate attack when tested in a 13% ammonium sulphate solution for 180 days. The basis for this test is U.S. Bureau of Reclamation "Procedure for Length Change of Hardened Concrete Exposed to Alkali Sulphates", and Australian Standard AS 1141.24-1974. The effect of the Xypex crystalline treatment has also been tested in a 5% sulphuric acid solution for six months. The methodology for this testing is based on the JIS (Japanese Institute of Standards), used for determining durability of concrete against chemicals by soaking samples in solution, which is designed to determine improvement in relative dynamic modulus of elasticity.

**Freeze Thaw Resistance Testing** involves evaluating the effects of the Xypex crystalline treatment according to ASTM C666 "Freeze/Thaw Durability Test" with minimum 80% relative durability rating. Another acceptable standard is the Japanese methodology, JIS A 6204 "Concrete Freeze/Thaw".

**Radiation Resistance Testing** of the Xypex crystalline treatment of concrete is according to the U.S.A. Standard No. N69 or JAERI (Japan Atomic Energy Research Institute) "Exposure to Radioactive Solution <sup>137</sup> Cs". Typically, this methodology involves ensuring that the concrete does not break down or deteriorate when subjected to radiation.

**Compressive Strength Testing** is most valuable when utilizing the Xypex Admix products. It is essential to demonstrate that the Xypex treatment will not have any detrimental effect to the design strength of the concrete. Results indicate clearly that Xypex Admix will improve the compressive strength of various mix designs. Test methodology for determining compressive strength includes: ASTM C 39, BS 1881 : Pt 120 : 1983 and STN 73 1317.

**Tensile Bond Testing** has been used to evaluate the ability of a Xypex coating or patching material to adhere to a substrate. Test methodology for determining bond strength include: CSA A23.2-6B and ESN 73 2577.

**Abrasion Resistance** is specifically related to the Xypex DS-2 and Xypex Quickset, which are both designed to increase the surface hardness of a concrete slab. The Taber Abrasion Test evaluates the mass loss in grams, while the Moh's Hardness Evaluation is utilized to determine the degree of hardness of the aggregate component on a scale of 1 - 10 when compared to other minerals.

**Potable Water and Public Health Testing** has been extensive. Each state or country seems to have its own standard or methodology. The most rigorous testing of the Xypex treatment has been performed according to the NSF International methodology. This involves an audit of our plant and independent selection of Xypex products to be tested.

# ABSTRACTS OF INDEPENDENT TESTING OF XYPEX

## **WATER PERMEABILITY TESTING**

### ***U.S. Army Corps of Engineers (USACE) CRD C48-73 “Permeability of Concrete”***

***Pacific Testing Labs, Seattle, USA PERM-100***

Two inch (51 mm) thick, 2000 psi (13.8 MPa) concrete samples were pressure tested for water permeability up to a 405 ft. (124 m) water head (175 psi/1.2 MPa), the limit of the testing apparatus. While untreated samples showed marked leakage, the Xypex Concentrate treated samples (as a result of the crystallization process) became totally sealed and exhibited no measurable flow through the sample.

### ***U.S. Army Corps of Engineers (USACE) CRD C48-73 “Permeability of Concrete” Warnock Hersey Lab Vancouver, Canada PERM-101***

Samples measuring 6 x 3 inches (150 mm x 74 mm) were cast utilizing 3000 psi (20.7 MPa) concrete. Following application and curing of the Xypex Concentrated treatment, the samples were placed into sealed vessels for water permeability testing. The maximum pressure of this particular apparatus of 180 psi (1.24 MPa) was attained and “it can be concluded that the samples treated with Xypex did not show any permanence or leakage”.

***U.S. Army Corps of Engineers (USACE) CRD C48-73 “Permeability of Concrete”***

***Aviles Engineering Corp., Houston, USA***

***PERM-102***

Two concrete samples containing Xypex Admix at 3% and 5% respectively, and an untreated control sample, were tested for water permeability. Both the treated and untreated samples were subjected to a pressure of 150 psi (350 ft. head of water). Results showed moisture and permeated water throughout the untreated sample when split in half after 24 hours. However, the Xypex Admix samples showed no flow through the sample, and water penetration of only 1.5 mm after 120 hours (5 days).

***U.S. Army Corps of Engineers (USACE) CRD C48-73 “Permeability of Concrete”***

***Setsco Services, Pte Ltd, Singapore***

***PERM-103***

Six Xypex Admix-treated and six untreated concrete samples were tested for water permeability. Pressure was applied in increments over seven days and then maintained at 7 bars (224 ft. head of water) for 10 days. The six reference samples showed water flowing through the sample beginning on the fifth day and increasing throughout the test period. In contrast, the Xypex Admix samples showed no water permeation at any time during the test.

***DIN 1048 “Water Impermeability of Concrete” Bautest - Corporation for Research & Testing of Building Materials, Augsburg, Germany*** ***PERM-200***

Xypex-treated and untreated concrete samples 200 mm thick were pressure tested up to 7 bars (230 ft./70 m water head) for 24 hours to determine water impermeability. The control samples measured water penetration up to a depth of 92 mm. The Xypex-treated samples measured water penetrations in the samples to an average of 4 mm, with one sample measuring zero.

***DIN 1048 “Water Impermeability of Concrete” DICTU S.A. Dept. Of Engineering and Construction Mgt., Santiago, Chile PERM-201***

Xypex Admix treated concrete samples and control samples 120 mm thick were tested to determine water permeability. Samples were subjected to pressure for 28 days. It was noted that water had totally permeated through the untreated samples but no water penetration was detected in any of the Xypex-Admix-treated samples.

***Onorm B 3303 “Water Impermeability of Concrete” Technologisches Gerwerbemuseum, Federal Higher Technical Education & Research Institute, Vienna, Austria  
PERM-202***

Xypex-treated concrete samples were pressure tested to a maximum 7 bars (230 ft./70 m water head) for 10 days. Tests revealed that while 25 ml of water had penetrated the untreated concrete samples, no measurable volume had penetrated the Xypex-treated samples. Test specimens were then broken and showed water penetration to a depth of 15 mm on untreated samples but no measurable water penetration on the Xypex-treated samples.

***Laboratories for Preparation and Methodology (LPM), Luzern, Switzerland  
PERM-205***

Untreated specimens and Xypex treated specimens (7 cm thick) were subjected to a water pressure of  $2.8 \times 10^4$  Ap dyn/cm<sup>2</sup> for 10 months. The purpose of the testing was to determine the ability of the Xypex material to make the concrete impermeable. The test results indicate that the Xypex treated sample was shown to have “very good imperviousness”, at  $7 \times 10^6$  higher than that of the untreated reference sample.

***GOST 12730.5-84 Testing Procedures “Evaluation of Water Tightness”, Orgenergostroi, Center of Technology and Quality, Nuclear Power Stations Engineering - Central Construction Laboratory, Moscow, Russia PERM-206***

Concrete cylinders were cast 150 mm x 150 mm with a design water tightness of W2 or 2 atmospheres according to standards of GOST 12730.5-84. Samples were moist cured for 28 days and then treated with 2 coats of Xypex Modified to a thickness of 1 mm each. Control samples were also moist cured for 28 days.

GOST 12730.5-84 test procedures are utilized to determine “water tightness” or ability of a product to make concrete impermeable. The test methodology is similar to the European DIN 1048 procedures. Water pressure was applied to the negative side (opposite surface to the Xypex treatment) of the cylinder samples and the pressure was increased in increments over time. Test results for the untreated control samples produced the design water tightness index of 2 atmospheres. The samples treated with the Xypex Modified had the following “water tightness” indices: 3 days - 4 atmospheres, 7 days - 7 atmospheres, 14 days - 8 atmospheres, and 28 days - 8 atmospheres. (Note - 1 atmosphere=14 psi or 32.4 ft of head pressure).

***GOST 12730.5-84 Testing Procedures “Evaluation of Water Tightness”,  
Orgenergostroi, Center of Technology and Quality, Nuclear Power Stations  
Engineering - Central Construction Laboratory, Moscow, Russia PERM-207***

Concrete cylinders were cast 150 mm x 150 mm with a design water tightness of W2 or 2 atmospheres according to GOST 12730. Xypex Concentrate was applied to the samples at the rate of 1 kg per m<sup>2</sup>. The samples were cured and the negative side (surface opposite to the Xypex treatment) of the cylinder was subjected to hydrostatic pressure for 14 days. The Xypex treated samples withstood a pressure of 12 atmospheres (168 psi or 389 ft. head pressure). The Xypex treatment demonstrated a sharp rise in the concrete’s impermeability to water at all stages and that the effect increases with time. Tests were also conducted on sample cylinders where a second coat of Xypex Modified was applied on top of the hardened Concentrate coat. It was shown that an additional “waterproofing” effect can be achieved by utilizing this two-coat system.

Testing was also performed on a Xypex Patch’n Plug installation. Concrete cylinders were cast 150 mm x 150 mm with a design water tightness of W2 or 2 atmospheres according to GOST 12730.5. A hole measuring 15 mm wide by 3 mm deep was cored into the surface of the cylinder. Xypex Patch’n Plug was placed into this hole and firmly packed until hardened. The hole that was filled with Xypex Patch’n Plug was then subjected to hydrostatic pressure as per GOST 12730.5-84. Test result confirmed that Xypex Patch’n Plug repair material withstood 14 atmospheres of pressure (196 psi or 454 ft. head pressure).



***DIN 1048 Test Procedures “Evaluating Depth of Water Penetration Under Pressure”, Klokner Institute of the Czech Technical University, Prague, Czech Republic***

*PERM-208*

Six concrete block samples 200 mm long x 100 mm high with a compressive strength of 23.2 mPa were utilized for the permeability testing. Three were treated with a coating of Xypex Concentrate followed by a coating of Xypex Modified and then cured. Three untreated concrete block samples were similarly cured. Water pressure was applied to the positive side (surface of the Xypex treatment) of the concrete block samples and the pressure was increased in increments over time (100 kPa for 48 hours, 300 kPa for 24 hours, and then 700 kPa for 24 hours). All samples were then broken transversely to expose the depth of water penetration. The depth of water penetration for the Xypex samples averaged 17 mm, while the untreated samples all allowed water to penetrate the entire thickness of the samples (ie. 100 mm).

## **CHEMICAL PERMEABILITY RESISTANCE**

### ***Test Procedures “Evaluating Fluid Tightness and Measurement of Penetration Under Pressure of Sulfuric Acid and Sulfide”, Technical Testing Institute of Civil Engineering, Bratislava, Slovak Republic REST-200***

Eighteen concrete samples measuring 150 x 150 x 150 mm were prepared to the standard Class B 20 (STN 73 2400). Six samples were prepared with a one coat application of Xypex Concentrate, another six had a second coat of Concentrate applied. The twelve treated samples and six reference samples were similarly cured in a moist curing room. A similar number of each of the above samples were subjected to a solution of either Sulfuric Acid or Sulfide using an apparatus that exerted 1.20 kPa of pressure for a 7 day period. Special measures were taken to avoid evaporation or volatilization of the solutions. Each sample was then fractured in a press transversely to expose the depth of penetration of the solution. In the Sulfuric Acid test, the three samples with the single Xypex Concentrate coating and the three samples with a two-coat application showed an average 1.2 mm for the depth of penetration. The three non-treated samples showed an average penetration of 48 mm. In the test using the Sulfide solution, all six samples with the Xypex Concentrate coating(s) had no penetration. The three non-treated samples showed an average penetration of 1.7 mm.

### ***Test Procedures “Evaluating Fluid Tightness and Measurement of Penetration Under Pressure of Acetone”, Technical Testing Institute of Civil Engineering, Bratislava, Slovak Republic REST-201***

Eighteen concrete cubes measuring 150 x 150 x 150 mm were prepared to the standard Class B 20 (STN 73 2400). Nine samples were prepared with a single coat application of Xypex Concentrate and then cured. Nine reference samples were similarly cured. All samples were then subjected to a solution of Acetone using an apparatus that exerted 1.70 kPa of pressure for a 7 day period. Special measures were taken to avoid evaporation or volatilization of the solutions. At intervals of 24 hours, 3 days and 7 days of exposure, three treated and three untreated samples were fractured in a press transversely to expose the depth of penetration of the solution. All nine samples with the Xypex Concentrate coating showed no penetration. The three non-treated samples broken at 24 hours showed an average penetration of 21.7 mm. The three non-treated samples broken at 3 days showed an average penetration of 36.7 mm. The three non-treated samples broken at 7 days showed an average penetration of 48.3 mm.

## **PETROLEUM PRODUCTS PERMEABILITY TESTING**

### ***Test Procedure No. 28, "Impermeability and Resistance to Diesel Oil, Klokner Institute, Czech University, Prague, Czech Republic***      PETR-100

Xypex treated samples were exposed to various liquids, including silage juices, diesel oil, gasoline and transformer oil to a pressure of 14 kPa. The depth of penetration of these liquids into concrete samples (with a average design strength of 29.9 Mpa) was determined following a 28 day exposure. All samples were then split open to expose the depth of penetration. With each liquid, the Xypex treated samples significantly reduced the depth of penetration compared to that of the control samples.

### ***Test Procedures for "Impermeability and Resistance to Crude Oil" Institute of Civil Engineering, Technology and Testing, Bratislava, Slovak Republic*** PETR-101

Xypex-treated and untreated concrete samples were tested to determine resistance and impermeability to crude oil. A PVC tube measuring 1500 mm in height and 100 mm in diameter was attached to the surface of each specimen. The tubes were filled with 1400 mm of crude oil and sealed at the top to prevent evaporation. Samples included: un-treated concrete specimens, samples with 1 coat of Concentrate, samples with 1 coat of Modified, samples with 2 coats of Concentrate and samples with 2 coats of Modified. Both treated and untreated samples were subjected to contact with the various fluids up to 14 kPa (1.4m of water column) for 28 days. Samples were broken transversely to expose the depth of the liquids' penetration. In comparison to the control samples, the Xypex-treated samples enhanced the concrete's resistance and provided effective protection against the penetration of these solutions.

***Test Procedures for “Impermeability and Resistance to Various Fluids” and  
CSN1209 & 1321 (Modeled on the DIN 1048 Test Procedures)  
“Impermeability and Resistance to Pressurized Water”, Institute of Civil  
Engineering, Technology and Testing, Bratislava, Slovak Republic      PETR-  
102***

The basis of this test regime was to determine the ability of Xypex treated concrete in comparison to untreated concrete to make concrete impermeable to various fluids, including: diesel oil, transformer oil, gasoline, silage juices and pressurized water. Samples included: un-treated concrete specimens, samples with 1 coat of Concentrate, samples with 1 coat of Modified, samples with 2 coats of Concentrate and samples with 1 coat of Concentrate and a second coat of Modified. Two separate test procedures were utilized. The first test procedure subjected both treated and untreated concrete specimens to contact with the above solutions. A PVC tube measuring 1500 mm in height and 100 mm in diameter was attached to the surface of each specimen and the tubes were filled with each of the solutions to a height of 1400 mm (ie. 1.4 MPa / 1.4 m of head pressure) and was maintained for 28 days. The samples were then broken transversely to visually examine and measure the depth of penetration of each solution. In each case, it was noted that the Xypex treated samples reduced the depth of penetration of the various fluids. In a similar fashion, treated and untreated samples were exposed to pressurized water to a maximum of 1.2 MPa for 28 days (refer to PERM-203)

## **AIR PERMEABILITY TESTING**

***“Test of Air Permeability” Department of Concrete Construction and  
Bridges, Faculty of Civil Engineering, Bratislava, Slovak Republic      AIR-  
100***

Cored concrete samples, 100 mm diameter and 30 mm long, were tested for air permeability. Samples were dried up to reach a stable weight of 105° C and were then left to cool down to the temperature of the testing chamber. The samples were placed into sealed testing cells and air was forced through the concrete cylinders using a pressure of 100 kPa. The volume and time period for air to pass through each sample was measured. The samples were then treated with a two-coat application of Xypex Concentrate, moist cured for 2 day and then air cured for 18 days. The samples were again dried up at a temperature of 105° C, left to cool down and then placed into the sealed cell. Air was again forced through the concrete cylinders using a pressure of 100 kPa. The flow rate of air passing through each sample was measured. The Xypex treated samples reduced the air permeability in half compared to that of the untreated samples.

## **CARBONATION RESISTANCE**

### ***“Evaluating the Effectiveness of Xypex Treatment to Suppress or Limit Carbonation”, Building Materials Testing Center, Tokyo Japan***

*CARB-100*

Concrete prism samples were produced in accordance with the Japanese atomic surface barrier specification. Some of the samples were treated with a Xypex coating. Treated and untreated samples were placed in a chamber for two month at 30° C, 60% relative humidity (RH) and 5% carbon dioxide (CO<sub>2</sub>). The test results indicated that the Xypex samples reduced carbonation by 70 - 80% as compared to the control samples.

## **SEALING CRACKS**

### ***“Testing of Xypex Repair of Heavily Cracked Bridge Deck Subjected to Continuous Load and Vibration” Construction Bureau of Chubu District, The Ministry of Construction, Hokutoh Overpass - National Route 23, Chubu District, Japan***

**CRAK-101**

A series of field tests were performed on the concrete bridge deck of the Hokutoh Overpass in Chubu Japan. The purpose of the test was to determine if a Xypex Concentrate treatment would permanently seal the cracks in this dynamic concrete structure. Two sections of the bridge deck were utilized in this test. In August 1994 Xypex Gamma Cure was applied at a rate of 1.2 kg / m<sup>2</sup> to one section prior to a brush application of Xypex Concentrate to accelerate the crystalline growth. In July 1995 (10 months following application) testing was initiated on 10 cores (10 cm in diameter & 20 cm long) extracted from the decks. The Xypex treated section and the untreated section were both tested. A series of tests were conducted on the samples, including permeability, compressive strength and scanning electron microscopy (SEM).

Six samples were placed in the testing apparatus with the treated surface opposite to the pressure side. Samples were then subjected to a hydrostatic pressure of 2 kgf / cm<sup>2</sup> for 16 hours to measure any leakage or “output”. The samples treated with Xypex Concentrate had some initial minor leakage but this gradually decreased and stopped entirely. In contrast, the group of untreated specimens had an initial outflow reaching almost 5 ml/sec and due to the amount of leakage, it was assumed that the water flow through the cracks in these untreated samples was constant.

***“Testing of Xypex Treatment Ability to Block Capillary Pores and Seal Cracks”, James Neill and Associates, Vancouver, Canada CRAK-102***

A “cracked slab test” was specifically developed to determine the effectiveness of a coating to re-seal a non moving crack that occurs after the coating is applied (ie. the crack penetrates through the coating). This test can also be used to distinguish between waterproof coatings that simply act as a barrier and those that release reactive chemicals to accomplish waterproofing. The test procedures basically involved coating a concrete paving stone with a two coat system of Xypex Concentrate and Xypex Modified. The treated slab was then cracked in half and the two halves were set back together with a crack width of 0.2 and 1.0 mm. for two sample slabs. A dam was then placed around the perimeter of the slab and sealed so that the top surface can pond water. The slab was then elevated to allow for observation and measurement of any water-flow through the crack to the underside. The reservoir was filled and the water was maintained at a constant level. Initially water leaked through the cracks, with the crack self-healing over time. The test specimens were subjected to ponded water for 100 days at which time it was clear that the cracks had totally re-sealed with the Xypex crystalline structure.

***ASTM C856-88 “Standard Practice for Petrographic Examination of Hardened Concrete”, Setsco Services Pte. Ltd., Singapore CRAK-103***

A number of cores were extracted from a concrete deck at various intervals (3, 10, 14 and 20 days) after application of the Xypex treatment. The slab had developed numerous hairline cracks and a petrographic examination of the cores was undertaken to determine the crack sealing capabilities of the Xypex treatment. This included both a visual inspection and a microscopic analysis using a polarizing and fluorescent microscope (PFM) under transmitted and reflected light of thin sections sawn from the core. The results of the visual inspection of the extracted core samples showed evidence of cracks with various widths typically along the whole length of the core. Typically the cracks were widest at the top surface. A hardener was noted in the top 9-10 mm of the core, while the deeper layers of the core consisted of normal concrete. A steel bar was observed 74 mm below the top surface. The concrete appeared homogeneous, with low voids (@ 0.5%) and no sign of damage was observed. Thin sections were taken from each core in preparation for examination of the hairline cracking. In each case, the examination showed evidence that the Xypex crystalline structure had penetrated into the crack to a depth of about 20 mm. It was also noted that the Xypex crystalline structure in this 20 mm section had reduced the width of the cracks dramatically. Photographs at 100 x magnification of the crack was taken showing evidence of the Xypex crystallization.



## **POROSITY TESTING**

***“Porosimetric Testing”, Klotner Institute, Czech Technical University, Prague, Czech Republic***

*PORS-100*

Two concrete samples were prepared to the standard Class B 20 (STN 73 2400). One sample was treated with a single coat application of Xypex Concentrate and the other remained untreated for reference purposes. Both samples were subjected to a porosimetric test by means of a high-pressure porosimeter, which can apply up to 100 mPa of pressure to determine the size of pores between 7.5 and 7,500 mm. The average pore size of the untreated sample was 41.6 mm<sup>3</sup> /g, and 25.2 mm<sup>3</sup> /g for the treated sample. It was also shown that there was a decrease in the overall porosity of the Xypex treated sample to almost half that of the untreated sample.

## **SCANNING ELECTRON MICROSCOPY**

### ***Scanning Electron Microscopy “Observing and Photographing the Xypex Crystalline Structure Within the Concrete” Central Research Laboratory of Nikki Shoji in association with Hosei University, Japan SEM-100***

A concrete block measuring 60 cm (W) x 70 cm (L) x 40 cm (H) was cast. Xypex was applied to the block and cured. The block was left outdoors for approximately 1 year. A specimen for observation by SEM was a core of concrete with a length of 40 cm cut perpendicularly to the Xypex treatment. The cylinder was then cut into 18 pieces of equal length and numbered for reference purposes. SEM measurement was carried out by using Nihon-Denshi Corporation's Super Probe 733. Observation of the crystal growth was made at a 20x magnification factor. The crystal growth was then photographed with a 1000x magnification factor. Photographs were taken at various depths (10 cm, 20 cm & 30 cm) from the surface of the Xypex application. It was noted that the crystalline structure was most dense in the photographs taken of the concrete located closest to the treated surface. It was also noted that there was evidence of the Xypex crystalline growth in the concrete at 30 cm from the treated surface. SEM photographs of an untreated sample were also undertaken, showing no evidence of crystallizing formation.

### ***Scanning Electron Microscopy “Observing and Photographing the Xypex Crystalline Structure Within the Concrete” Central Research Laboratory of Nikki Shoji, Japan SEM-101***

This is a second SEM test carried out by the Central Research Laboratory of Nikki Shoji. A cylindrical concrete test specimen was treated with a slurry coating of Xypex Concentrate and cured with a water mist spray for 10 days. The opposite (untreated) end of the test piece was then immersed in shallow water for 14 days. An untreated control sample was sheared through at 50mm below the surface and a SEM photograph was taken of the sheared face. Precipitated  $\text{Ca}(\text{OH})_2$  Calcium Hydroxide together with cubic and rhombi particles were visible. The sample treated with Xypex was similarly sheared through at 50mm below the treated surface and a SEM photograph was taken to illustrate considerable crystalline growth at the initiation phase of the Xypex treatment (ie. at 24 days following application). A SEM second photograph was taken of this sheared surface (ie. 50mm from the treated surface) 26 days after the application of Xypex Concentrate. A dense, fully developed crystalline structure had formed within the capillary tracts of the concrete to completely block the flow of water.

**Scanning Electron Microscopy “Testing of Xypex Repair of Heavily Cracked Bridge Deck Subjected to Continuous Load and Vibration” Construction Bureau of Chubu District, The Ministry of Construction, Hokutoh Overpass - National Route 23, Chubu District, Japan**

SEM-102

A series of site testing including Scanning Electron Microscopy (SEM) was performed on samples from the concrete bridge deck of the Hokutoh Overpass in Chubu Japan. The purpose of the test was to determine if a Xypex Concentrate treatment would permanently seal the cracks in this dynamic moving concrete structure. Two sections of the bridge deck were utilized in this test. In August 1994 Xypex Gamma Cure was applied to one section as an accelerant prior to a brush application of Xypex Concentrate at a rate of 1.2 kg / m<sup>2</sup>. In July 1995 (10 months following application) testing was initiated as 10 cores (10 cm in diameter & 20 cm long) were extracted from the decks, including both the Xypex treated section and the untreated section. Initial testing included permeability and compressive strength before undertaking the SEM testing.

Samples were subjected to a negative side hydrostatic pressure of 2 kgf / cm<sup>2</sup> for 16 hours to measure any leakage or “output”. The samples treated with Xypex Concentrate had some initial minor leakage but this gradually decreased and stopped entirely. The untreated samples showed constant outflow up to 5 ml/sec. Compressive tests were conducted on three Xypex treated samples and three untreated samples according to JISA 1107. Results indicated that there was an average 28% compressive strength increase in the Xypex treated sample.

Treated and untreated specimens for SEM testing purposes were extracted from the cores. Scanning Electron Microscope (Model EMA-733) was used with a voltage of 29KV, 1 x 10<sup>-10</sup>A. The 10 micron voids were first examined under a magnification of 20x. A SEM photograph was taken at a magnification of 1000x. An increase of crystals can be observed in cracks in the Xypex Concentrate treated specimen. The untreated sample only the gel wall is observable. It was clear from this SEM testing that there was increased crystalline development in the cracks and by associating this evidence with the permeability testing it is clear that the Xypex treatment was effective in improving the durability of the concrete samples and hence a waterproofing effect resulted.

***Scanning Electron Microscopy “Testing of Xypex Repair to Cracks & Construction Joints of Deteriorated Tunnel Lining Subjected to Freeze-Thaw Damage”, Japan Rail Tunnel, Northern Japan***

***SEM-103***

To confirm the effects of the Xypex treatment to repair the leakage occurring in a Japan Rail tunnel, tests we conducted one year after the application of various Xypex crystalline products, including a two coat application of Xypex Concentrate and Xypex Modified with the additional use of Xypex Patch'n Plug for structural repair of crack and joints. Three separate cylindrical cores (86mm in diameter x 65mm in length) were obtained from the site, two from the area of the Xypex treatment and one from an area that had not been treated. The samples were sheared through at 5cm below the end surface and examined by Scanning Electron Microscopy (SEM). A photograph with a magnification of 1000x was taken of the internal structure of each of the concrete cylinders. In the case of the Xypex treated samples, increased crystalline growth is observed. No such crystalline structure is observable in the SEM photograph of the untreated concrete cylinder. Both the treated and untreated specimens were subjected to permeability testing with a hydrostatic pressure of 5kgf/cm<sup>2</sup>. The coefficient of permeability for the two treated samples was 0 and 11.6, while the untreated sample was 112.7. The Xypex application was examined 4 years after the treatment. No water leakage and deterioration due to freeze-thaw were observed.

## **CHEMICAL RESISTANCE**

### ***ASTM C 267-77 “Chemical Resistance of Mortars”, Pacific Testing Labs, Seattle, USA***

*CHEM-100*

Xypex-treated cylinders and untreated cylinders were exposed to hydrochloric acid, caustic soda, toluene, mineral oil, ethylene glycol, pool chlorine and brake fluid and other chemicals. Results indicated that chemical exposure did not have any detrimental effects on the Xypex coating. Following chemical exposure, the Xypex treated specimens had measured an average 17% higher compressive strength over the untreated control samples.

### ***“Evaluation of Resistance to Acid Attack”, Japan Atomic Energy Research Institute, Tokyo, Japan***

*CHEM-101*

Xypex treated samples and untreated samples were subjected to a 5% H<sub>2</sub>SO<sub>4</sub> solution for 100 days. A measurement of the “corrosion ratio” (ie. ratio of final to initial mass) for the treated sample was 11.7%, while the untreated sample was 21.0%.

### ***IWATE University Technical Report “Resistance to Acid Attack” Morioka, Japan***

*CHEM-102*

Xypex Concentrate treated mortar and untreated mortar were measured for acid resistance after exposure to a 5% H<sub>2</sub>SO<sub>4</sub> solution for 100 days. Xypex suppressed concrete erosion to 1/8 of the reference samples.

### ***“Chemical Durability Test”, C.R.S. (Central Research Laboratory), Tokyo, Japan***

*CHEM-103*

Concrete mortar samples containing 5% Xypex Admix were tested against containing other admixtures, and untreated control samples to determine resistance to corrosion (ie. mass loss) and deterioration caused by contact with aggressive chemicals. All samples were soaked in a 5% sulfuric acid solution at 20° C for six months. Various evaluations and measurements were assessed every month during the test period, including: visual comparison, relative dynamic modulus of elasticity, change in length, weight and flexural rigidity. Although the Xypex Admix sample was subjected to acid conditions well outside its published range, the results found that Xypex had the best performance among the samples tested.

***“Sulfuric Acid Resistance Test”, Aviles Engineering Corporation, Houston, USA***

*CHEM-104*

Concrete samples containing Xypex Admix at different dosage rates (3%, 5% and 7%) were tested against untreated control samples for sulfuric acid resistance. After immersion in the sulfuric acid, each sample was tested for weight loss on a daily basis until a weight loss of 50% was obtained. The weight loss of the samples containing Xypex Admix was significantly lower than the control samples.

***“Sulphate Resistance Test” Taywood Engineering Ltd., Perth, Australia***

*CHEM-105*

Xypex Admix-treated concrete samples were immersed in an ammonium-sulphate solution and tested for “resistance in a harsh environment”. The performance of the Xypex-Crystalline-Technology was compared with five other concretes, including one containing a sulphate-resistant cement and one containing silica fume. Each of the test samples was cured for seven days and then placed in an ammonium-sulphate solution (132 g/l) for 180 days. The rate of deterioration was determined by measuring weight loss and length change (bulk expansion) on a weekly basis. The Xypex crystalline technology substantially improved concrete performance as compared to the reference concrete(s) and in particular provided the highest level of protection as measured by lowest relative length gain.

***“Evaluation of Chloride Ion Penetration into Concrete” Mahaffey Associates Pty. Ltd, Rydalmere, Australia***

*CHEM-107*

Five concrete 150 mm cylinders containing the Xypex Admix were cast along with similar cylinders with no Admix and other cylinders with a pore blocking additive. All samples were exposed to a varied regime of exposure to a salt water bath. Samples were also tested for compressive strength, flexural strength and drying shrinkage. Samples from each of the cylinders were cycled in and out of salt water every 24 hours for 28 days, 90 days and 180 days immediately after casting. Other samples were water cured for 7 days then cycled in and out of salt water every 24 hours for 83 days. Other samples were water cured for 56 days then cycled in and out of salt water every 24 hours for 28 days (ie most common form of diffusion testing). Following immersion, each cylinder sample's face was ground down to remove increments of 2 mm depth of concrete dust. The dust samples were then tested for chloride ion content.

Results of this chloride ion testing regime clearly indicate that the Xypex treated samples reduce the amount of chloride ion penetration significantly especially if concrete is allowed to cure for 7 days prior to immersion. Based on this regime the amount of chloride diffusion ( $\text{m}^2/\text{s} \times 10^{-12}$ ) was 11.1 for the untreated concrete sample, 16.4 for the concrete containing the pore blocker and 8.1 for the Xypex Admix sample.

***“Chloride Ion Penetration & Chloride Diffusion Analysis”, Building Research Centre (BRC), University of New South Wales, Sydney, Australia*** CHEM-108

Precast concrete slabs containing Xypex Admix were exposed to a severe marine environment for four years, then were evaluated and tested for chloride ion penetration. A slab that had been manufactured at the same time, but had not been installed and therefore not exposed to the marine environment was used for comparison purposes. Visual observation indicated that the concrete pre-cast planks showed no signs of deterioration as a result of exposure to this harsh marine environment. Concrete powder samples were taken from each slab at four depths (5-15 mm, 15-25 mm, 25-35 mm & 35-45 mm). The powder samples were analyzed for chloride ion contents. Test results of the samples containing the Xypex Admix, showed that the chloride content was relatively low and drops rapidly with an increase in the slab depth. A “Half-Cell Potential Survey” was also performed and a contour map of the deck slab was undertaken to plot any pattern of surface corrosion on the slabs exposed to the marine environment. The results indicated a few minor spots of active corrosion reactions.

## **FREEZE-THAW DURABILITY**

### ***JIS A 6204 “Concrete Freeze/Thaw”, Japan Testing Center For Construction Materials, Tokyo, Japan***

#### ***FREZ-101***

The resonating frequency of both untreated and Xypex Concentrate treated concrete samples were measured throughout 435 freeze/thaw cycles. At 204 cycles, the Xypex-treated samples showed 96% relative durability compared to 90% in the untreated samples. At 435 cycles, the Xypex-treated samples measured 91% relative durability compared to 78% in the untreated reference samples.

### ***ASTM C 666 “Freeze/Thaw Durability”, Independent Laboratory, Cleveland, USA***

#### ***FREZ-102***

After 300 freeze/thaw cycles, the Xypex Admix treated samples which were air entrained indicated 94% relative durability.



## **RADIATION RESISTANCE**

### ***U.S.A. Standard No. N69 “Protective Coatings for the Nuclear Industry” Pacific Testing Labs, Seattle, USA RADN-100***

Xypex treated samples were exposed to  $5.76 \times 10^4$  rads of gamma radiation. Visual examination, photographic documentation, and adhesion testing (ASTM 3359-78) was performed on the Xypex treated sample. There was no indication of any visible change or damage due to exposure to gamma radiation.

### ***Japan Atomic Energy Research Institute (JAERI) “Exposure to Radioactive Solution $^{137}\text{Cs}$ ”, Tokyo, Japan RADN-101***

JAERI performed comparative testing on cement mortar treated with Xypex to that of untreated reference samples to determine if there is a difference in the penetration of the radioactive solution  $^{137}\text{Cs}$ . The test results demonstrated that the penetration of radioactive  $^{137}\text{Cs}$  was reduced in the cement mortar specimens that were coated with the Xypex. At a depth of 5 to 7 mm the concentrate of the radioactive solution  $^{137}\text{Cs}$  was about 10 times less in the Xypex treated samples than the untreated sample.

## **COMPRESSIVE STRENGTH**

### **ASTM C 39 “Compressive Strength of Cylindrical Concrete Specimens”**

***HBT Agra, Vancouver, Canada      COMP-100***

Concrete samples containing Xypex Admix at various dosage rates (1%, 2% and 5%) were tested against an untreated concrete control sample. Compressive strength test results after 28 days indicated a significant strength increase in the samples incorporating Xypex Admix. The compressive strength increase varied between 5% and 20% (depending on the Xypex Admix dosage rate) over that of the reference sample.

### **ASTM C 39 “Compressive Strength of Cylindrical Concrete Specimens”**

***Kleinfelder Laboratories, San Francisco, USA      COMP-101***

Kleinfelder evaluated the compressive strength of concrete containing the Xypex Admix. At 28 days the compressive strength test for the Xypex Admix sample measured 7160 psi (49 MPa) as compared to the reference sample at 6460 psi (44 MPa), a 10% increase. Compressive strength results performed at 56 days indicate that the concrete sample containing the Xypex Admix reached a 8340 psi (57 MPa) as compared to the reference with 7430 psi (51 MPa) at 12% increase.

### **BS 1881 : Pt 120 : 1983 “Compressive Strength Testing”, Setsco Services**

***Pte. Ltd., Singapore***

***COMP-103***

Compressive strength testing in accordance with British Standards (BS) 1881 : Pt 120 : 1983. Testing was performed on 15 Xypex Admix treated and untreated cubes measuring 150 mm x 150 mm x 150 mm at 1, 3, 7, 28, and 56 days. As well, compressive strength testing was performed at 7 and 28 days on two 100 mm x 900 mm cylinders (one treated and one untreated). The Xypex treated samples exhibited between 7 and 14% strength increase at 28 days over that of the control samples.

**“Compressive Strength of Cylindrical Concrete Specimens”, Contest  
Concrete Testing Pty. Ltd., Sydney, Australia   COMP-104**

Compressive strength testing was performed on cylinders containing the Xypex Admix. The concrete had been dosed with 4.2 kg of Admix per cubic meter and the design strength required 32 MPa at 36-40 hours. This strength was achieved and further test results indicated that the cylinders were 50 MPa at 7 days and 70 MPa at 28 days.

**ASTM C 109 “Compressive Strength of Xypex Patch’n Plug Specimens”  
Powertech Labs Inc., Surrey, Canada   COMP-106**

Compressive strength testings of 2" cubes of Xypex Patch’n Plug was performed with breaks at 24 hours, 7 and 28 days. The average compressive strength at 24 hours of test specimens was 14.3 MPa (2100 psi). The 7 day break results for test specimens was 21.3 MPa (3100 psi), 28 day break result for test specimens was 31.0 MPa (4500 psi).

## **TENSILE BOND STRENGTH**

### ***CSA A23.2-6B “Tensile Bond Pull-off, Xypex Patch’n Plug”, Metro Testing Laboratories Ltd., Vancouver, Canada TENS-100***

Tensile Bond Pull-off testing was performed on Patch’n Plug sample cubes. The average test result for 12 samples was 0.8 Mpa (120 psi).

### ***CSA A23.2-6B “Tensile Bond Pull-off, Xypex Concentrate & Xypex Modified Coating System”, Metro Testing Laboratories Ltd., Vancouver, Canada TENS-101***

Tensile Bond Pull-off testing was performed on the Xypex Concentrate and Xypex Modified coatings applied to concrete pavers. The test results of the samples was 1.49 Mpa (216 psi). In examining the bond failure, it was noted that the failure occurred to a greater extent in the concrete paver than in the Xypex coating.

### ***ESN 73 2577 “Test Procedures for Adhesion”, Klolner Institute, Czech Technical University, Prague, Czech Republic TENS-102***

Adhesion testing was performed on concrete samples where two pool paints (Biopol’s polystyrene rubber paint and Mathy’s Fassiclor paint) has been applied over samples where a single coat of Xypex Concentrate had been applied and where a two coat application of Xypex Concentrate and Modified had been applied. The paint was applied on samples both where a HCL rinse had been used and where no such preparation was performed. The adhesion testing was conducted on the samples 14 days following application of the paint. The adhesion results for the single coat Concentrate was 2.13 Mpa and for the two coat Concentrate and Modified was 2.15 Mpa.

## **ABRASION RESISTANCE TESTING**

***ASTM C 501-84 “Taber Abrasion of Xypex DS-2” AGRA Earth & Environment Ltd., / James Neill & Associates, Vancouver, Canada***

### ***ABRA-100***

Since 1978, various tests have been performed on concrete specimens containing the non-metallic / synthetic aggregate hardener utilized in Xypex DS-2. Testing included the evaluation of the concrete specimens for abrasion resistance as measured by mass loss (Taber Abrasion). The concrete control samples exhibited an average mass loss of 6.0 grams, while the five commercial hardeners tested had mass losses between 3.5 and 4.2 grams. Subsequent Taber Abrasion testing of concrete treated with Xypex DS-2 showed a mass loss of 3.3 grams. Xypex Quickset was then applied to samples treated with Xypex DS-2 and mass loss was further reduced to 2.2 grams. Test results indicate that use of Xypex DS-2 significantly improves the abrasion resistance of concrete.

## **APPROVALS RE POTABLE WATER & PUBLIC HEALTH**

XYPEX products have been tested for toxicity and / or its suitability in contact with potable water by numerous independent agencies throughout the world.

In each test, Xypex has been shown to be non-toxic and to contain no ingredients or constituents that are harmful to potable water. Approvals for Xypex use have been obtained from the following Government and / or Independent Agencies.

- NSF 61 “Drinking Water System Component - Health Effects”, NSF International, Ann Arbor, Michigan *APPR-100*
- Drinking Water Inspectorate - DWI - (UK Authority responsible for product approval re potable water), London, England *APPR-201*
- Singapore Institute of Standards and Industrial Research *APPR-102*
- Japan Food Research Laboratories (Water Quality Test according to Tap Water Act) Tokyo, Japan *APPR-203*
- Australian Water Quality Centre (Authority for approval of all products in contact with potable water) Bolivar, South Australia *APPR-204*
- State Health Institute & Center For Drinking Water, State Health Institute, (Prague, Czech Republic) *APPR-105*
- Federal Department of Health, Division of Chemicals (Berne, Switzerland) *APPR-008*
- National Institute of Occupational Health, Register of Substances and Materials (Copenhagen, Denmark) *APPR-009*
- Mairie De Paris, Research Center for the Control of Water, (Paris, France) *APPR-010*