Foundation Structure

A foundation is a structure that supports a building. The type of foundation varies according to ground conditions, structural material, structural type, and other factors.

- **Pile Foundations**
  
  Foundations consisting of vertical structures are forced into the ground by impact (a "pile driver"). Piles can be driven into bedrock, or more commonly, "to refusal" (until underlying soil resists the pile being driven significantly further into the soil).

- **Mat Foundations**
  
  Mat foundations (also known as "raft foundations") are a foundation in which the entire building is placed on a large continuous footing. Mat foundations are utilized to effectively resolve special soil or design conditions.

  In locations where the soil is weak and the bedrock is extremely deep, "floating or compensated mat foundations" are utilized.

- **Spread Foundations**
  
  For spread foundations, the structural load is literally spread out over a broad area under the building. Spread foundation systems utilize one or more horizontal mats or pads to anchor the building as a whole or to anchor individual columns or sections separately. Spread foundations are also known as "footing foundations" and are often utilized in low-rise buildings.
• **Load-bearing Wall Foundations**

Many building foundations, including buildings that have basement levels, apply slurry to the edges of the wall to hold out surrounding dirt. In some cases this slurry wall, or other underground wall element, becomes a major load-bearing part of a high-rise building's foundation. This type of foundation is usually found in combination with one of the others stated above.

• **Caisson Foundations**

Caisson foundations are similar in form to pile foundations but are installed using a different method. Caissons (also called "piers") are created by auguring a deep hole into the ground and filling it with concrete. Steel reinforcement is sometimes utilized for a portion of the length of the caisson.

Caissons are drilled either into the bedrock (called "rock caissons") or deep into the underlying soil strata if a geo-technical engineer finds the soil suitable to carry the building load. When caissons rest on soil, they are generally "belled" at the bottom to spread the load over a wider area. Special drilling bits are used to remove the soil for these "belled caissons".
Why Concrete Structures Deteriorate

Moisture, water and chemicals damage to concrete

- **Even concrete of high quality is a porous material**
  - Excess water evaporation during hardening will leave millions of pores and capillaries in concrete
  - The zones between cement and aggregates are prone to cracking during hardening due to drying shrinkage, temperature stress and outside forces

- **Porosity of concrete**
  - Allows moisture, water and chemicals to move freely throughout the concrete
  - Increases absorption of deleterious chemicals

- **Moisture, water and chemicals intrusion**
  - Result in corrosion of the concrete due to chemicals dissolved in water
  - Result in concrete neutralization (carbonization)
  - Result in alkali-aggregate reaction
  - Freeze/thaw cycles can lead to concrete cracking and damage
  - Reduce structural property
Moisture, water and chemicals damage to reinforcing steel

Millions of pores and capillaries are left in untreated hardened concrete

Chlorides penetrate into concrete with the help of surface moisture and water

When chlorides penetrate to reinforcing steel, corrosion begins

Further penetration of chlorides results in further corrosion, deterioration and spalling

Over time, any untreated concrete structure will succumb to damage in the presence of water and chemicals.
What Are Penetron Products?

- **Penetron products are cementitious capillary crystalline waterproofing materials**
  - Powders consisting of Portland cement, quartz sand and multiple activating chemicals
  - A range of activating chemicals in powder form that can be applied to concrete as a admixture, slurry and dry-shake

- **Penetron products can effectively stop water and moisture penetration into concrete, and provide the best protection for concrete by improving the capillary structure and reducing porosity**
  - Penetron: Applied by brush or spray on hardened concrete surface
  - Penetron Plus: Dry shake application on horizontal fresh concrete surface
  - Penetron Admix: An additive mixed into new concrete at the time of batching for complete integral waterproofing

- **Application**
  - Water towers & storage tanks
  - Subway & other tunnel systems
  - Off-shore & marine structures
  - Sewage and water treatment plants
  - Reservoirs & dams
  - Bridge decks
  - Basements
  - Traffic-bearing structures
  - Swimming pools
  - Parking decks
  - Foundations
  - Elevator shafts

- **Company passed ISO 9001 quality system authentication**
How Penetron Products Waterproof & Protect Concrete

- **Penetron or Penetron Plus**

1. Typical concrete structure with moisture
2. When mixed with water and applied as a coating, the active chemicals in Penetron cause a reaction leading to the formation of nonsoluble crystals within the pores and capillary canals of concrete.
3. The concrete becomes permanently sealed and neither water nor any other liquids are able to penetrate the concrete from any direction.

Concrete has been saturated with water so that there is an adequate amount of liquid water present to allow movement of chemicals into the concrete pores. The chemicals are pushed into the concrete through the action of diffusion. Under the right conditions, the chemicals can also move into the concrete by seeping water, or by the natural wicking action of the concrete.

Once into the concrete, the chemicals react with unhydrated cement particles and by-products of cement hydration to form needle-like crystals, which fill and block the pores and capillaries in the concrete. As water can no longer pass through the concrete, the concrete is said to be “waterproof”.

In absence of moisture, the activating chemicals remain dormant in concrete for years. If minute cracks recur at any time, any penetrating moisture can activate the dormant materials, and the chemical reaction and sealing process will repeat itself automatically.
**Penetron Admix**

Penetron Admix is a unique crystal-forming additive that provides permanent protection for buildings and other structures by waterproofing concrete from the inside out.

Penetron Admix is added to the concrete mix at the time of batching. The activating chemicals of the product react with water, unhydrated cement particles and by-products of cement hydration in concrete to form needle-like crystals. These crystals grow and migrate through the concrete to fill in hairline cracks and microscopic voids that would otherwise serve as passages for harmful moisture.

Penetron Admix enhances the natural hydration process in concrete by intensifying hydration crystal growth, increasing compressive strength and reducing cracking caused by shrinkage.

In absence of moisture, the activating chemicals remain dormant in concrete for years. Should cracks recur at any time, these dormant materials are activated by any penetrating moisture, and the chemical action and sealing process repeats itself automatically.
Features, Advantages & Benefits

- **Features and Advantages**

  -- Penetron Admix

  **Permanent waterproofing admixture**
  - Impermeability lasts as long as the concrete
  - System becomes an integral part of the concrete
  - Does not require re-application

  **Resists high hydrostatic pressure from either positive or negative surface**
  - Ideal for below grade application
  - Does not need any other form of waterproofing
  - Protects against waterborne ground contaminants

  **Protects reinforcing steel from corrosion**
  - Highly resistant to waterborne aggressive chemicals
  - Stops ingress of water required for AAR
  - Allows concrete to breathe, eliminating vapor buildup and leaving the concrete completely dry

  **Will grow crystals years after initial construction**
  - Will re-activate in the presence of moisture
  - Self-heals hairline cracks of up to 0.4mm and stop water ingress that may occur from subsequent damage to the structure
  - Continually improves with time

  **Multifunctional admixture**
  - Does not contain stearates, sodiums or silicates
  - Not a hydrophobic type product
  - Not a surface densification product
  - Assists concrete in the hydration process, acting as a catalyst to un-hydrated cement particles already existing in the concrete
  - Water-reducing, increasing workability of fresh concrete
  - Increases compressive strength of hardened concrete
  - Non-toxic
  - Approved for portable water use
In integral capillary barrier system, Penetron or Penetron Plus provides comprehensive concrete waterproofing.

**In-depth waterproofing property**
- Penetrates deeply, and impermeability lasts as long as the concrete
- System becomes an integral part of the concrete, forming a complete body of strength and durability
- Waterproofing and chemical resistance property remain intact even if the surface is damaged

**Completely effective against high hydrostatic pressure**
- Idea for below grade application, reservoirs and pipelines
- Does not require protection during backfilling, placement of steel or wire mesh and other common procedures
- Protects against waterborne ground contaminants

**Protects reinforcing steel from corrosion**
- Resists chemical attack (PH3-11 constant contact; PH2-12 periodic contact) and provides a wide range of protection from freeze/thaw cycles, aggressive waters, sea water, carbonates, chlorides, sulfates and nitrates
- Stops ingress of water required for AAR
- Allows concrete to breathe, eliminating vapor buildup and leaving the concrete completely dry

**Will grow crystals years after initial application**
- Will re-activate in the presence of moisture
- Self-heals hairline cracks of up to 0.4mm and stop water ingress that may occur from subsequent damage to the structure
- Continually improves with time

**Efficient application method**
- Can be applied from either the positive or negative side
- Can be applied to moist or green concrete
- Can be used for new or existing concrete
- Compatible with waterbased glues and surface coatings

**High-growth technology**
- Zero VOC
- Does not contain stearates, sodiums or silicates
- Not a hydrophobic type product
- Not a surface densification product
- Non-toxic
- Approved for portable water use
Benefits of Penetron Technology

-- Penetron Admix

Benefits to Property Owners

- Cost effective
- Lowers overall project costs
- Permanent waterproofing system
- Requires no maintenance
- Increases the quality of the concrete for structural performance and integrity
- Increases usage of infrastructure
- Eliminates down-time and costs associated with maintenance and repairs
- Reduces project time requirements
- Long-term manufacturer’s warranty
- Manufacturer’s history of international success in various climatic & environmental conditions

Benefits to Contractors

- Unmatched technical support
- Reduces application errors associated with installation of other systems
- Improves pouring and placement of concrete
- Eliminates construction delays due to elimination of traditional waiting period to install membranes on cured concrete

-- Penetron or Penetron Plus

Benefits to Property Owners

- Cost effective
- Lowers overall project costs
- Permanent waterproofing system
- Requires no maintenance
- Long-term manufacturer’s warranty
- Manufacturer’s history of international success in various climatic & environmental conditions

Benefits to Contractors

- Unmatched technical support
- Reduces application errors associated with installation of other systems
- Reduces risk of membrane failure
- Requires no protective cement mortar in comparison with other systems
## Comparison of Penetron Products to Other Waterproofing Systems

<table>
<thead>
<tr>
<th>Description</th>
<th>Penetron</th>
<th>Penetron Plus</th>
<th>Penetron Admix</th>
<th>Membranes (Positive Side)</th>
<th>Other Surface Applied Products</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
<td>Cementitious material applied on concrete surface to transfer needle-like crystals to infiltrate the concrete mass</td>
<td>Cementitious material added into fresh concrete to form needle-like crystals within the concrete mass</td>
<td>Liquid and sheet applied bitumens and polymers affixed to the concrete surface</td>
<td>Materials applied to concrete surface containing mainly water repellents and sealants</td>
<td></td>
</tr>
<tr>
<td><strong>Resistance to hydrostatic water pressure</strong></td>
<td>• Improves with time</td>
<td>• Improves with time</td>
<td>• Protection breached by any pinhole or seam</td>
<td>• Reduces initial absorption but will deteriorate with time</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Resistance to exceeding 150m head pressure</td>
<td>• Continuous self-healing ability</td>
<td>• Once leaking, will require replacement</td>
<td>• Limited penetration leads to poor resistance to hydrostatic pressure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Withstands 3Mpa in permeability test</td>
<td>• Initiates full hydration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Protection of reinforcing steel</strong></td>
<td>• Prevents corrosion of reinforcing steel by stopping passage of water and chlorides</td>
<td>• Permanent protection</td>
<td>• No negative side protection</td>
<td>• No negative side protection</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Prevents any permeation of water and chlorides</td>
<td>• Easily leaks at the joints and seams</td>
<td>• Limited protection as it slows the water ingress in uncracked areas</td>
<td></td>
</tr>
<tr>
<td><strong>Crack self-healing ability</strong></td>
<td>• Will re-activate in the presence of moisture to seal new cracks even years later</td>
<td>• Will re-activate in the presence of moisture to seal new cracks even years later</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• No self-healing ability</td>
<td>• No self-healing ability</td>
<td></td>
</tr>
<tr>
<td><strong>Crack resistance</strong></td>
<td>• Rigid material, can not bear excessive transformation, but self heals minor cracks of up to 0.4mm</td>
<td>• Reduces cracking in plastic and curing stage</td>
<td>• Can bear excessive transformation</td>
<td>• No crack resistance</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Self heals minor cracks of up to 0.4mm in the presence of moisture</td>
<td>• Limited time protection at existing cracks locations</td>
<td>• Temporarily fills existing cracks</td>
<td></td>
</tr>
<tr>
<td><strong>Freeze/thaw durability</strong></td>
<td>• Improves durability by removing water within concrete</td>
<td>• Improves durability by removing water within concrete</td>
<td>• Slow deteriorating factors initially</td>
<td>• Slow deteriorating factors initially</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Eliminates water penetration at cracks</td>
<td>• Eliminates water penetration at cracks</td>
<td></td>
<td>• No durability at crack locations</td>
<td></td>
</tr>
<tr>
<td><strong>Repair requirement</strong></td>
<td>• Permanent waterproofing protection, does not need repair</td>
<td>• Easily repaired from positive or negative side</td>
<td>• Difficult to repair</td>
<td>• Repairs may require removal of previous materials</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Wide range of options are available</td>
<td>• Difficult to locate pinholes and poor joints</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Repairs are cost effective</td>
<td>• May require total removal &amp; repair</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Expensive and sometimes impossible due to accessibility</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Penetron Capillary Brick System

#### Application
- **Penetron**
  - Applied by brush/spray to positive or negative side of old/new concrete
  - Or, dry shake application on horizontal fresh concrete surface
- **Penetron Plus**
- **Penetron Admix**
  - Mixed at batch plant or on-site
  - No additional applications required
- **Membranes (Positive Side)**
  - Liquids: brush application
  - Sheets: glued or welded to the concrete surface
  - Correct joints and seams critical to performance
- **Other Surface Applied Products**
  - Only applied to positive side
  - Substrate profile critical to performance

#### Surface preparation
- **Penetron**
  - Needs coarse, water saturated, clean surface for brush or spray
  - No surface prep for dry shake
- **Penetron Plus**
- **Penetron Admix**
- **Membranes (Positive Side)**
  - Clean surface
  - Dry surface
  - Smooth surface
- **Other Surface Applied Products**
  - Needs surface prep depending on products requirements

#### Construction schedule
- **Penetron**
  - Can be applied during concrete finishing or anytime following
- **Penetron Plus**
  - Added into fresh concrete at the time of batching
  - Saves 10-50% time and construction costs
- **Penetron Admix**
  - Must be applied at completion of structural work
  - Require protective cement mortar
- **Membranes (Positive Side)**
  - Spaces required between property line and concrete for membrane installation
- **Other Surface Applied Products**
  - Some require 28 days cured concrete
  - Similar scheduling as membranes

#### Effective land usage
- **Penetron**
  - Can be applied to the negative side of concrete allowing construction tight to property lines
- **Penetron Plus**
  - Can build tight with property lines
- **Penetron Admix**
  - Spaces required between property line and concrete for membrane installation
- **Membranes (Positive Side)**
  - Spaces required between property line and concrete for surface application
- **Other Surface Applied Products**
  - Spaces required between property line and concrete for surface application

#### Sub-surface drainage system
- **Penetron**
  - Not required
- **Penetron Plus**
  - Not required
- **Penetron Admix**
  - Require drainage under high hydrostatic pressures
- **Membranes (Positive Side)**
  - Require drainage under high hydrostatic pressures
- **Other Surface Applied Products**
  - Require drainage under high hydrostatic pressures

#### Additional coatings
- **Penetron**
  - Can be finished with coatings, tiles, etc.
- **Penetron Plus**
  - Does not affect coatings
  - Adhesion excellent for coatings or tiles
- **Penetron Admix**
  - Require protective mortar prior to surface finishes
- **Membranes (Positive Side)**
  - May require special preparation prior to surface finishes

#### Maintenance
- **Penetron**
  - Not only as a surface coating
  - Maintenance not required
- **Penetron Plus**
  - Maintenance not required for the life of the concrete
- **Penetron Admix**
  - Costly replacement generally required
- **Membranes (Positive Side)**
  - Re-application required under hydrostatic conditions

#### Service life
- **Penetron**
  - Permanent and improves with time
- **Penetron Plus**
  - Life time of concrete
- **Penetron Admix**
  - Become brittle with age resulting in cracks and openings
  - Surface damage will eliminate protection
- **Membranes (Positive Side)**
  - Best when first applied
  - Deteriorate with time
  - Vulnerable to surface damage
Penetron Foundation Treatment

- Positive Side Waterproofing
  - Concrete surface waterproofing treatment
  Penetron is applied on the surface of concrete by brush or spray.
**Negative Side Waterproofing**

-- Concrete surface waterproofing treatment

Penetron is applied on the surface of concrete by brush or spray.

**Concrete self-waterproofing treatment**

Penetron Admix is added into concrete at the time of batching for complete integral waterproofing.
Application of Penetron Products

- Application of Penetron
  -- Surface Preparation
  The concrete surface must be structurally sound and free of dirt, soil, oil, release agents, laitance or any other foreign materials which may impair the bond, penetration and/or overall performance of Penetron materials.
  Extremely smooth concrete surfaces must be waterblasted or sandblasted to make sure the concrete surface has an open capillary system.
  Rout out visible cracks exceeding 0.4mm in size to a depth of 20mm to 25mm. Also rout out honeycombed pockets and faulty construction joints to sound concrete.
  Construction joints are routed or provided with a formed 20mm*20mm reglet.
  Wet down dry surfaces prior to the application of Penetron materials. Moisture must be present in the concrete strata to ensure maximum chemical penetration. Surfaces must be damp when Penetron products are applied.
  -- Mixing
  Brush application: 0.8-1.5kg/m², 5 parts Penetron to 2 parts water
  Spray application: 0.8-1.5kg/m², 5 parts Penetron to 2.75-to-3.25 parts water (varies with climate and spray equipment)
  Penetron should be mixed to the consistency of thick latex paint. Stir the slurry mixture frequently during the application and prepare only as much as can be applied within a 30-minute period.
  -- Application
  Apply Penetron coating by masonry-type brush (artificial fibers, if available). For spray application, drop hopper or piston pump type equipment is recommended.
  Prior to application of Penetron coatings, fill form tie holes, rout out cracks, honey bombs, reglets and seal strips at construction joints with Penecrete Mortar in a laminating layer of 2.5cm to 3cm. Prime concrete surface of these areas with one slurry coat of Penetron prior to applying Penecrete Mortar.
  Penetron slurry must be applied to damp concrete surface. Second coat should be applied when first coat is dry to the touch. A light misting of water may be required between coats in hot/dry climates.
Horizontal concrete surfaces: Apply Penetron slurry in one coat with stiff bristle brush/broom or squeegee.

Dry sprinkle Penetron or Penetron Plus on “still plastic” concrete by broadcasting or with a fine mesh sieve, in specified quantities. Work the slab surface with wood flat or power trowel until required finish has been achieved.

-- Coverage

Horizontal concrete surface: Penetron at 1.4 to 1.6kg/m². Apply in one slurry coat or powder application when concrete reaches initial set. Trowel or float to specified finish. Penetron Plus powder application at 0.5kg/m² when concrete reaches initial set. Trowel or float to specified finish.

Vertical concrete surfaces: Penetron at 1.4 to 1.6kg/m². Apply in two coats (0.8kg per coat).

-- Curing

Except for extremely hot weather and very low humidity, curing of the Penetron system is not required. In these extreme conditions curing, using a light water misting, must begin as soon as the Penetron coating has hardened sufficiently. Under most conditions it is sufficient to mist the areas treated with Penetron three times a day for the first day. In extremely hot climates spraying may be required more frequently and for several days.

Penetron Plus (trowel applied): Follow concrete specifications for curing procedures.

-- Temperature requirement

Penetron system can be applied in coating or in mortar form when the temperature is above 32 degrees Fahrenheit or 0 degrees Centigrade.

Penetron Plus (trowel applied) can be applied in temperatures where concrete can be placed. Follow concrete specifications for protection requirements according to standard concrete procedures.
**Application of Penetron Admix**

-- **Dosage rate**
Penetron Admix: 0.8%-1% by weight of the cementitious materials, including fly ash, silica fume, etc.

Note: Under certain conditions the dosage rate may have to be increased to 2% - 3%, depending on the quantity and type of total cementitious materials.

-- **Application**

Ready Mix Plant-Dry Batch Operation: Add Penetron Admix in powder form to the drum of the ready-mix truck. Drive the truck under the batch plant and add 60%-70% of the required water along with 136-227kg of aggregate. Mix the materials for 2-3 minutes to ensure the Admix is distributed evenly throughout the mix water. Add the balance of materials to the ready-mix truck in accordance with standard batch practices.

Ready Mix Plant- Central Mix Operation: Mix Penetron Admix with water to form a very thin slurry (e.g., 18kg of powder mixed with 22.7 liters of water). Pour the required amount of material into the drum of the ready-mix truck. The aggregate, cement and water should be batched and mixed in the plant in accordance with standard practices (taking into account the quantity of water that has already been placed in the ready-mix truck). Pour the concrete into the truck and mix for at least 5 minutes to ensure even distribution of Penetron Admix throughout the concrete.

Precast Batch Plant: Add Penetron Admix to the rock and sand, and then mix thoroughly for 2-3 minutes before adding cement and water. The total concrete mass should be blended using standard practices.

-- **Note**
Penetron Admix is compatible with other water-reducing admixtures and superplasticizers.

Retardation of set may occur when using Penetron Admix. Trial mixes should be carried out under project conditions to determine setting time. Once the concrete mix design is determined, without testing any adjustment of the dosage rate is prohibited.
QA/QC of Penetron Products

- QA/QC of Penetron

Project: ________________________________
Application Section: ________________________________
Client: ________________________________
Contractor: ________________________________
Date of Inspection: ________________________________

Before-Application Inspection:

Surface Repair: Crack repair [ ]
                Spalling repair [ ]
                Void repair [ ]
                Construction debris removed [ ]
Smooth Surface Treatment: Sandblast [ ]
                          Acid Etch [ ]
                          Waterblast [ ]
                          Scabbling [ ]
Final Wash-down (High pressure water) [ ]
Comments on surface preparation: ____________________________________________

During-Application Inspection:

Mixing Product: Mix water quality [ ]
                 Mix rater [ ]
Application rate [ ] kg/m²
Number of coats 1[ ] or 2 [ ]
Application by brush [ ]
Or spray [ ]
After-Application Inspection:

Observe and comment on consistency of application:

Thickness:_______________________________________________________
Coverage:_____________________________________________________
Joints:_________________________________________________________
Overlap:_______________________________________________________
Penetration:___________________________________________________

Curing Program:

Water fogging [ ] times per day, for [ ] days

Volume of product used in this section: [ ] kgs
Surface area treated [ ] m²

Comments: ______________________________________________________
______________________________________________________________
______________________________________________________________

Inspected by:

Date:
QA/QC of Penetron Admix

Pre Casting

Project: ________________________________
Type of Structure: ________________________________
Section Identification: ________________________________
Date of Inspection: ________________________________
Date of Proposed Casting: ________________________________
Curing Proposed? Yes/No  Curing Period _____ Days
Curing Type: Water  Burlap (Wetted)  Plastic
Sand/Water  Chemical (Note Brand or Type)

Site Condition Report:
Construction Debris Removed Yes/No
Formwork Clean and Sound Yes/No
Rebar Clean, Secure (well tied) Yes/No
Construction Joints Prepared Yes/No

General Site Conditions: ________________________________
Casting Surface- Construction Joint/ Lean Concrete/ Plastic Sheeting/Packed Earth/ Formwork/ Other__________________________
Evidence of Ground Water Flow or Seepage? ________________________________
Surface Water Runoff or Drainage Points Created? ________________________________
Waterbar Installed Yes/No  Type ________________________________
Condition of Waterbar Installation: ________________________________
Nature and location of all defects to be described in detail


Inspected by:________________________  Witnessed by:________________________
Concrete Mix Design

Specification
Specified Characteristic Strength:  
Target Mean Strength:
Free-water/Cement Ratio:
Type of concrete:
Concrete Slump:

Cementitious Materials
Cement
Type:
Content:
Silica Fume
Content:
Fly Ash
Content:
Other
Type:
Content:

Aggregates
Type
Coarse:
Fine:
Relative Density of Aggregates:
Nominal Coarse Aggregate Size:
Grading of Fine Aggregate:
Coarse Aggregate Content:
Fine Aggregate Content:

Water
Free Water Content:

Admixtures
Type: Penetron Admix
Dosage: per 100kg cementitious materials
Other
Type:
Dosage:
Type:
Dosage:

Inspected by:  Witnessed by:  
Date:
Post Casting

Volume of Concrete: __________________________

Cast Section Identification: ____________________

Date of Inspection: __________________________

Date of Casting: ______________________________

Date of Formwork Removed: ____________________

Curing Applied? Yes/No Curing Period _______ Days

Curing Type: Water Burlap (Wetted) Plastic
             Sand/Water Chemical Formwork

Condition Report:

Evidence of Honeycombing? Yes/No/Photo

Evidence of Cracking? Yes/No/Photo

Evidence of water leakage? Yes/No/Photo

Exposed rebar Yes/No/Photo Tie Bolt Holes Yes/No/Photo

Finish Surface Condition: __________________________

________________________________________________

Waterbar Installed Yes/No

Condition of Waterbar Installation: ______________________

Is it continuous? ________________________________

Re-welding required? _________ Cleaning required? __________________

All defects to be described in detail, including location, extent, apparent depth, etc.

________________________________________________

________________________________________________

Inspected by: ________________ Witnessed by: ________________
## Project Case History

<table>
<thead>
<tr>
<th>Project Location</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zhongguancun, Beijing, China</td>
<td>Penetron is used for the basement waterproofing of Zhongguancun West Zone.</td>
</tr>
<tr>
<td>House of Rest Zelehnogorsk, St. Petersburg, RUSSIA</td>
<td>This cathedral is of immense importance in Russia as the last Russian Emperor Nicholas II and his family is buried here. In 1995, Penetron system was used for the protection and waterproofing of all above and below grade masonry.</td>
</tr>
<tr>
<td>Regent Heights Condo., Singapore</td>
<td>Penetron Admix was used in semi-basement car park slabs and first floor ground slabs.</td>
</tr>
<tr>
<td>SenKang Square, Singapore</td>
<td>Penetron Admix was used on basement slabs and walls.</td>
</tr>
</tbody>
</table>
Test Data

- **Penetron**
  -- Laboratory Testing of PENETRON Waterproofing System
    Riga Technical University Determination of Waterproofing
    RTU Testing Review Nr.64-98 Determination of Waterproofing
    Scanning Electron Microscope (SEM) Tests X-Ray Diffraction Analysis
    Test Report/Shenzhen, China
  -- Compressive Strength
    Shimel and Sor 12/21/94
    Shimel and Sor 11/22/93
    AITA 4/3/85
  -- Water Permeability Tests
    Shimel and Sor 12/21/94
    AITA 8/7/85
    AITA 12/10/90
  -- Microscopic Examinations
    Shimel and Sor 12/21/94
  -- Analysis of Concrete for Penetron Content
    Shimel and Sor 12/21/94
  -- Chemical Resistance
    Shimel and Sor 10/19/93
    Chemical Resistance/Corrosion Chart
  -- Chloride Content
    Shimel and Sor 12/21/94
  -- Shear and Bond Tests
    Shimel and Sor 12/21/94
    AITA 3/7/85
    AITA 3/8/85
    Riga 4/97
  -- Toxicity
    Acute Oral Toxicity
    Migration of toxic Element
    Cytotoxicity Test

- **Penetron Admix**
  SETSCO Singapore-crack bridging report on Terminal 3, Changi Airport
  Impermeability, University of Aleppo
  Penetron Admix effect on concrete- Helsinki
  ACCI-University of NSW, Australia- full examination of Penetron Admix effect on concrete
  SETSCO Singapore-microscopic examination of crack bridging effect of Penetron Admix on PBFC concrete
  SETSCO Singapore-performance assessment of Penetron Admix

Microscopic examination of concrete at 14 days
Microscopic examination of concrete at 28 days
TEST REPORT

MICROSCOPIC ANALYSIS ON THE CONCRETE CORES FROM RETAINING WALL AT CHANGI AIRPORT TERMINAL 3

Prepared for:
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Attn: Mr. Gary Loh

Report prepared by:
Chen Hong Fang
Senior Engineer
Construction Technology Division

Report received and approved by:
Wong Chung Wan
Divisional Director
Construction Technology Department
1. INTRODUCTION

Cracking and seepage of water on the retaining wall at Changi Airport Terminal 3 was reported by Reverton Engineering(s) Pte Ltd (herein refers to as the client). SETSCO has been engaged by the client to carry out laboratory analysis to determine the crack width and crystal growth in the crack on the concrete cores extracted from the said structure.

The proposed basement was constructed with three sides of wall, labeled as wall 1-3 in this report (refer to figure 1 in Appendix A). Thickness of the wall was about 600mm. PENETRON waterproofing admixture was said to be used in the concrete. Water leakage was found along the crack line and tie pin after backfill. However, the water leakage has been stopped on wall 1, which was cast somewhere in 2001. Sign of efflorescence was found on all three sides of the walls. Most of the efflorescence emanated from the tie pins, but cracks with some sign of efflorescence were also noted at some areas (Refer to the photographs in Appendix).

A total of three core samples were extracted from wall 1 on 05/10/2002. Samples S1 and S3 were extracted from crack area while sample S2 was taken at the tie pin. During extraction, the cores were drilled to a depth of 400mm but due to the presence of reinforcement, the length of the core S3 removed was only 240mm.

The concrete mix design furnished by the client is given in Appendix A.

2. MICROSCOPIC ANALYSIS

The microscopic analysis was performed on a ground section using a stereo microscope and metallurgical microscope and on a thin section with a polarizing and fluorescent microscope (PFM) under transmitted and reflected light. For preparation of the ground section, a small block of the sample was cut and ground to attain a smooth finish. For preparation of a thin section, a small concrete block was sawn from the core sample, glued to an object glass and impregnated with an epoxy resin containing a fluorescent dye. After hardening of the epoxy, a thin section with a surface area of approximately 33*63mm and a thickness of 20-30mm was prepared for PFM analysis.
Under transmitted light, the various components (type of cement and aggregates), air voids content, compaction pores and damage phenomena in the samples were identified. Under reflected light, the fluorescent microscopy made it possible to study the homogeneity of the mix and cement paste, capillary porosity, microcracks and other defects in the samples. Scanning Electron Microscope (SEM) and Energy Dispersive X-ray (EDX) Analysis technique was also applied for semi-quantitatively analysis of the element composition of the crystals present in the crack and topography of the crystals.

In summary, SEM utilizes a beam of electrons in a vacuum environment to form an image of the surface topography of a sample. A high level of resolution and good depth of view characterize such magnified images. The characteristic X-ray emitted from the sample surface upon being irradiated with the electrons are then analyzed using an EDX accessory/detector that is coupled to the SEM, allowing evaluation of the % elemental content at the irradiated areas/spots on the sample.

3. RESULTS

I) Visual examination

The length of the cores varied from 240mm to 310mm. Crack perpendicular to the surface was noted in samples S1 and S3. The width of the crack ranged from 0.04mm to 0.3mm. The paste matrix appeared light gray in color while the paste matrix was noted to be generally light gray.

Thin sections were prepared at the top of sample S2 and the end of sample S3 for further microscopic analysis. Stereo microscope and SEM-EDX analysis were performed on sample S3 to determine the presence of the crystals in the crack and their elemental composition.

ii) Microscopic analysis

Under stereo microscope, a lot of coarse-grained elongated crystals were seen lining the crack. Thin section of sample S3 showed that coarse-grained elongated crystals and fine-grained needle-like crystals in the crack. All these crystals showed low birefringence under crossed polarized microscope.
Further scanning electron microscope and energy dispersive X-ray analysis were performed on the crystals present in the crack. The coarse-grained elongated crystal (BEI image in Appendix) contained mainly Calcium (Ca), Oxygen (O) and Silicon (Si). The fine-grained needle-like crystal was predominantly made up of Calcium (Ca), Silicon (Si), Oxygen (O), Sulfur (S), Aluminum (Al), which was probably ettringite (C₆A₃S₃H₃₂).

Well-formed CaCO₃ crystals were present as laminated texture on the surface of sample S2.
Figure 1: The layout of the retaining wall

Casting date of extracted cores

<table>
<thead>
<tr>
<th>Sample reference</th>
<th>Date of cast</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>19/12/2001</td>
</tr>
<tr>
<td>S2</td>
<td>19/12/2001</td>
</tr>
<tr>
<td>S3</td>
<td>06/08/2001</td>
</tr>
</tbody>
</table>
**CONCRETE MIX DESIGN**

Project: Pile Foundation & Basement Construction For Terminal 3  
Singapore Changi Airport

Contractor: Sato Kogyo., Ltd

Date: 8th March 2001

Ref: RE/SK/PU/40P/01

Concrete Grade

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Specific Characteristic Strength</td>
<td>40N/mm² at 28 days in accordance with BS 5328</td>
</tr>
<tr>
<td>1.2 Designed Standard Deviation</td>
<td>4.6 N/mm²</td>
</tr>
<tr>
<td>1.3 Design Margin</td>
<td>7.5 N/mm²</td>
</tr>
<tr>
<td>1.4 Target Mean Strength</td>
<td>47.5 N/mm²</td>
</tr>
<tr>
<td>1.5 Free Water/Cement Ratio</td>
<td>0.46</td>
</tr>
<tr>
<td>1.6 Type of Concrete</td>
<td>Pump Concrete</td>
</tr>
<tr>
<td>1.7 Concrete slump</td>
<td>100±25mm</td>
</tr>
</tbody>
</table>

| Cement | Ordinary Portland Cement |
| Cement Type | 398kg/m³ |

| Aggregates | |
| Coarse | Crushed Granite |
| Fine | Natural Sand/ Manufactured Sand |
| Relative Density of Aggregates | 2.60-2.65 |
| Normal Aggregate Size | 20mm |
| Grading of Fine Aggregate | BS 882 Table 5 |
| Coarse Aggregate Content: SSD | 1000 Kg/m³ |
| Fine Aggregate Content: SSD | 695 Kg/m³ |

| Water | 185 Kg/m³ |
| Free Water Content | |

| Admixtures | |
| Admixture Type 1 | Penetron (mix design) Admixture |
| Dosage | 0.8 kg per 100 kg of cement |
| Admixture Type 2 | Daratard 88. Water reducing, plasticizing and set retarding |
| Dosage | 550 ml per 100kg cement |

<p>| Summary | Kg/m³ |
| (Batch weighs (SSD) Per Cubic Metre of Concrete) | |</p>
<table>
<thead>
<tr>
<th>Grade</th>
<th>Slump</th>
<th>Cement</th>
<th>Coarse Agg</th>
<th>Fine Agg</th>
<th>Water</th>
<th>Admix</th>
<th>A/C</th>
<th>W/C</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>100±25mm</td>
<td>398</td>
<td>1000</td>
<td>695</td>
<td>185</td>
<td>3.18</td>
<td>4.26</td>
<td>0.46</td>
<td>2281.18</td>
</tr>
</tbody>
</table>
APPENDIX B   PHOTOGRAPHS

A6127/CHF

A crack connecting with tie pin with sign of Efflorescence was observed on wall 1

Sign of efflorescence was found along the crack line on wall 1.

The location of sample S1 extracted at the cracked area on wall.

A 75mm diameter core containing a crack at Wall 1 was extracted for laboratory analysis.
A crack perpendicular to the exposed surface was seen in core S1.

A crack perpendicular to the exposed surface was seen in core S3.

Relative thick whitish substance was on the surface of core S2.

Sign of efflorescence was found along the crack line where core S3 was taken on wall 1.

Core S2 was extracted at the tie pin on wall 1.

A crack perpendicular to the exposed surface was seen in core S3.
Sample S3: Some crystals grew in the crack.

Sample S3: Backscattered electron image (BEI) showed some crystals was in the crack.

Sample S2: Laminated CaCO3 crystals on the surface of the concrete. The width of the field is 3.88mm under crossed polarized light.

Sample S2: Laminated CaCO3 crystals on the surface of the concrete. The width of the field is 3.88mm under plane light.

Sample S3: Coarse-grained elongated crystals and fine-grained needle-like crystals were lining the crack. The width of the field is 3.88mm under plane light.

Sample S3: Abundant coarse-grained crystals in the crack.
Sample S3: Backscattered electron image (BEI) showed elongated crystals and fine needle-like crystals in the crack.

Sample S3: High magnified view of needle-like crystals in the crack.

Sample S3: Secondary electron image (SEI)

EDX spectrum of elongated crystals in the crack.

EDX spectrum of needle-like crystals in the crack.

Sample S3: Secondary electron image (SEI) showed coarse-grained flaky crystals in the crack.

Sample S3: SEI image showed the crystals in the Crack.
Reference is made to our report No. 94-6175, dated December 21, 1994. In that report, effects of Penetron coating on the properties of concrete were reported. As indicated in that report, the depth of penetration of some of the components of Penetron were as deep as 50 mm, although most penetrations were down to 10 mm depths of the concrete surface.

At the Client's request, additional studies were performed to determine and photograph the type of materials penetration or diffusing into the concrete from the Penetron coating. In order to perform these tests, the test techniques used were scanning electron microscopy and energy dispersive x-ray diffraction methods.

TEST RESULTS

1. Scanning Electron Microscope (SEM) Tests

The concrete core section tested was coated with a minimum of gold in order to provide a surface, which could be studied by light microscopy and compared to the SEM images.

The photographs taken under SEM are presented on Attachment I.

2. X-Ray Diffraction Analysis

According to the attached four spectrums of x-ray diffraction, there is a calcium accumulation in the concrete below the Penetron coating to 25 to 50 mm depths. Calcium appears to be in the form of Ca(OH)2 and calcium-silicate gel. Obviously, these crystalline growths are the diffusion products of the components of the Penetron coating on the concrete surface. Below 50 mm depths Ca(OH)2 is less while the silica content (from the cement) becomes dominant.
CONCLUSIONS

Based on these test results, it is our opinions that Penetron coated concrete surfaces develop improved concrete microstructure and waterproofing properties.

KS/smd
cc: (1) Client
Robert Revera
Client: ICS/Penetron International Ltd., C/o All Island Testing Labs.

Project: Information of Client

Subject: Laboratory Testing of Penetron Material for Chemical Resistance

Report No. 93-3981 Date 10/19/93

At the request of the Client, laboratory tests were performed to determine the chemical resistance of Penetron treated concrete.

Experimental Design

The concrete used for the study had a design strength f"c = 4000 psi. The concrete mix proportions are presented on Attachment 1.

The concrete specimens used were saw-cut from 6 x 12 inch concrete cylinders. The specimens were 2 inches thick and 6 inches in diameter. At the time of the study, the concrete was 28 days old.

The Penetron material (which was received in powder form in a sealed bag) was mixed with water into a slurry. The ratios were:

- 2 parts Penetron
- 0.8 parts water

The slurry was then applied on all surfaces of the concrete specimens by brushing. After the final setting of Penetron the surfaces of the specimens were moistened and placed in a regular concrete curing room for 14 days at 73 °F and 100% relative humidity.

At the end of 14 days, the specimens were removed from the curing room and placed in various chemical solutions, which provided a wide range of pH levels and corrosive conditions.
Test Results

<table>
<thead>
<tr>
<th>SAMPLE NO.</th>
<th>SAMPLE TYPE</th>
<th>TYPE OF TREATMENT</th>
<th>PH</th>
<th>OBSERVATIONS</th>
<th>7 day</th>
<th>28 day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>Penetron Treated</td>
<td>Dilute Hcl</td>
<td>3</td>
<td>No Effect</td>
<td>No Effect</td>
<td></td>
</tr>
<tr>
<td>1B</td>
<td>No Penetron</td>
<td>Dilute Hcl</td>
<td>3</td>
<td>No Effect</td>
<td>Surface Weathered</td>
<td></td>
</tr>
<tr>
<td>2A</td>
<td>Penetron Treated</td>
<td>Dilute H2SO4</td>
<td>3</td>
<td>No Effect</td>
<td>No Effect</td>
<td></td>
</tr>
<tr>
<td>2B</td>
<td>No Penetron</td>
<td>Dilute H2SO4</td>
<td>3</td>
<td>No Effect</td>
<td>Surface Weathered</td>
<td></td>
</tr>
<tr>
<td>3A</td>
<td>Penetron Treated</td>
<td>Rain Water</td>
<td>4</td>
<td>No Effect</td>
<td>No Effect</td>
<td></td>
</tr>
<tr>
<td>3B</td>
<td>No Penetron</td>
<td>Rain Water</td>
<td>4</td>
<td>No Effect</td>
<td>Surface Weathered</td>
<td></td>
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<tr>
<td>4A</td>
<td>Penetron Treated</td>
<td>CaCl₂</td>
<td>7</td>
<td>No Effect</td>
<td>No Effect</td>
<td></td>
</tr>
<tr>
<td>4B</td>
<td>No Penetron</td>
<td>CaCl₂</td>
<td>7</td>
<td>No Effect</td>
<td>Slight Effect</td>
<td></td>
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<tr>
<td>5A</td>
<td>Penetron Treated</td>
<td>NaOH</td>
<td>11</td>
<td>No Effect</td>
<td>No Effect</td>
<td></td>
</tr>
<tr>
<td>5B</td>
<td>No Penetron</td>
<td>NaOH</td>
<td>11</td>
<td>No Effect</td>
<td>No Effect</td>
<td></td>
</tr>
</tbody>
</table>

CONCLUSIONS

Based on these test results, the following conclusions were drawn:

1. The Penetron treated concrete was found to be resistant to acidic and alkaline conditions ranging between pH values of 3 to 11. Also, chloride containing solutions did not have any measurable effect on the Penetron concrete.

2. The untreated concrete (control samples) had surface weathering when exposed to pH of 3, rain water chlorides and sulfate solutions.

KS/smdcc: (1) Client
Doug Quick
ATTACHMENT I

CONCRETE MIX DESIGN USED
FOR THE PENETRON TREATMENT TESTS

<table>
<thead>
<tr>
<th>MATERIALS</th>
<th>AMOUNTS PER CUBIC YARD</th>
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<tbody>
<tr>
<td>Portland Cement, Sacks</td>
<td>6.0</td>
</tr>
<tr>
<td>Portland Cement, Lbs</td>
<td>564</td>
</tr>
<tr>
<td>*Sand, Lbs</td>
<td>1450</td>
</tr>
<tr>
<td>*Coarse Aggregate</td>
<td>1860</td>
</tr>
<tr>
<td>Water, Ga</td>
<td>36.3</td>
</tr>
<tr>
<td>Water, Lbs</td>
<td>302.4</td>
</tr>
<tr>
<td>W/C Ratio</td>
<td>0.54</td>
</tr>
<tr>
<td>Slump</td>
<td>4.0</td>
</tr>
<tr>
<td>Entrapped Air, %</td>
<td>1.8</td>
</tr>
</tbody>
</table>

(*) SSD basis