Technology and Concepts
Repair and Protection of Reinforced Concrete
The successful repair and protection of concrete structures which have been damaged or which have deteriorated requires professional assessment, then design, supervision and execution of a technically correct strategy - according to the forthcoming European Standard being developed by CEN/TC 104.

This brochure is intended to give guidance on the correct procedure and on the appropriate products and systems for the selected strategy. The key stages in the process are:-

**Assessment Survey of the Condition of the Structure**

The assessment of the condition of a damaged or deteriorated reinforced concrete structure should only be made by qualified and experienced people.

- The current condition of the structure including visible, non-visible and potential defects.
- Review of the past, current and future exposure.

**Diagnosis of the Cause of Deterioration**

Following review of the original design, construction methods and programme, and the assessment survey identify the “root causes” of damage:

- Identify mechanical, chemical and physical damage to the concrete.
- Identify concrete damage due to reinforcement corrosion.

**Determine the Repair and Protection Objectives**

The process of assessment will always include the following aspects:

**Select the Appropriate Repair and Protection Strategy**

**Definition of the future Maintenance Requirements and Procedures**

**Assessment Survey of the Condition of the Structure**

**Diagnosis of the Cause of Deterioration**

**Determine the Repair and Protection Objectives**

**Select the Appropriate Repair and Protection Strategy**

**Definition of the future Maintenance Requirements and Procedures**
Determine the Repair and Protection Objectives

With most damaged or deteriorated structures the Owner has a number of options which will effectively decide the appropriate repair and protection strategy to meet the future requirements of the structure.

The options include:-

■ Do nothing.
■ Downgrade the structure or its capacity.
■ Prevent or reduce further damage without repair.
■ Improve, refurbish or strengthen all or part of the structure.
■ Demolition.

Select the appropriate Repair and Protection Strategy

It is necessary to clarify the Owner’s requirements and instructions in relation to:-

■ The required durability, requirements and performance.
■ Intended design life.
■ How loads will be carried before, during and after the repair.
■ The possibility for future repair works including access and maintenance.
■ Costs of the alternative solutions.
■ The consequences and likelihood of structural failure.
■ The consequences and likelihood of partial failure (falling concrete, water ingress etc).

And Environmentally:-

■ The need for protection from sun, rain, frost, wind, salt and/or other pollutants during the works.
■ The environmental impact or restrictions on the works in progress particularly the noise and the time taken to carry out the work.
■ The likely environmental/aesthetic impact of the improved/reduced appearance of alternative solutions.

Definition of the future Maintenance Requirements and Procedures

■ What is the mode and result of the selected materials deterioration ie. chalking, embrittlement, discolouration, delamination?
■ What surface preparation and access systems will eventually be required and when?
■ Who is responsible and how will it be financed?
Assessment Survey and Diagnosis of Damage

CONCRETE DAMAGE DUE TO REINFORCEMENT CORROSION

CARBONATION
- Carbon Dioxide (CO₂) in the atmosphere reacting with Calcium Hydroxide in the concrete pore liquid.
- CO₂ + Ca(OH)₂ → CaCO₃ + H₂O
- Soluble and pH 12-13 → Almost insoluble and pH 9
- Steel Passivated → Steel Unprotected

STRAW/ELECTRICAL CURRENT
- Metals of different electropotential are connected to each other in the concrete and corrosion occurs.
- Also corrosion can be due to stray electrical currents from transmission networks.

CORROSIVE CONTAMINANTS eg CHLORIDES
- Chlorides accelerate the corrosion process however originally caused.
- At above 0.2-0.4% they break down the passive oxide.
- Chlorides can be from marine exposure or deicing salts.
- Their use to accelerate concrete setting at low temperatures is now mostly banned in reinforced concrete.

Reinforcement corrosion following reduction of the passivating concrete alkalinity by carbonation.

Reinforcement corrosion showing as rust staining from cracks after galvanised steel railings were fixed into the parapet.

The damaging effects of steel corrosion accelerated by chloride ingress from deicing salts.
Cracking caused by incorrect handling or fixing of precast panels.

Chemical attack (and subsequent reinforcement corrosion) on a factory roof.

Freeze thaw effect on a parking structure.
Determine the Objectives and Select the Appropriate Strategy

Having fully considered their options owners normally face having to “Improve, refurbish or strengthen all or part of the Structure”:-

- For structural strengthening requirements refer to Sika Technical Services for full details of the innovative Sika Carbodur structural strengthening system.
- For concrete structures there are now alternative solutions proposed for improvement and refurbishment that are considered as corrosion management, these include:-

Provide Additional Concrete Cover

**Advantages:**
- The old traditional approach.

**Disadvantages:**
- Very expensive if correctly applied over all of the concrete surface.
- Has no effect on further aggressive influence ingress.
- Provides no protection against latent damages.
- Very poor appearance.

Conventional Repair and Protection

**Advantages:**
- Meets existing national standards (DIN/BBA/SIS/NF etc).
- Proven performance (over 20 years with Sika systems).
- Provides some protection against latent carbonation damages.
- Cost effective.

**Disadvantages:**
- No protection against latent chloride damage.
- Requires extensive concrete break out.
- Considerable noise, vibration and dust.

Apply Cathodic Protection

**Advantages:**
- The only way to completely stop steel corrosion.
- Permanent solution (with full repairs and monitoring).

**Disadvantages:**
- Ongoing cost to maintain.
- Many structures not suitable (access / non continuous reinforcement / prestressing steel etc).

Realkalisation or Desalination

**Advantages:**
- Based on reversing the principles of Cathodic protection.
- Limited concrete removal.
- No ongoing maintenance (except protective coatings).

**Disadvantages:**
- Very high installation cost.
- Not all structures are suitable (as Cathodic Protection).
- Where there is potential for ASR/AAR.
- Not environment friendly (caustic waste disposal).

Overcladding and Insulation

**Advantages:**
- Greatly improves appearance.
- Provides the additional benefit of insulation.
- Provides a long term solution.

**Disadvantages:**
- Very expensive.
- Can hide latent defects.
- Extended contract period.

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Concrete Repair and Protection with Corrosion Inhibitors

Advantages:

- All the advantages of conventional concrete repair and protection.
- Greatly reduced concrete break out.
- Greatly reduced noise vibration and dust.
- Reduced contract periods.
- Provides protection against residual chlorides and against incipient anode formation.
- Extremely cost effective.
- Most structures suitable
- No ongoing maintenance (except refresher top coatings after 10-15 years).

Disadvantages:

- Not proven on prestressed structures (at this time).

Sika® FerroGard® Technology

System Positioning with Sika FerroGard®-903 Corrosion Inhibitor

Sika FerroGard®-903 In New Construction.

Sika FerroGard®-903 Protection before Visible Damage.

Sika FerroGard®-903 as part of a Complete Repair and Protection Strategy after Visible Concrete Damage.
The Sika® Principles of Concrete Repair & Protection

Remove damaged concrete and prepare exposed steel

Protecting exposed reinforcement

Replacing damaged concrete

Select the Appropriate Sika System
Protecting against the development of latent damage

Levelling the profile and filling surface pores

Sealing and Coating - preventing the ingress of aggressive influences

Sika FerroGard® -903
- Penetrates via liquid and vapour diffusion
- Film forming inhibitor
- Mixed inhibitor acting on anodic and cathodic sites
- Blended inhibitor combining special amino alcohol and inorganic inhibitors

SikaTop® Levelling Mortars coarse/fine
- Use to fill surface defects to ensure continuous protective coating
- Produce the desired surface texture
- Provides uniform substrate

SikaGard® - 700S/-702W
- Prevents water and chloride ingress
- Allows each way water vapour diffusion

Hydrophobic Impregnations

SikaGard® - 680S/-675W
- Effectively halts carbonation
- Allows each way water vapour diffusion
- Prevents water and chloride ingress
- Outstanding colour retention

Anti-Carbonation Coatings

SikaGard® - 720 EpoCem®
- Unique epoxy cement technology
- Integral curing ability
- Also as a protective coating
- Ideal for levelling and reprofiling after application of Sika FerroGard® -903

Sika MonoTop® Levelling Mortars coarse/fine
- One component levelling and repolishing mortar

SikaGard® - 550W Elastic
- All the special properties of SikaGard® 675W/ 680S plus:
  - Bridges dynamically moving cracks even at low temperatures
  - Water and solvent based primers
The Worldwide Independent Proof Statements

Independent Assessment and Approval

■ Product Performance
The specific criteria that Sika use to evaluate all of our products and systems for Concrete Repair and Protection, are in accordance with the requirements of the draft European Standard developed by CEN/TC104 where appropriate. They include the following:-

■ System Performance
There are functional and performance requirements which must be met by both the individual products and components of a system and by the system together as a whole.

■ Quality Assurance
It is necessary for any product or component or system to meet well defined quality assurance and control standards in production. This is why Sika produce to ISO Standards at our factories throughout the world.

■ Application Criteria
In addition to its performance in place, it is also essential to define and test the application properties of products and systems to ensure that they can actually be applied practically on site, and in the differing conditions that will be necessary. For example:- Sika Mortars must be suitable for differing thicknesses and areas/volumes of repair and applied in as few layers as possible. SikaGard® coatings must have adequate thixotropy to obtain the desired wet and dry film thicknesses in the minimum number of coats, and with these they must also achieve adequate opacity.

Sika have developed Product Performance Testing
■ The Bänziger block for testing repair mortars

■ System Performance
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Sika Undertake Extensive Durability Testing
■ In the Laboratory
SikaGard® products are tested for their performance as anti-carbonation and water vapour diffusable coatings, both when freshly applied, and also after up to 10,000 hours accelerated weathering (equivalent to in excess of 15 years). Only this can give a complete picture of the product’s true performance. SikaGard® coatings therefore continue to perform long after other coatings have ceased to provide effective protection.
An International review was undertaken by leading independent Consultants and Testing Institutes. Major projects repaired and protected with Sika Systems between 1977 and 1986 were Inspected and their Durability and Performance Assessed in 1997.

**Sealing with Hydrophobic Impregnations**
- Penetration ability
- Permeability to water
- Permeability to water vapour
- Freeze thaw resistance

**Anti-Carbonation Coatings**
- Bond strength
- Cross hatch performance
- Permeability to carbon dioxide
- Permeability to water vapour
- U.V. light resistance
- Alkaline resistance
- Freeze thaw resistance
- Fire resistance
- Cleanability

**Crack Bridging Anti-Carbonation Coatings**
As above for Anti-Carbonation Coatings, plus:-
- Crack bridging ability
  - Statically
  - Dynamically
  - At low temperatures (-20°C/-20°F)
International Case Studies

Structure
24 Storey Housing Block. Reinforced Concrete Frame with Architectural Precast Concrete Cladding Panels

Problem
- Loading and impact damaged architectural precast cladding panels (from time of original construction).
- Cracks and inadequate cover over steel reinforcement.

Sika Solutions
- Removal of loose concrete and preparation of exposed reinforcement.
- Protect reinforcement with: SikaTop®-Armatec 110 EpoCem®.
- Replace damaged concrete with: Sika repair mortar.
- Provide a uniform, attractive surface finish and protection with: SikaGard®-550W.

Structure
Factory Roof over Production Facilities

Problem
- Aggressive chemical attack on the concrete.
- Followed by corrosion of the steel reinforcement in a high temperature, high humidity environment.

Sika Solutions
- Removal of damaged concrete and preparation of exposed reinforcement.
- Protect reinforcement with: SikaTop®-Armatec 110 EpoCem®.
- Replace damaged concrete: SikaCem®-133 Gunite.
- Protect the surface from future aggressive chemicals with: SikaGard® high performance coating.
International Case Studies

Structure
Precast Reinforced Concrete Framed Office Building

Problem
- Alkali Aggregate Reaction (AAR/ASR) in the concrete leading to typical cracking and expansive gel formation.

Requirement
- Durable holding repairs to bridge moving cracks and to significantly reduce the rate of deterioration thereby extending the service life of the structure.

Sika Solutions
- Mechanical preparation.
- Patch repair and fill surface defects and cracks with SikaDur®-31 epoxy mortar.
- Provide crack bridging protection against future water ingress with SikaGard®-550W.

Structure
Multi Storey Concrete Parking Structure

Problem
- Freeze thaw damage on concrete columns and soffits from condensation and deicing salts exposure.

Sika Solutions
- High pressure water jetting followed by blast cleaning.
- Repair and reprofiling with: SikaTop® mortars.
- Protection against future water and deicing salt ingress with SikaGard®-680S (columns and soffits) and SikaGard®-550W (areas subject to cracking - parapets and external facades).
- Joint sealing with Sikaflex® sealants.
- Steel corrosion protection with Sika Icosit® coatings.
International Case Studies

**Structure**
150 metre (500 feet) Long Major Road Bridge

**Problem**
- Concrete damage on the parapet and underside of the bridge due to freeze thaw action accelerated by deicing salts.

**Sika Solutions**
- Surface preparation and defective concrete removal by high pressure water jetting.
- Parapet: Sika MonoTop®-610 as corrosion protection for exposed reinforcement and as a bonding bridge followed by Sika MonoTop® repair mortar at 3-6cm thickness.
- Substructure: SikaTop®-Armatec 110 EpoCem® as corrosion protection, allowed to cure, and then repair by dry spray application of SikaCem®-133 Gunite repair mortar.

**Structure**
Multi Storey Residential Housing Block with Concrete Frame and Precast Cladding Panels

**Problem**
- Inadequate concrete cover to steel reinforcement with extensive cracking and spalling after depth of carbonation reached the steel.

**Sika Solutions**
- Concrete surface preparation by high pressure water jetting.
- Exposed steel reinforcement prepared by blast cleaning.
- Steel reinforcement protection and bonding bridge with SikaTop®-Armatec 110 EpoCem®.
- Repair and reprofiling with Sika repair mortar.
- Crack bridging anti carbonation protection on large concrete surfaces with SikaGard®-550W coating.
- Joint sealing with Sikaflex® sealants.
- Galvanized balcony handrail protection with Sika Icosit® coatings.
International Case Studies

Structure
26 Storey Lightweight Insitu Concrete, Residential Housing Block

Problem
- Inadequate concrete cover over steel reinforcement with subsequent cracking, staining and spalling.

Sika Solutions
- Preparation by blast cleaning.
- Exposed steel reinforcement protection with SikaTop®-Armatec 110 EpoCem®.
- Repair with SikaTop® lightweight mortar.
- Levelling and pore filling with SikaTop® levelling mortars.
- Crack bridging anti carbonation protection and architectural design feature with Sikagard®-550W and Sikagard®-680S.
- Joint sealing with Sikaflex® sealants.

Structure
Historic Reinforced Concrete Drinking Water Tower

Problem
- Externally carbonation depth had reached the main steel reinforcement allowing expansive rusting to occur with subsequent concrete cracking and spalling.

Sika Solutions
- Surface preparation by blast cleaning.
- Steel reinforcement protection and bonding bridge with SikaTop®-Armatec 110 EpoCem.
- Repair and levelling with SikaTop® mortars.
- Anti carbonation protection and enhanced appearance with Sikagard®-680S.
Structure
Concrete Parapet Wall at an Airport Parking Structure

Problem
- Galvanized steel handrail fixed into the steel reinforced concrete edge beam with direct contact between galvanising and reinforcing steel leading to corrosion.

Sika Solutions
- Remove and reinstall Sikagard® epoxy paint coated steel handrails with SikaGrout®-42 (epoxy grout).
- Patch repair and level damaged concrete with SikaTop® repair mortars.
- Protect against future water ingress with Sikagard®-550W.

Structure
1200 metre (3/4 mile) Viaduct consisting of 10 bridges over road and rail tracks

Problem
- Extensive chloride accelerated reinforcement corrosion particularly below expansion joints in the deck.

Sika Solutions
- Following replacement of bridge deck joints.
- Removal of all damaged concrete.
- High pressure water jetting (also to reduce residual chloride levels).
- Blast cleaning to prepare exposed steel reinforcement.
- Repair and reprefiling with SikaCem®-133 Gunite dry spray mortar.
Structure
Second Floor Pedestrian Walkway/Bridge at a Hospital

Problem
- Concrete damaged by freeze thaw action and reinforcement corrosion accelerated by chlorides from deicing salts.

Sika Solutions
- Surface preparation by high pressure water jetting and exposed steel reinforcement prepared by blast cleaning.
- Steel reinforcement protection with SikaTop®-Armatec 110 EpoCem®.
- Repair with SikaTop® mortars.
- Protection against latent damages by impregnation with Sika FerroGard®-903 corrosion inhibitor.
- Crack bridging surface protection with SikaGard®-550W.

Structure
New Light Rail Bridge Superstructure

Problem
- Inadequate low concrete cover with future deicing salt exposure on the deck
- Mechanical damage to architectural panels by a nearby bomb explosion.

Sika Solutions
- Bridge Deck Surface and Soffit
  - Impregnation with Sika FerroGard®-903.
  - Protective coating to prevent future water and chloride ingress with SikaGard®-550W. Architectural Precast Parapet Panels.
  - Replacement with new thin section panels using Sikament® superplasticiser and Sika FerroGard®-901 corrosion inhibiting admixture.
Summary Flow Chart of the Sika Process

Additional Complementary Sika Systems

- **Sika Deck Coatings**
  - for crack bridging balcony, podium and deck waterproofing plus elastic wearing surfaces.

- **Sikaflex® Joint Sealing**
  - a unique range of one component sealants, specifically designed for compatibility with the Sika repair and protection systems.

- **Sika Icosit® Steel Coatings**
  - for the protection of steel and galvanised steel surfaces such as handrails, window frames and support structures.
**Sika Structural Waterproofing**
- Well proven systems that provide internal waterproofing for both new and refurbishment projects in basements, lift pits, cellars, car parks etc.

**Sikadur® Resin Injection**
- Structural resins for the injection and bonding of cracks and voids to restore integrity.

**Sika Carbodur® Structural Strengthening**
- Externally bonded composite reinforcement system for structural strengthening and to increase load bearing capacity of floors, walls, beams etc.
The information, and, in particular, the recommendations relating to the application and end-use of Sika products, are given in good faith based on Sika's current knowledge and experience of the products when properly stored, handled and applied under normal conditions. In practice, the differences in materials, substrates and actual site conditions are such that no warranty in respect of merchantability or of fitness for a particular purpose, nor any liability arising out of any legal relationship whatsoever, can be inferred either from this information, or from any written recommendations, or from any other advice offered. The proprietary rights of third parties must be observed. All orders are accepted subject to our current terms of sale and delivery. Users should always refer to the most recent issue of the Product Data Sheet for the product concerned, copies of which will be supplied on request.