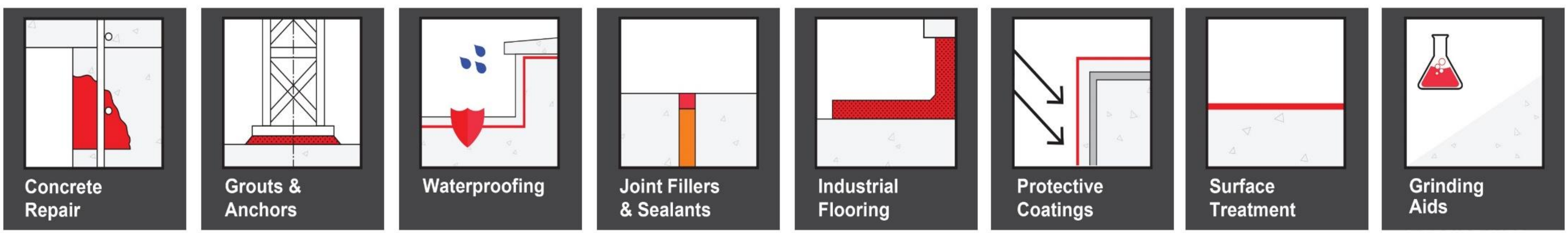
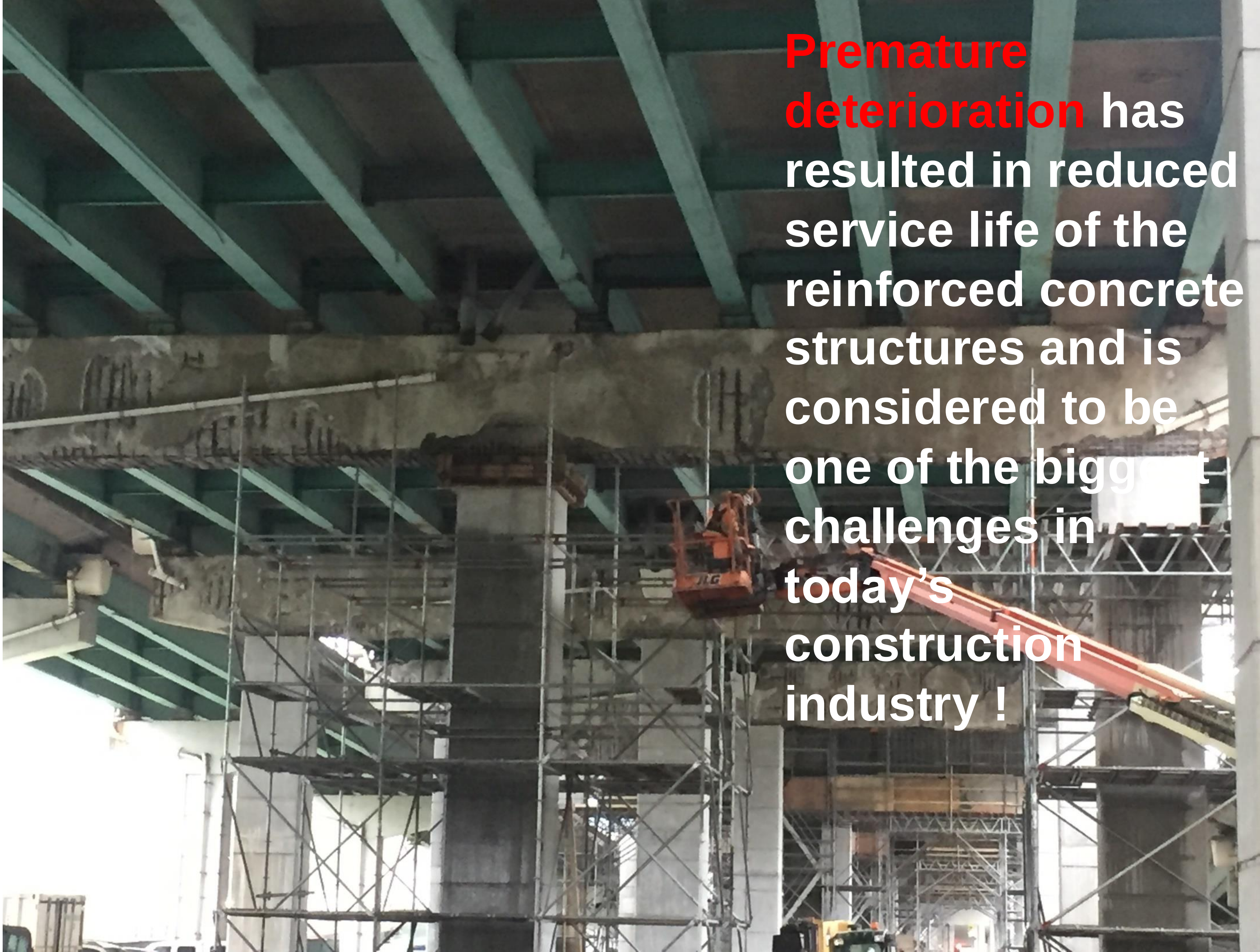
constructive solutions

FOSROC CONSTRUCTION SOLUTIONS

2025




Premature deterioration has resulted in reduced service life of the reinforced concrete structures and is considered to be one of the biggest challenges in today's construction industry !

ACI Excellence Award-winning paper 2021 identified severe cracking was responsible for the falling of a large slab edge from more than 200 ft (60m) of a 59-story building

Presenter

Hamid Khan

Director Board ACRA

Past Present ACRA (2017-19)

National Product Segment Specialist, Fosroc ANZ
Concrete Repair & Grouting

27 years global industry experience

Challenge

In today's world asset owners, desire their buildings to last for a century and bridge structures to 100 years (AS5100, 2004), 120 years (BS5400.1, 1988) to as high as 300 years.

Bridge Hierarchy

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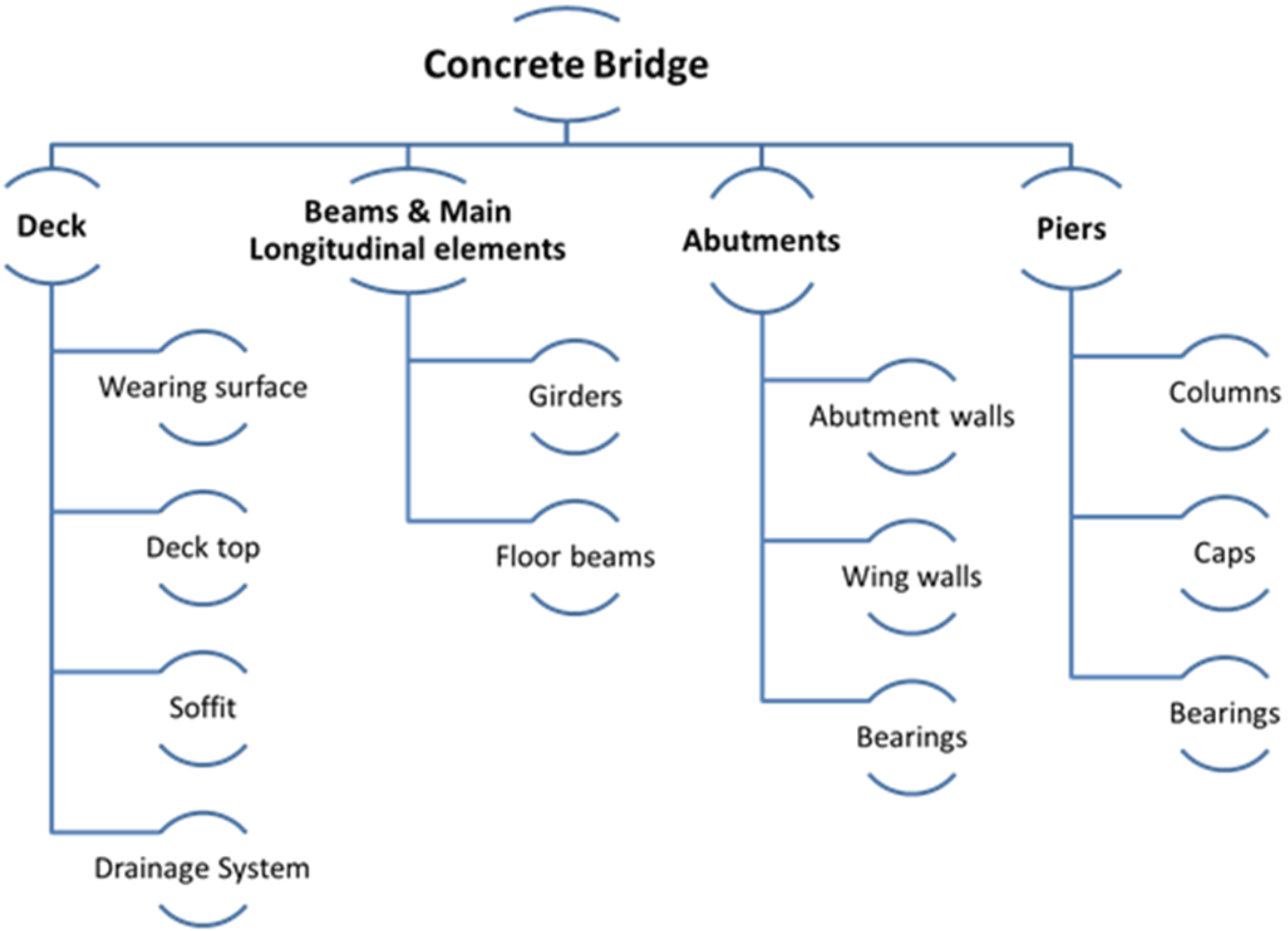

Damage classification - concrete bridges

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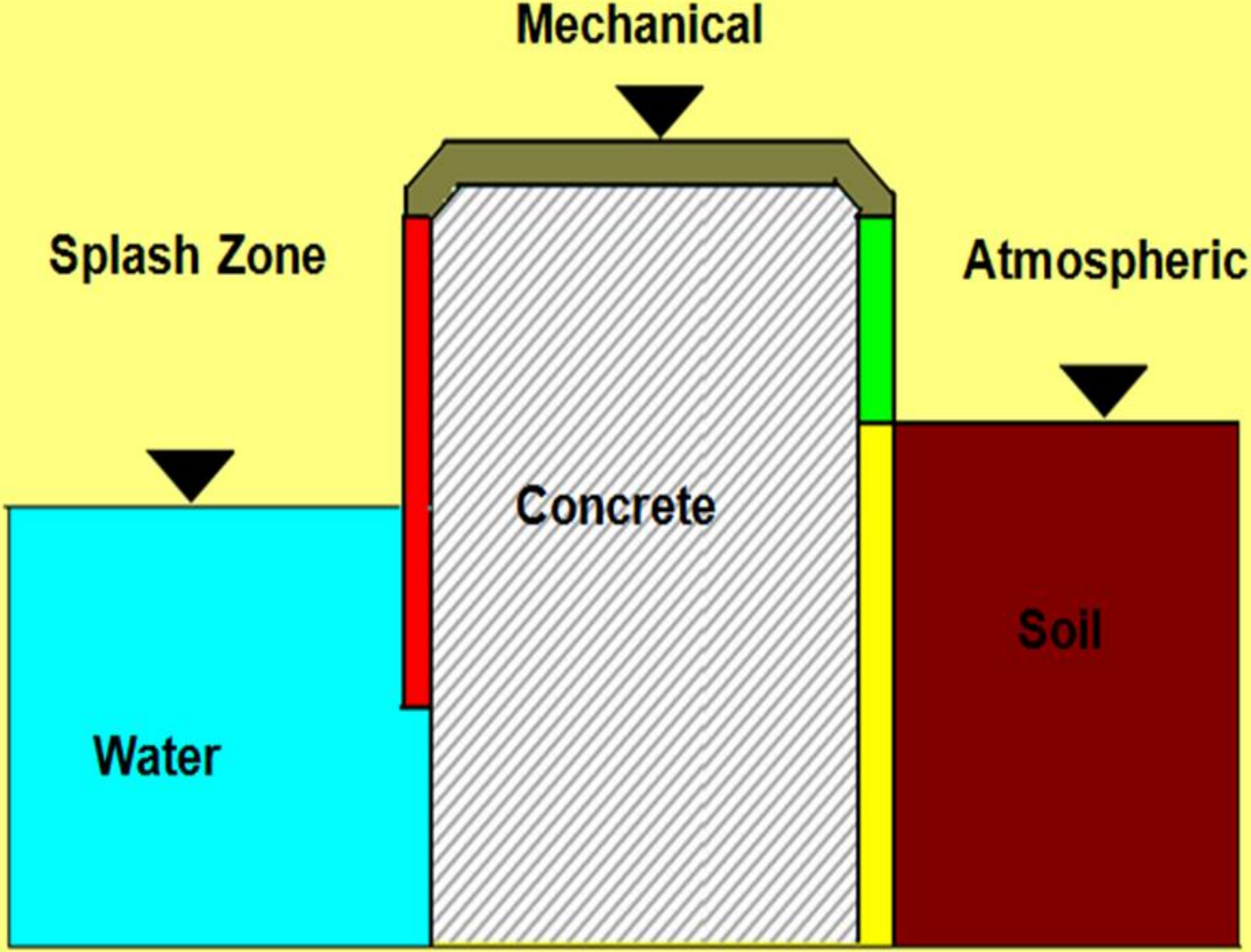
Cracks	Deteriorations
Overload-induced crack	Scaling
Erroneous construction- induced crack	Rebar Corrosion
Foundation non-symmetrical Shrinkage induced crack	Crazing
Fatigue crack	Spalling
Pre-cast element crack	Pop-out
Chloride Contamination crack	Pitting
Carbonation crack	Honeycombing
Rebar corrosion crack	Efflorescence
Sulphate attack crack	Delamination
Acid attack crack	Cavitation
Alkali-Silica-Reaction (ASR) crack	Discolouration
Freeze-thaw crack	Peeling
Plastic shrinkage crack	Exudation
Plastic settlement crack	Leaching
Settlement crack	Traffic Collision and Wearing
Long-term drying shrinkage crack	Water void
Early thermal contraction crack	Settlement

Source: Wang *et al* (2001)

Bridge Hierarchy

Enright et al (2000), in their study *"Survey and Evaluation of Damaged Concrete Bridges"* reported:

Water leakages through deck joints as the most common source of bridge damages


Mechanical
Splash Zone
Atmospheric
Concrete
Soil
Water

Durability “Menu” of possible materials choices

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Cement	Admixture	Rebar	Surface	Electrochem
PC	Super-plasticisers	Carbon Steel Rebar	Extended Curing	Chloride Monitoring
Micro-silica	Self-compacting agents	Non-reinforced Design	Controlled Permeability Formwork	Corrosion Monitoring
PFA	Waterproofing additives	Stainless Steel Rebar	Penetrating Sealers	Provision for future CP
GGBS	Corrosion Inhibitors	Non-metallic Rebar	Surface Coatings	Cathodic Prevention

Legend:

Controlling Penetration	Controlling Corrosion

Disasters in Concrete in New Construction

 

Challenges

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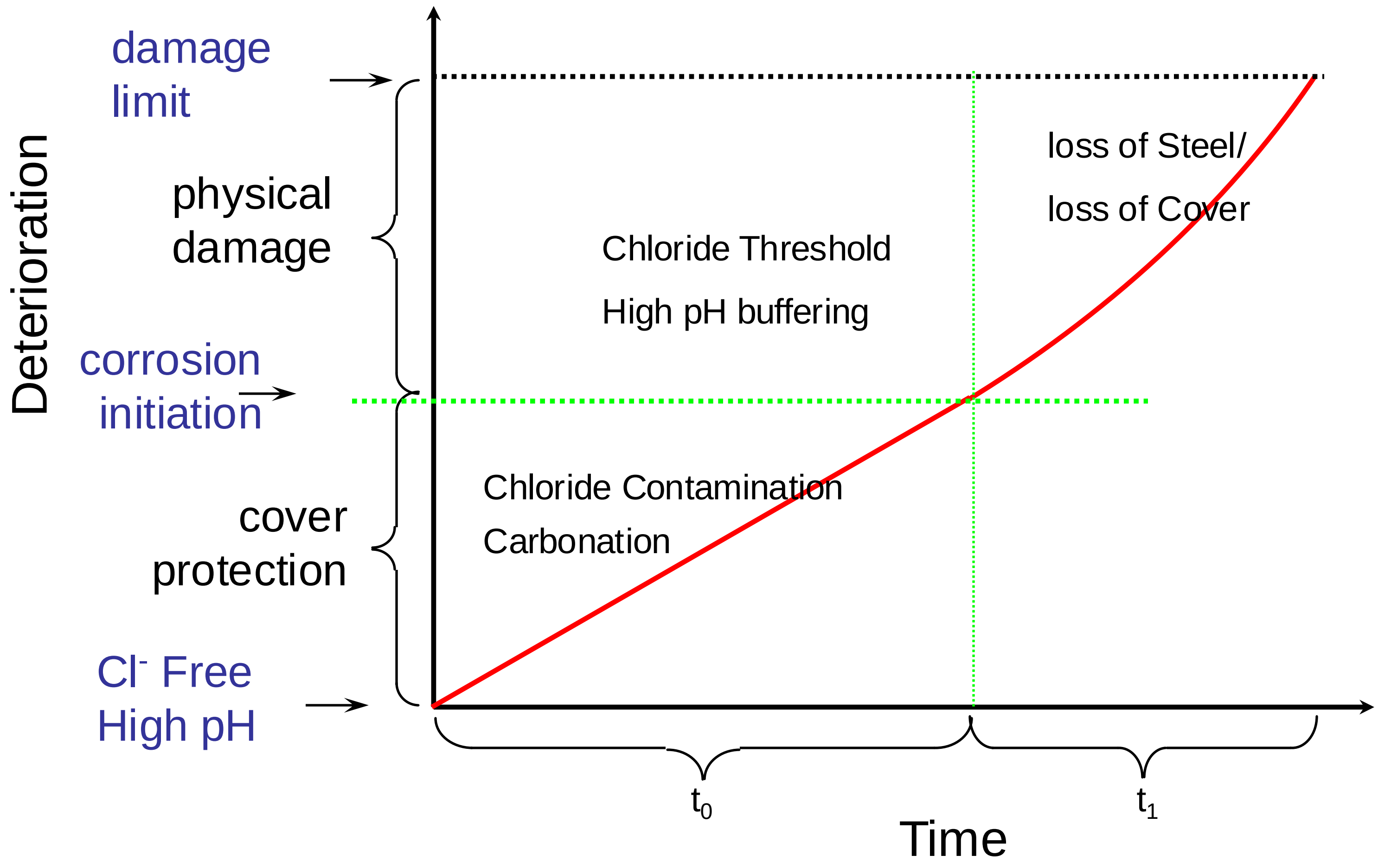
Basic service life model



Service Life

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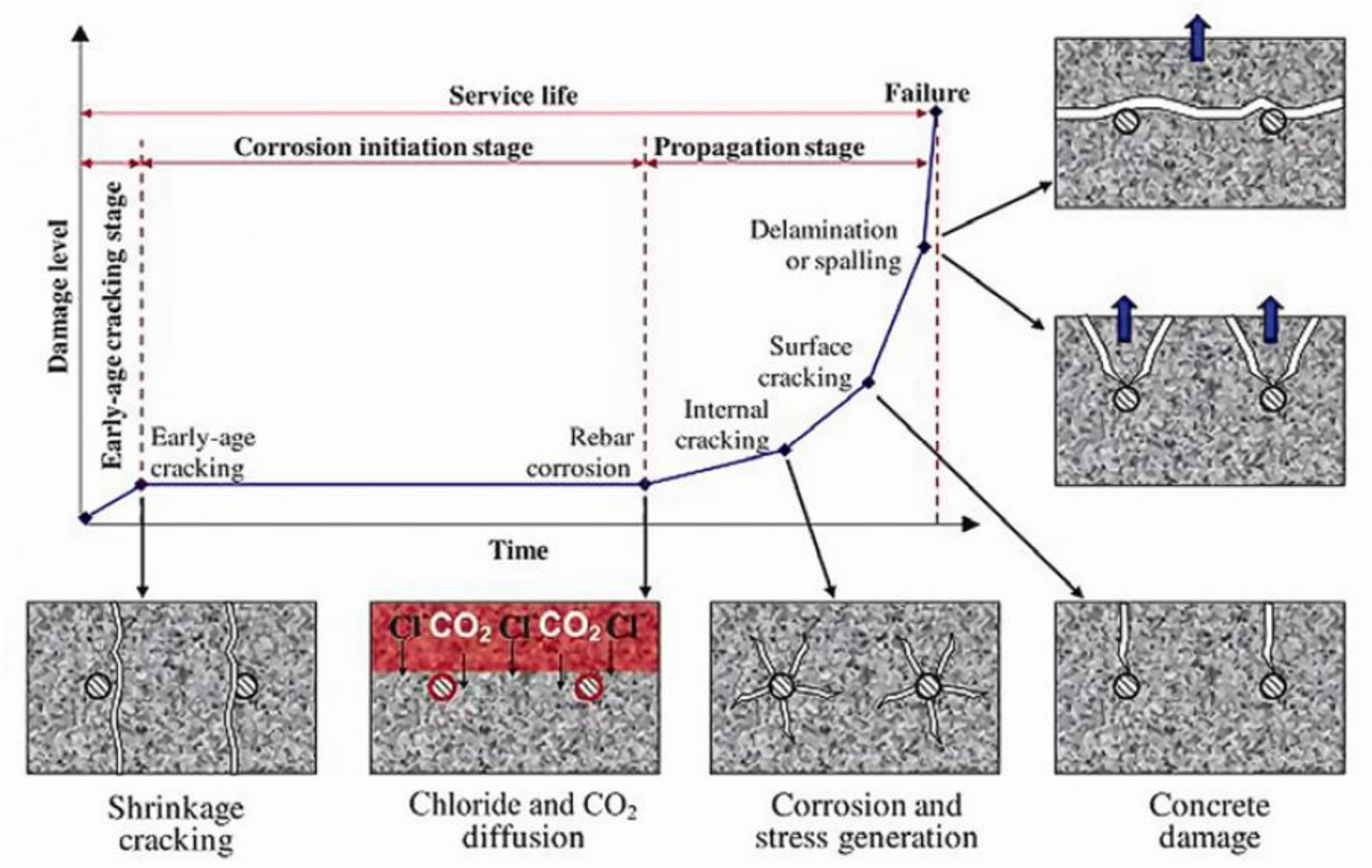


Schematic of conceptual model of corrosion of reinforcement steel in concrete

Source: Woubishet Zewdu, Taffesea, and Esko Sistonen, 2013

The Corrosion Conundrum: Durability Risks and Protection to Bridge Structures

Over the past few decades, the desire of extending the useful service life of infrastructures has become of paramount significance. Where the aging infrastructure is a serious problem faced by countries across the world, the premature deterioration has also emerged as the major problem that results in reduced service life of the reinforced concrete structures. The construction industry has recently been witnessing ambitious designs and specifications to achieve this desired design service life. The adoption of high standards of design and construction of new concrete structures has become a major focus. Despite the ambitious project specifications and design parameters, reinforced concrete structures are always subjected to numerous durability risks. This article attempts to highlight the carbonation and chloride attack risks to the reinforced concrete bridges.

Bridge Hierarchy - *Bridge Structural Elements and Exposure to Risks:*
There are different types of bridges and a general classification of bridge components is shown in Figure 1. Concrete bridge structural elements are constantly subjected to multiple risk factors that result in deterioration over the course of their service lives. The causes of deterioration and concrete distress are due to multiple expository variables such as aging, corrosion, cracking, vehicular overload, environmental factors, climates, material properties, inadequate design and poor asset management. Natural hazards, floods and collisions are also primary causes of bridge failures.

Bridge failure may be defined as the inability of a bridge to serve its intended function with the desired levels of safety and serviceability. Failure of a bridge may be attributed to a number of independent and interrelated factors. Corrosion of the steel generates iron oxides and hydroxides, resulting in 5 to 6 times increase of volume than the original size. This increase in volume causes expansive forces to accumulate within the concrete around reinforcement and results in concrete spalling. The American National Bridge Inventory, 2006, reported that environment-induced corrosion has structurally affected 73,764 bridges in the USA. The US Department of Transportation report suggested in 2012 that 11% of the country's 607,380 bridges fall under the classification of structurally deficient assets due to traffic loads, aging of construction materials and other factors. Similarly, a considerable number of bridges located in the coastal areas of Japan have experienced early onset concrete deterioration due to corrosion within ten to 15 years of construction completion.

The Environment - *Understanding the Climate Change and Carbonation*
Concrete deterioration rate depends not only on material specifications and construction practices, but also relies on the on-going climatic environment during the life cycle of the structures. Atmospheric CO_2 is a growing cause of corrosion in bridges, buildings and other concrete infrastructure throughout the world. Using probabilistic and reliability-based approach, Stewart et al. researched on "Climate Change Impact and Risks of Concrete Infrastructure Deterioration" and concluded that carbonation-induced damage risks may increase by over 400% by 2100 for inland arid or temperate climates in Australia.

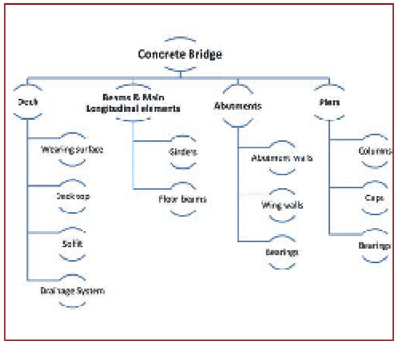
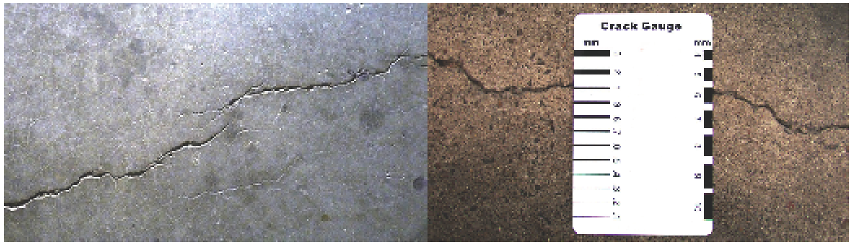


Figure 1.. Bridge hierarchy – concrete bridge components and elements. Source: Moufti, Zayed and Dabous, (2014)

Concrete Problems Today are Multifactorial — Root Causes

BY HAMID KHAN



Concrete cracks provide easy access to corrosive agents

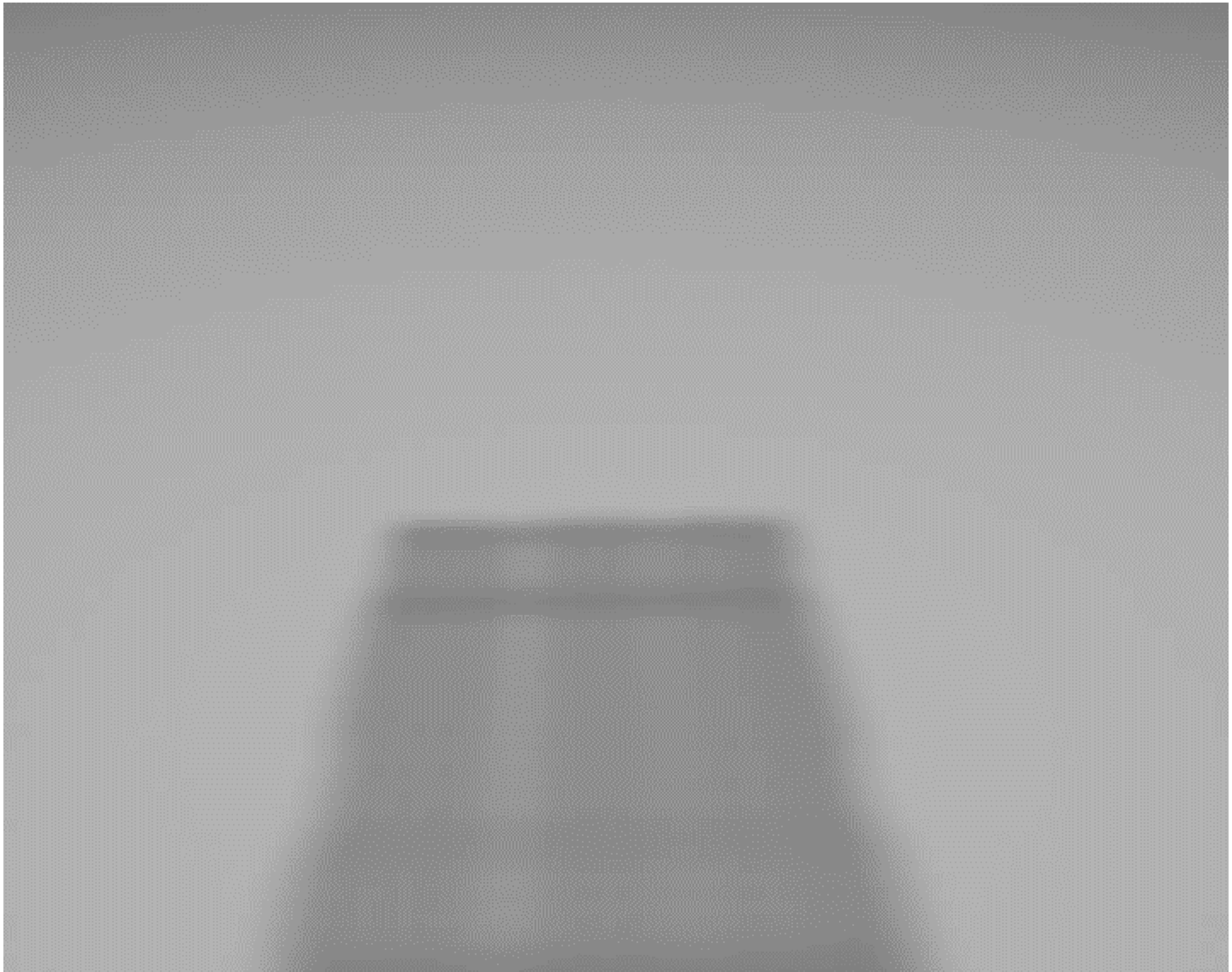
Regular and planned asset maintenance is vital for reinforced concrete structures. Such maintenance shall not be a 'cosmetic repair' but rather a proper root cause analysis that must be carried out to identify and understand the actual source of the problem. Material selection is an important step in asset maintenance and refurbishment projects though only after the root cause has been addressed. Conducting proper root cause analysis in restoration and refurbishment projects will prevent one from falling into a vicious cycle of 'repairing the repair'. A study conducted by Jingmond and Agren (2015)[1] has highlighted the importance to look at the root causes of the defects in concrete from the organisational perspective as well, instead of the operational level only.

A defect or problem in an existing reinforced concrete structure is multifactorial; it often stems from obscure reasons. Like the cause of a common headache that is often attributed to a pathological cause leading to expensive and often needless investigations and treatments, whereas, the actual cause may be a stress-triggered tension headache. Similarly, stomach infections are common during monsoons in some countries, which are due to the 100 year-old corroded sewage pipes leaking into the parallel running municipal water pipes. A point to ponder here is whether treating the gastro patient with medicines or changing water filters would make the situation better without addressing the root cause of the problem?

Corrosion of the steel generates iron oxides and hydroxides, resulting in the increase of volume 5 to 8 times of its original size. This increase in volume causes expansive forces to accumulate within the concrete around reinforcement and results in cracking, and in areas with low cover, concrete spalling. Cracks provide easy access to oxygen, moisture, chlorides and other corrosive agents that create conditions suitable for accelerating the electrochemical corrosion process. Pretensioned concrete bridge girders may exhibit unexpected end cracking upon stress release. These cracks may propagate into the bottom flange of the girder where strands are located and can increase in width with increased traffic loads. Leakage from bridge expansion joint could penetrate the bottom flange cracks and trigger severe corrosion. In this case, expansion joints leakage must be arrested prior to the crack and concrete repair activity.

A common form of cracking at an early age on new concrete decks is known as *transverse cracking* which may appear over the length of span above transverse reinforcement. These cracks can accelerate corrosion rates, reduce the service life of the asset and increase maintenance costs. When a mass of concrete that shrinks as it ages is restrained, cracks will occur. For example, restraint of a concrete deck by an integral support girder against its volume change initiates cracking. Multiple factors such as concrete materials and mix design, ambient temperature changes, humidity, bridge design characteristics and construction practices can all contribute to volume change and/or to degree of restraint of concrete mass. However, transverse cracking cannot be attributed to all of the above factors. It is therefore important to identify the major contributing factor(s) to address the root cause of cracking.

A crude approach while examining the corrosion induced damage in bridge structures, particularly in the marine environment, is to assume the presence of chlorides as the main cause of failure. Chlorides might be the reason of corrosion but not the actual cause of the bridge defect. The root cause of failure of the bridge structure cannot be simply corrosion. There are many factors involved that could lead to corrosion and ultimately




QUALITY
DEVELOPMENT
INGENUITY
NEW
VISION
INSPIRATION
INNOVATION
CREATIVITY
TECHNOLOGY
FUTURE
SOLUTION
IDEAS

The EN1504 holistic approach to Repair & Protection

FOSROC

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PROJECT PHASES

INFORMATION ABOUT THE STRUCTURE	PROCESS OF ASSESSMENT	MANAGEMENT STRATEGY	DESIGN OF REPAIR WORK	REPAIR WORK	ACCEPTANCE OF REPAIR WORK
Basic considerations and actions					
• Condition and history of structure • Documentation • Previous repair and maintenance	• Defects and their classification and causes • Safety/structural appraisal before protection and repair	• Options • Principles • Methods • Safety/structural appraisal during protection and repair	• Intended use of products • Requirements - substrate - products - work • Specifications • Drawings • Safety/structural appraisal after protection and repair	• Choice and use of products and systems and methods and equipment to be used • Tests of quality control • Health and safety	• Acceptance testing • Remedial works • Documentation
Relevant Clauses in this European Standard and other Parts of the EN 1504 series					
• Clause 4 of this European Standard	• Clause 4 of this European Standard	• Clauses 5 and 6 of this European Standard	• EN 1504-2 to EN 1504-7 • Clauses 6, 7 and 9 of this European Standard	• Clauses 6, 7, 9 & 10 of this European Standard • EN 1504-10	• Clause 8 of this European Standard • EN 1504-10

Step 4

Design of Repair

After understanding the project objectives it is possible to select a strategy, and specify the materials and techniques that will be used to conduct the repairs.

Selecting the products & techniques

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Fosroc Products

Principal	Protection Against Ingress								Moisture Control				
Repair Method Description	Hydrophobic Impregnation	Impregnation	Coating	Surface bandaging of Cracks	Filling of Cracks	Transferring Cracks into Joints	Erecting External Panels	Applying Membranes	Hydrophobic Impregnation	Impregnation	Coating	Erecting External Panels	Electrochemical Treatment
Repair Method NumberNumber	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	2.1	2.2	2.3	2.4	2.5
Nitocote SN511, SN502	■								■				
Nitoflor Lithurin		■								■			
Dekguard E2000, S, W, PU			■								■		
Nitoflor Systems			■								■		
Expoband H45				■									
Nitofil LV, TH, Conbextra EPLV					■								
Nitoseal & Colpor Sealants						■	■					■	
Nitofil WS60, UR63					■								
Polyurea WPE								■			■		
Nitodek Car Park System								■			■		
Renderoc FC, HB, HB30, HB45, Patchroc													
Renderoc LA													
Renderoc DS, Renderoc SP													
Nitobond EP, PE													
Auracast & Auramix Admixtures													
Lokfix S, P, LokfixdurDUR													
Nitowrap, Nitoplate, Nitorod													
Conbextra Cable Grout													
Fosroc Life Jacket													
Nitoprime Zincrich													
Conplast CN													

Principal	Concrete Restoration				Structural Strengthening						
Repair Method Description	Hand Applied Mortar	Recasting With Concrete or Mortar	Spraying withConcrete or Mortar	Replacing Elements	Adding or replacing reinforcement	Anchoring reinforcement	Bonding Plate reinforcement	Adding Mortar or Concrete	Injecting Cracks and Voids	Filling Cracks	Prestressing & Post-Tensioning
Repair Method NumberNumber	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4	4.5	4.6	4.7
Nitocote SN511, SN502											
Nitoflor Lithurin											
Dekguard E2000, S, W, PU											
Nitoflor Systems											
Expoband H45											
Nitofil LV, TH, Conbextra EPLV									■	■	
Nitoseal & Colpor Sealants											
Nitofil WS60, UR63											
Polyurea WPE											
Nitodek Car Park System											
Renderoc FC, HB, HB30, HB45, Patchroc	■										
Renderoc LA		■						■			
Renderoc DS, Renderoc SP			■					■			
Nitobond EP, PE				■				■			
Auracast & Auramix Admixtures				■				■			
Lokfix S, P, LokfixdurDUR						■					
Nitowrap, Nitoplate, Nitorod							■				
Conbextra Cable Grout											■
Fosroc Life Jacket											
Nitoprime Zincrich											
Conplast CN											

Principal	Physical Resistance			Chemical Resistance			Preserving or Restoreing Passivity					Increasing Resistivity			Cath	Cathc	Control of Anodic Areas		
Repair Method Description	coating	Impregnation	adding mortar or concrete	coating	Impregnation	adding mortar or concrete	Increasing Concrete Cover	Replacing Contaminated Concrete	Electrochemical Realkalisation	Realkalisation by Diffusion	Chloride Extraction	Hydrophobic Impregnation	Impregnation	Coating	Limiting Oxygen at Steel	Cathodic Protection	Active Reinforcement Coating	Barrier Reinforcement Coating	Corrosion Inhibitors
Repair Method NumberNumber	5.1	5.2	5.3	6.1	6.2	6.3	7.1	7.2	7.3	7.4	7.5	8.1	8.2	8.3	9.1	10.1	11.1	11.2	11.2
Nitocote SN511, SN502												■							
Nitoflor Lithurin		■			■								■						
Dekguard E2000, S, W, PU	■			■										■					
Nitoflor Systems	■			■										■					
Expoband H45																			
Nitofil LV, TH, Conbextra EPLV																			
Nitoseal & Colpor Sealants																			
Nitofil WS60, UR63																			
Polyurea WPE				■										■					
Nitodek Car Park System				■										■					
Renderoc FC, HB, HB30, HB45, Patchroc			■			■	■	■											
Renderoc LA			■			■	■	■											
Renderoc DS, Renderoc SP			■			■	■	■											
Nitobond EP, PE			■			■	■											■	
Auracast & Auramix Admixtures			■			■	■												
Lokfix S, P, LokfixdurDUR																			
Nitowrap, Nitoplate, Nitorod																			
Conbextra Cable Grout																			
Fosroc Life Jacket																■			
Nitoprime Zincrich																	■		
Conplast CN																			■

Concrete repair

constructive solutions

- Hand applied repair mortars
- Sprayed repair mortars
- Form and pour micro-concrete repair mortars
- Resin injection systems
- Corrosion Protection
- Epoxy repair mortars

Repair mortar specifications

constructive solutions

SPECIFICATIONS

✓Low Permeability

✓Compatibility

✓Long Term Integrity

Repair mortar specifications

constructive solutions

Compatibility

- Modulus of Elasticity
- Thermal Co-efficient of Expansion
- Strengths (Compressive, Flexural, Tensile)

Low Permeability

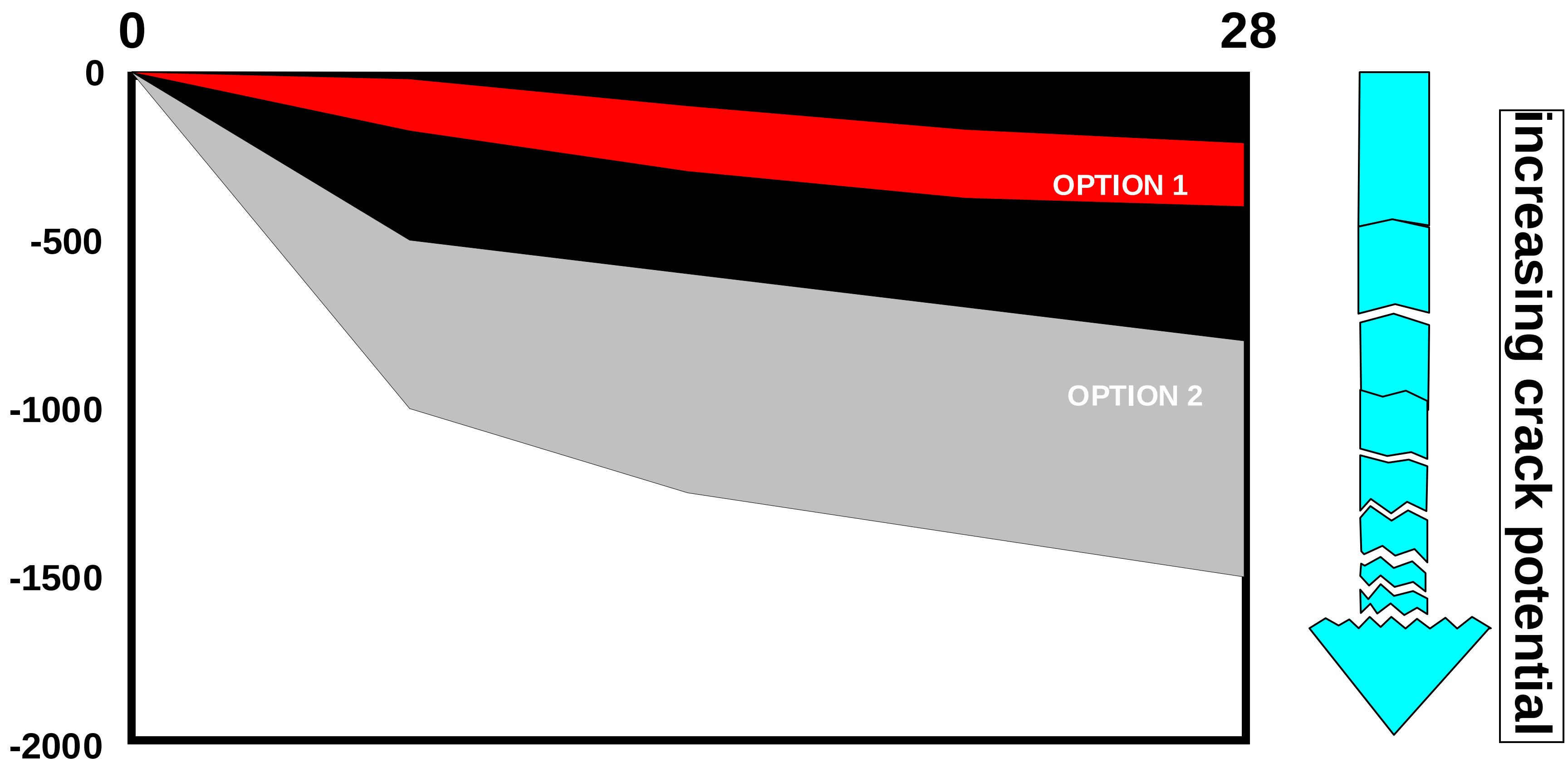
- Water
- Carbon Dioxide
- Chloride

Long Term Integrity

- Bond Strength
- Shrinkage

Repair mortar specifications

constructive solutions



Step 5

Repair Work

There are many techniques to repair and protect concrete. The next module will run through the most common and the best application practise.

BE PREPARED – Is Surface Preparation for Concrete Repairs a Fad?

Hamid Khan – Product Segment Manager – Parchem

Prior to the commencement of concrete repairs, the fundamental thing to consider is surface preparation. The amelioration of damaged concrete structures involves many elements, from engineers, applicators and even legal counsel. This paper details the primary value of surface preparation, for without good bonding no repair system can be expected to perform.

Repair Material to Concrete Substrate – An Alien or a Monolithic Bond:

In European standard (EN1504-10:2003), the term bond refers to the adhesion of the applied material or system to the concrete substrate. Hence, adhesion has an underlying importance in the repair of concrete structures. Surface preparation of the concrete substrate is considered to be the most crucial step in a concrete repair project. A poorly prepared surface will result in the weak association to the repair zone, no matter how proficient the applicator or expensive the repair material might be. The repair material when applied, should not act as 'an alien body' to the host concrete substrate, rather, it should determining the bond strength of the repair system, include exposure conditions, properties of the repair materials and concrete substrate to name a few.

Sawn Edges – Doing It Right the First Time:

Saw cutting is used to delineate the perimeter of the repair zone. A disc type mechanical grinder is used for saw cutting the edges along the perimeter of the repair area. The right angled saw cut to a depth of 10-15mm is recommended to avoid any feather edging and it should not be deeper than the reinforced concrete cover. Saw cut squared edges help contain the repair material. The saw cut edges should be roughened slightly by a needle gun or hacking, as a polished vertical sawed face may result in poor bonding.

The geometry of the repair area should be in simple square or rectangular shapes. Sharp acute angles and re-entrant corners should be avoided (Figure 1). Some concrete repair field installers usually form excessive or tortuous edge conditions as they try

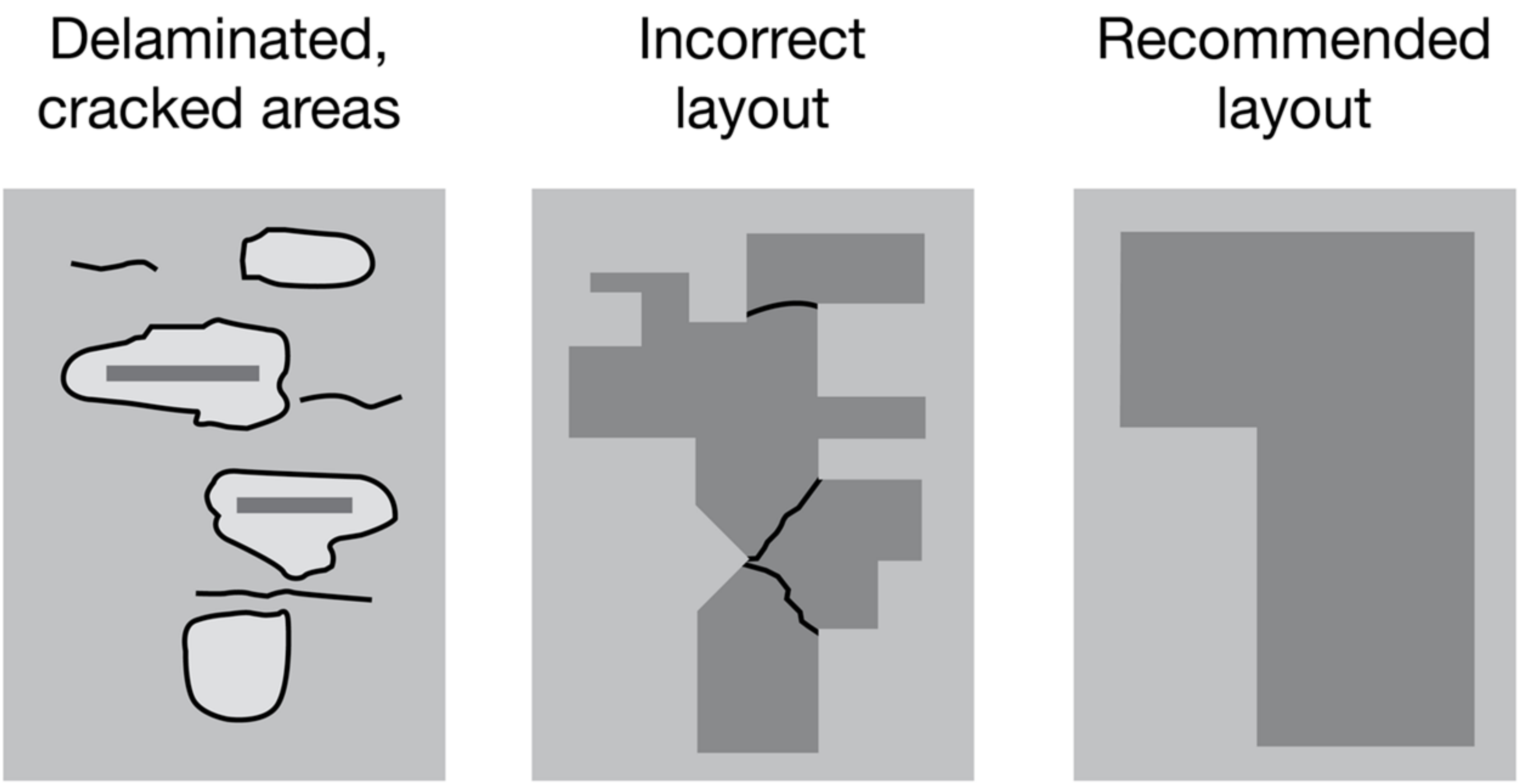
Removal of Spalled Concrete:

Most of the repairs require surface preparation comprising of roughening, exposure of the aggregates and removal of the damaged, delaminated and loose concrete. Regardless of the type of deterioration, all weak, flaky, unsound and disintegrated concrete must be removed. Defective concrete should be broken back to a sound and dense concrete surface. Prior to the removal of any spalled concrete from a load bearing structure, certified shoring must be provided to the structure. The removal of concrete usually starts with saw cutting the repair boundaries. The deteriorated unsound concrete in the centre of the repair area is then removed. Breaking out and the removal of concrete progresses from the centre outwards towards the edges. The next step is to remove the concrete near the edges without damaging the sound concrete at the interface.

The extent of concrete removal depends on the extent of damage. Concrete may be removed by impacting methods using power tools (Figure 2 and 3), or by hydro-demolition such as water

Sawn Edges

constructive solutions



Source: Concrete Repair Geometry. Source: ACI Webinar, 2013

Concrete is *THIRSTY* !


BRILLIANT!
GUINNESS
Concrete should be *DRUNK* !


Tool-Tech

In the SSD condition, the substrate is damp and saturated but does not contain any free water on the surface. Free water can impair the bond at the interface due to increased shrinkage leading to lower material strength and reduced bond strength

Hand placing New innovative

constructive solutions

- High compressive strength
- Extra high build
- High resistivity
- Ideal for concrete rectification in new structures

Hand applied Video

constructive solutions

High build hand applied mortars

constructive solutions

- Reduces multiple layer applications
- High build formulation
- Fewer applications
- Improved site productivity

Multiple layer application – criss-cross keyed pattern

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Damaged Floor and Pavement Repairs

Cause

- Vehicle traffic loading
- Natural wear and tear of floors
- Ageing of floor pavements
- For emergency patching of small areas of concrete pavements and floors

Pavement Repairs

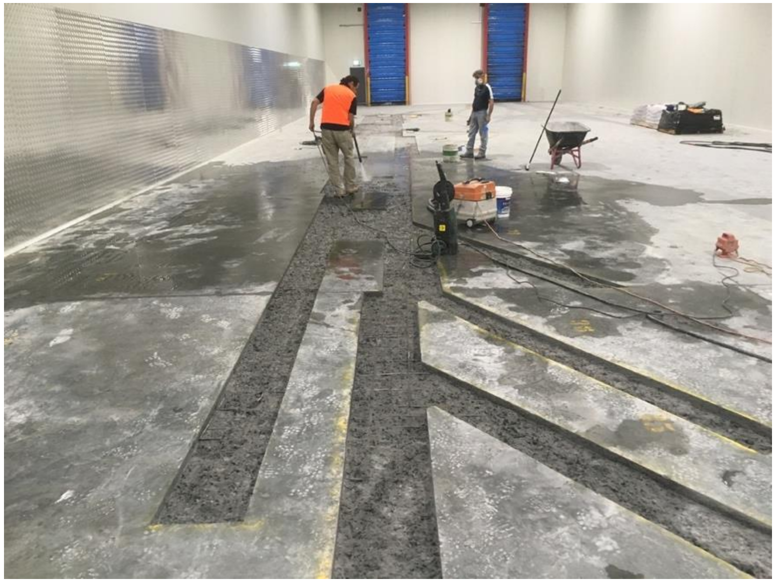
constructive solutions

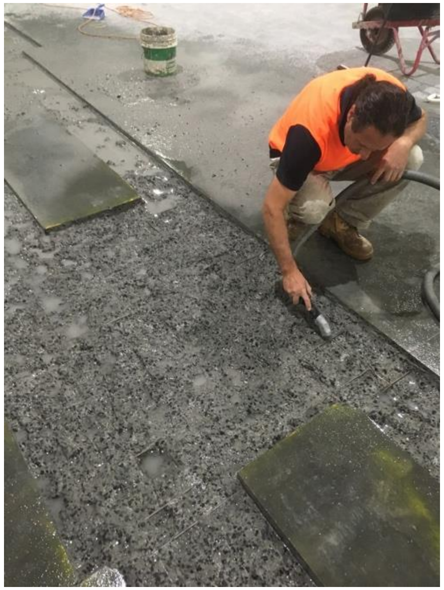
- Use for reinstatement of large areas of concrete floors and
- pavements, up to 18m2
- Trafficable after 16 hrs
- Apply by trowel or pour, 15mm to 50mm deep

Floor Reinstatement

constructive solutions






Bridge Deck Repair

FOSROC

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Sprayed repair mortars

- Very fast Application
- Large repairs and high build
- Low dust emissions
- High strengths
- Low rebound

Form & pour micro-concrete repairs

- Environmental friendly & sustainable
- Enhanced durability and service life
- Suitable for large volume pours (50mm – 500mm)
- Extremely low permeability

TECHNICAL NOTE

Concrete rectification using micro-concrete form-and-pour technique

Hamid Khan:
Product Segment Manager
Fosroc ANZ (Parchem)

Accelerated and premature deterioration of some reinforced concrete structures during the initial years of their life cycle is of major concern to asset owners. The premature deterioration results in reduced service life of the structures. The adoption of high standards for design and construction in new concrete structures has become a major focus today. The construction industry has recently been witnessing ever-increasing expectations for concrete's design life. This article highlights the use of high performance durable micro-concrete repair material to rectify defects in long design life structures during and after the construction phase.

Repair materials need to be able to be used in difficult locations and achieve good compaction around the reinforcing steel without any external aids such as vibration. The finished repair must provide protection against corrosive agents such as chlorides and carbon dioxide and present minimal shrinkage to reduce the risk of cracking.

What is the purpose of using fluid micro-concrete repair mortar?
The primary purpose of using the fluid micro-mortar system is to restore the structure to its original strength and integrity. The repair may include large damaged structural sections of concrete as well as for smaller locations where difficulties of access make hand or trowel applied mortars impractical and have a high associated failure rate.

How is it different from conventional concrete?
If a conventional mix of high strength concrete is used for replacement, small gaps can occur around the reinforcement steel either through poor compaction or settlement providing a potential site to initiate corrosion. To avoid these common pitfalls the repair materials need to be exceptionally fluid to completely eliminate this problem. Pre-bagged fluid micro-concrete such as Fosroc's Renderoc LA55 Plus typically have a compressive strength of ≥75 MPa and are based on supplementary cement materials making them environmental friendly and sustainable with a low carbon foot print.

The micro-concrete fluid repair materials are produced off site in manageable 20 kg bags so they are simple and

Renderoc LA55 – Form and Pour

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Fluid Micro Concrete

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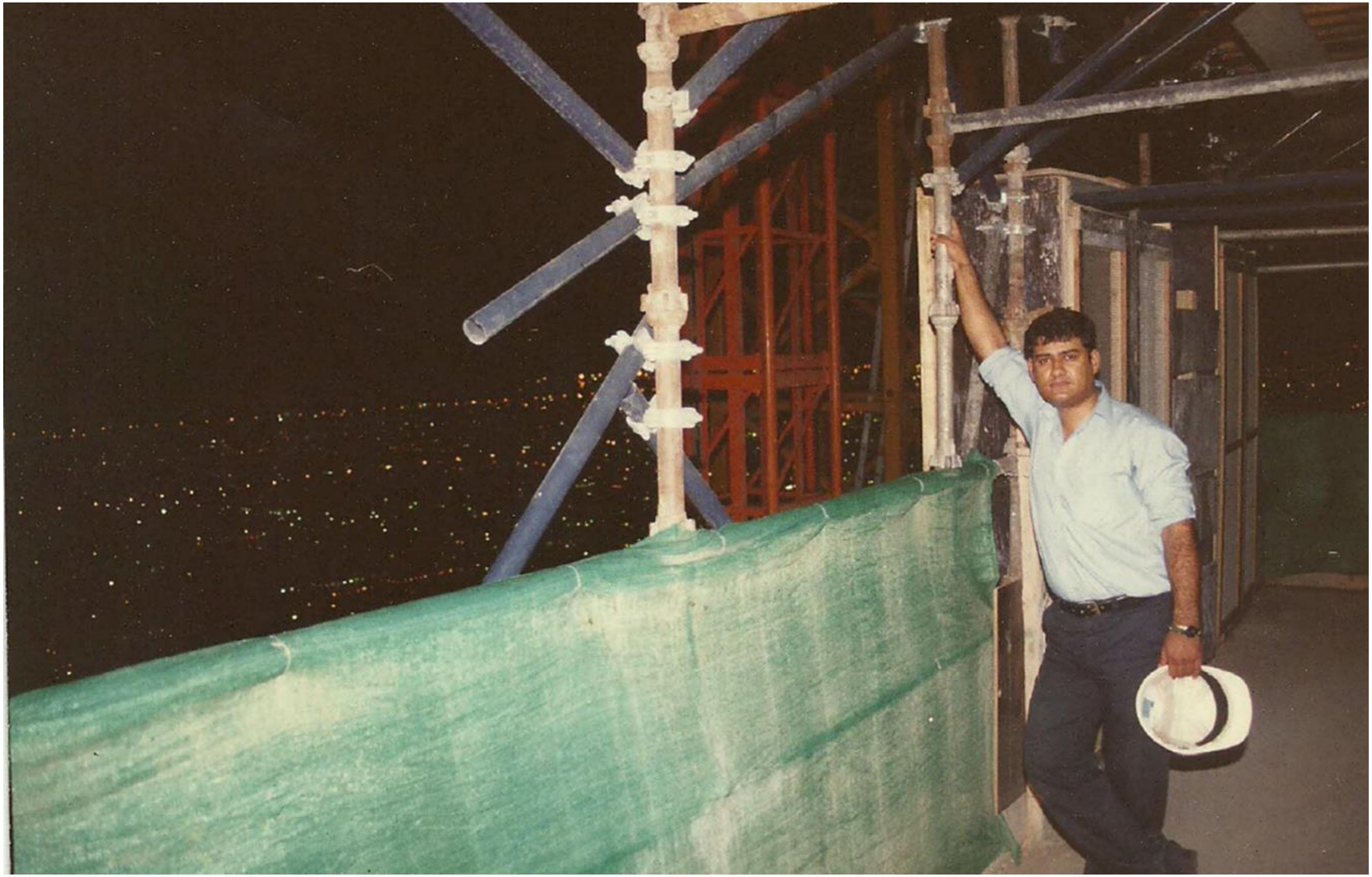

SCC pour for transfer beam, Shangri-La Hotel in Dubai - 2002

Fluid Micro Concrete

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SCC pour in progress for transfer beam, Shangri-La Hotel in Dubai - 2002

Crack repairs

Cracks

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- Cracks are a reality in concrete, as long as we build with it we will have to deal with it
- Cracks are a concern to asset owners for long term durability

Why inject

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- Structural integrity
- Water loss
- Water penetration
- Prevent further damage
- Reinforcement protection / durability
- Aesthetics

Injection Grout

constructive solutions


DANGER
KEEP OUT

Thank you

Hamid.khan@fosroc.com.au