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Guidance for repair/rehabilitation of concrete transport infrastructures (CTIS)

Activity Lead Partner

Queen's University Belfast, Northern Ireland, UK

European Union
European Regional Development Fund

Investing in our common future

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Transnational Programme

Aim of the Activity

To make a critical review concerning the main subjects involved in CTIS repair, damage and assessment and repair techniques

- Exposure variations
- Types of structures
- Causes of deterioration
- Impact of degradation on performance
- Testing techniques
- Decision on time of intervention
- Establishment of performance requirements
- Repair strategy – methods and materials
- Assessment of repair performance

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Exposure Classes in EN 206

- No risk of corrosion
- Carbonation-induced corrosion
- Chloride-induced corrosion resulting primarily from de-icing salts
- Chloride-induced corrosion resulting from seawater exposure
- Freeze-thaw attack
- Chemical attack

Exposure Classes in EN 206

Class	Environment	Examples
1. No risk of corrosion or attack		
X0	Concrete with no embedded metal (except where there is freeze/thaw, abrasion or chemical attack) For concrete with reinforcement or embedded metal: very dry	Concrete inside buildings with very low air humidity.
2. Corrosion induced by carbonation		
XC1	Dry or permanently wet	Concrete inside buildings with low air humidity Concrete permanently submerged in water
XC2	Wet, rarely dry	Concrete surfaces subject to long-term water contact Many foundations
XC3	Moderate humidity	Concrete inside buildings with moderate or high air humidity, External concrete sheltered from rain
XC4	Cyclic wet and dry	Concrete surfaces subject to water contact, not within exposure class XC2

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Exposure Classes in EN 206

3. Corrosion induced by chlorides other than from seawater		
XD1	Moderate humidity	Concrete surfaces exposed to airborne chlorides
XD2	Wet, rarely dry	Swimming pools, Concrete exposed to industrial water containing chlorides
XD3	Cyclic wet and dry	Parts of bridges exposed to spray containing chlorides Pavements, Car park slabs
4. Corrosion induced by chlorides from seawater		
XS1	Exposed to airborne salt but not in direct contact with seawater	Structures near to or on the coast
XS2	Permanently submerged	Parts of marine structures
XS3	Tidal, splash and spry zones	Parts of marine structures

Exposure Classes in EN 206

Type of cement	CEM IV/A (Reference); CEM IV/B; CEM III/A; CEM III/B; CEM V; CEM II/B [1]; CEM II/A-D			CEM I; CEM II/A [1]		
Exposure class	XS1/ XD1	XS2/ XD2	XS3/ XD3	XS1/ XD1	XS2/ XD2	XS3/ XD3
Minimum nominal cover (mm)	45	50	55	45	50	55
Maximum water/cement ratio	0.55	0.55	0.45	0.45	0.45	0.40
Minimum cement content, C (kg/m^3)	320	320	340	360	360	380
Minimum strength class	C30/37 LC30/33	C30/37 LC30/33	C35/45 LC35/38	C40/50 LC40/44	C40/50 LC40/44	C50/60 LC50/55

[1] Not applicable to cements II-T, II-W, II/B-L and II/B-LL.

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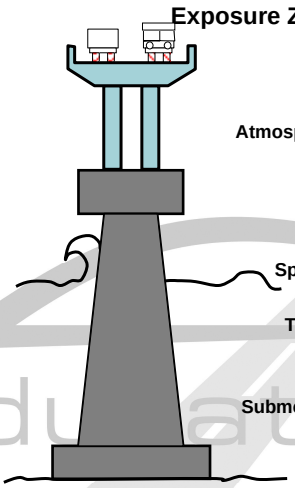
Types of Structure



Exposure Zone	Primary Concerns?
Atmospheric	Corrosion due to air-borne chlorides and carbonation
Splash	Corrosion due to chlorides, Erosion due to wave impact
Tidal	Corrosion due to chlorides, Growth of bio-organisms
Submerged	Corrosion due to chlorides, Change in microclimate due to seafloor sediments

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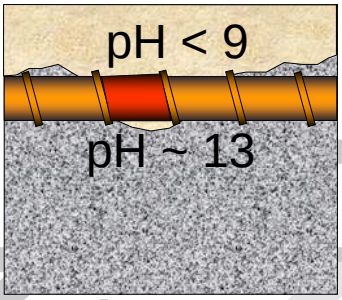
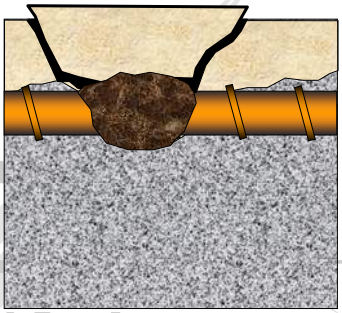
Corrosion of steel reinforcement

Loss of passivity



Advance of carbonation or chloride front

Formation of rust



Expansion of steel due to corrosion

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Causes of Deterioration

Common Causes of Deterioration

Concrete

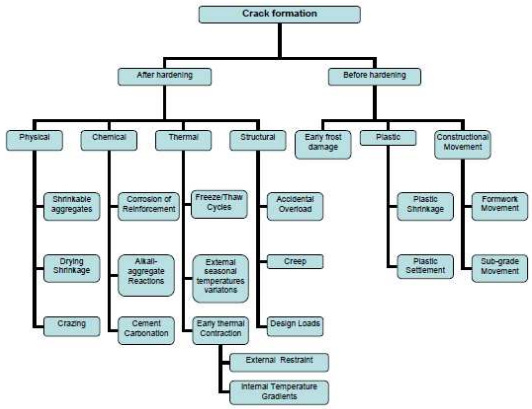
- **Mechanical**
  - Abrasion
  - Fatigue
  - Impact
  - Overload
  - Movement (e.g. settlement)
  - Explosion
  - Vibration
- **Chemical**
  - Alkali-aggregate reaction
  - Aggressive agents (e.g.: sulfates, salts, soft water)
  - Biological action
- **Physical**
  - Freeze / thaw
  - Thermal effects
  - Salt crystallization
  - Shrinkage
  - Erosion
  - Wear
- **Fire**

Reinforcement Corrosion

- **Carbonation**
  - Cement content & type
  - w/c ratio
  - Curing
  - Rainfall
  - Temperature / humidity
- **Corrosive Contaminants**
  - At mixing:
    - Chloride salts
  - From external environment:
    - Sea water
    - Road salt
    - Other contaminants
- **Stray currents**

Causes of Deterioration

Relationship between deterioration processes vs. Symptoms and defects observed in concrete



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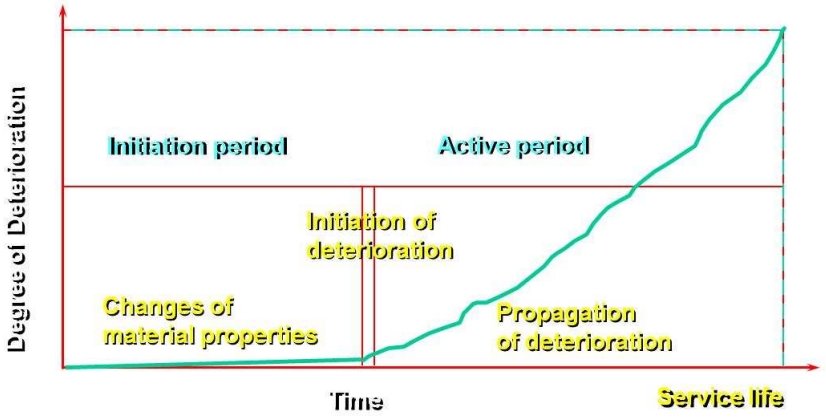
Impact of degradation on structural performance



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Defects vs Testing techniques

Non destructive testing methods (NDT)	Processes Design Compliance: Concrete Strength	Thickness measurement	Concrete Cover	Reinforcement location	Construction Defects: Grouting voids	Pop-Outs	Honeycombing	Bug Holes	Deterioration: Scaling	Eroded Concrete	Efflorescence	Cracks Type I - Early age formation	Cracks Type II- Structural	Cracks Type III- Corrosion	Cracks Type IV - (AA/DEF/ FREEZE & THAW)	Steel Fracture	Steel Loss	Element TRANSLATION OR ROTATION	Deflection	Joint sealant failures	Discoloration	Ingress/Organic &/or Biologic Contamination	Spalling	Carbonation	Chloride ingress	Water "content"
Visual exam.																									
Crack index																									
Hammer taping																									
Rebound Hammer	X																								
Pullout test	X																								
Ultrasonic Pulse Velocity	X *		X *																						
Pulse Echo		X			X																				
Surface Wave			X									X	X	X											
Transm. Thermography																									
Impact Echo	X	X		X		X																			

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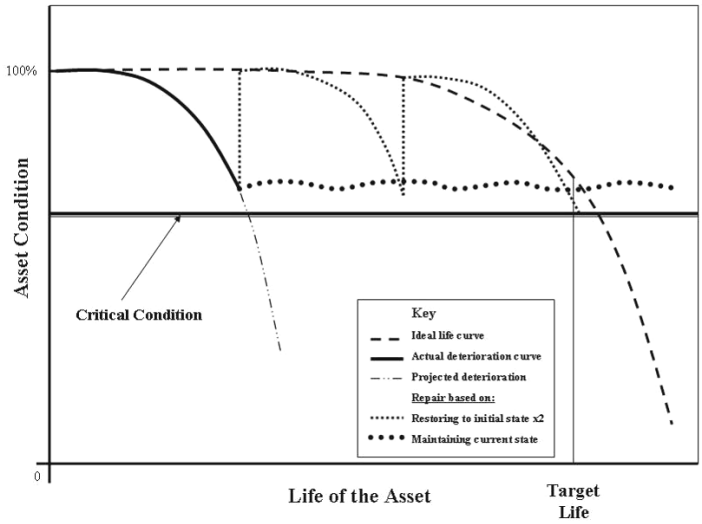
Decision on Time of Intervention



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Repair Strategies

Defects in Concrete	Reinforcement corrosion
1. Protection against ingress	7. Preserving or restoring passivity
2. Moisture control	8. Increasing resistivity
3. Concrete restoration	9. Cathodic control
4. Structural strengthening	10. Cathodic protection
5. Physical resistance	11. Control of anodic areas
6. Resistance to chemicals	

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Activities

- Review of requirements of concrete durability
  - Task Leader: QUB
- Mechanism and types of damage in reinforced concrete
  - Task Leader: U. La Rochelle
- In situ inspection techniques – specifications and comparisons
  - Task Leader: LCPC
- Repair techniques for concrete structures
  - Task Leader: LNEC

QUB contributes also to Activity 6 - Smart structural materials with permanent monitoring systems in concrete

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Thank You

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