



5 - 8 DECEMBER 2022
DUBAI WORLD TRADE CENTRE

Durability Design of RC Structures

Mohamad Nagi

Concrete Talks by ACI





Durability Design of RC Structures

Durability Design and Service Life



Durability Design

- What is concrete durability
- Designing durable concrete structures
- Service life of RC structures in the Gulf region
- Recommendation for enhancing the durability and service life of RC structures in the ME.

What is Durability

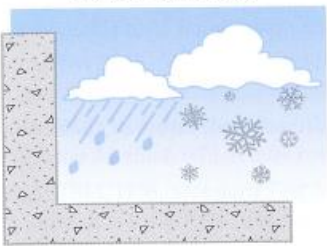
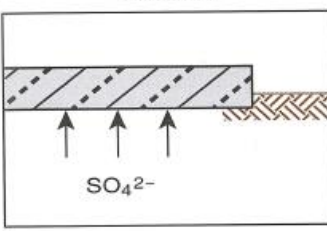
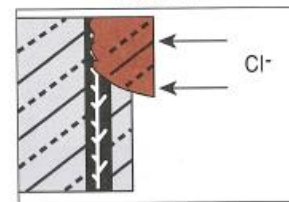
Durability by definition is the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties

- Concrete ingredients, proportions and interaction
- Placement and curing

Durability Design

- The art of durability design is to combine technically suitable methods in the best combination to produce the most cost effective solution
- - Service life
- Degradation models and QA
- Assessment and Repair

Traditional Durability Requirements

		Exposure Categories	Max. w/cm	Min. Design Compressive Strength, MPa (psi)
F	<p>Freezing and thawing</p> 	F0 (Not applicable) – for concrete not exposed to cycles of freezing and thawing	—	17 (2500)
		F1 (Moderate) – Concrete exposed to freezing and thawing cycles and occasional exposure to moisture (and no deicing chemicals)	0.55	24 (3500)
		F2 (Severe) – Concrete exposed to freezing and thawing cycles and in continuous contact with moisture	0.45	31 (4500)
		F3 (Very Severe) – Concrete exposed to freezing and thawing cycles that will be in continuous contact with moisture and exposure to deicing chemicals or seawater†	0.40	35 (5000)
S	<p>Sulfates***</p> 	S0 (Not applicable) – Soil: SO ₄ <0.10% – Water: SO ₄ <150 ppm	—	—
		S1 (Moderate) – Soil: 0.10% ≤ SO ₄ < 0.20% – Water: 150 ppm ≤ SO ₄ <1500 ppm – Seawater	0.50	28 (4000)
		S2 (Severe)‡ – Soil: 0.20% ≤ SO ₄ < 2.0% – Water: 1500 ppm ≤ SO ₄ <10,000 ppm	0.45	31 (4500)
		S3 (Very severe)‡ – Soil: SO ₄ > 2.0% – Water: SO ₄ >10,000 ppm	0.40*	35 (5000)**
C	<p>Corrosion</p> 	C0 (Not applicable) – Concrete that will be dry or protected from moisture in service	—	17 (2500)
		C1 (Moderate) – Concrete exposed to moisture but not to an external source of chlorides in service	—	17 (2500)
		C2 (Severe) – Concrete exposed to moisture and an external source of chlorides in service	0.40	35 (5000)

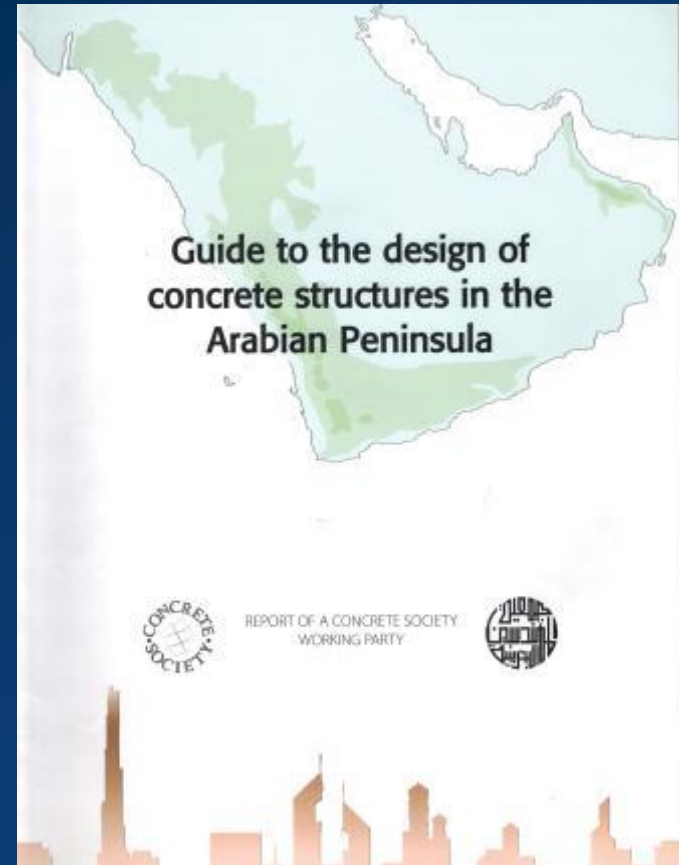
Updating Design Codes Based on Durability Requirements

Line #	Change proposal material in strikeout / <u>underline</u> (code or commentary text, figures, tables, etc.)						
10	ACI 318-14 Table 19.3.2.1—Requirements for concrete by exposure class						
	Exposure Class	Max w/cm ⁽¹⁾	Min f'_{cr} psi	<u>Max R, Coulombs</u>	Additional Requirements		
					Maximum water-soluble chloride ion (Cl ⁻) content in concrete, percent by weight of cement ⁽⁷⁾		Additional provisions
					<u>Nonprestressed concrete</u>	Prestressed concrete	
	C0	N/A	2500		1.00	0.06	None
	C1	N/A	2500		0.30	0.06	None
	<u>C2 (Opt 1)</u>	0.40	5000	<u>N/A</u>	0.15	0.06	Concrete cover ⁽⁸⁾
<u>C2 (Opt 2)</u>	<u>N/A</u>	<u>N/A</u>	<u>1500⁽⁹⁾</u>				

			Maximum water-soluble chloride ion (Cl ⁻) content in concrete, percent by weight of cement ⁽⁷⁾		Additional provisions
			Nonprestressed concrete	Prestressed concrete	
C0	N/A	17	1.00	0.06	None
C1	N/A	17	0.30	0.06	
C2	0.40	35	0.15	0.06	Concrete cover ⁽⁸⁾

Designing Durable Structures

- ACI 318
- AASHTO
- EUROCODE 2
- BS 5400
- BS 8500
- CS 163



Summary of Additional Durability Enhancement Techniques

Admixtures	Reinforcement	Surface	Electrochemical
Waterproofers Corrosion Inhibitors	Unreinforced Design Corrosion Resistant Steel Coated Rebar Galvanized FRP	Controlled Permeability Formwork Sealers Coatings	Monitoring Provision for CP CP at outset

Service Life

- The period of time during which a structure meets or exceeds the minimum requirements set for it
- Requirements limitation can be technical, functional or economical
- Durability
 - ASR
 - Sulfate attack
 - Corrosion

Degradation Mechanisms

Physical attack

- Salt crystallization
- Freezing-and-thawing attack
- Abrasion, erosion, and cavitation
- Thermal damage

Chemical attack

- Leaching
- Acid and base attack
- **Alkali-silica reactions**
- **Delayed ettringite formation**
- **Sulfate attack**
- **Steel reinforcement corrosion**

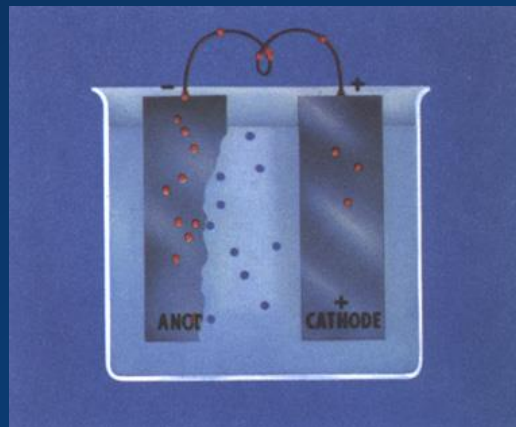
Sulphate Attack

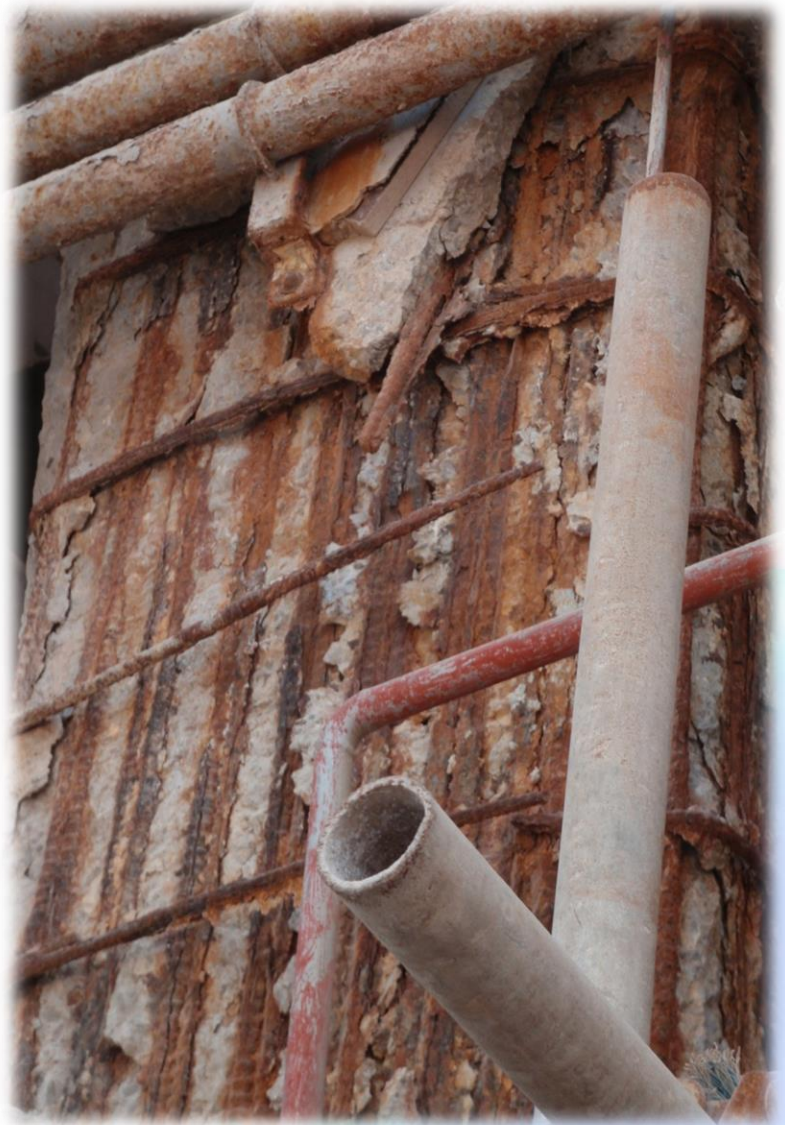
- A reaction between sulphate ions and calcium hydroxide and form gypsum and ettringite.
- BRE and ACI 201 Classification in UAE
- Low w/c ration and use of SCM



What is Corrosion

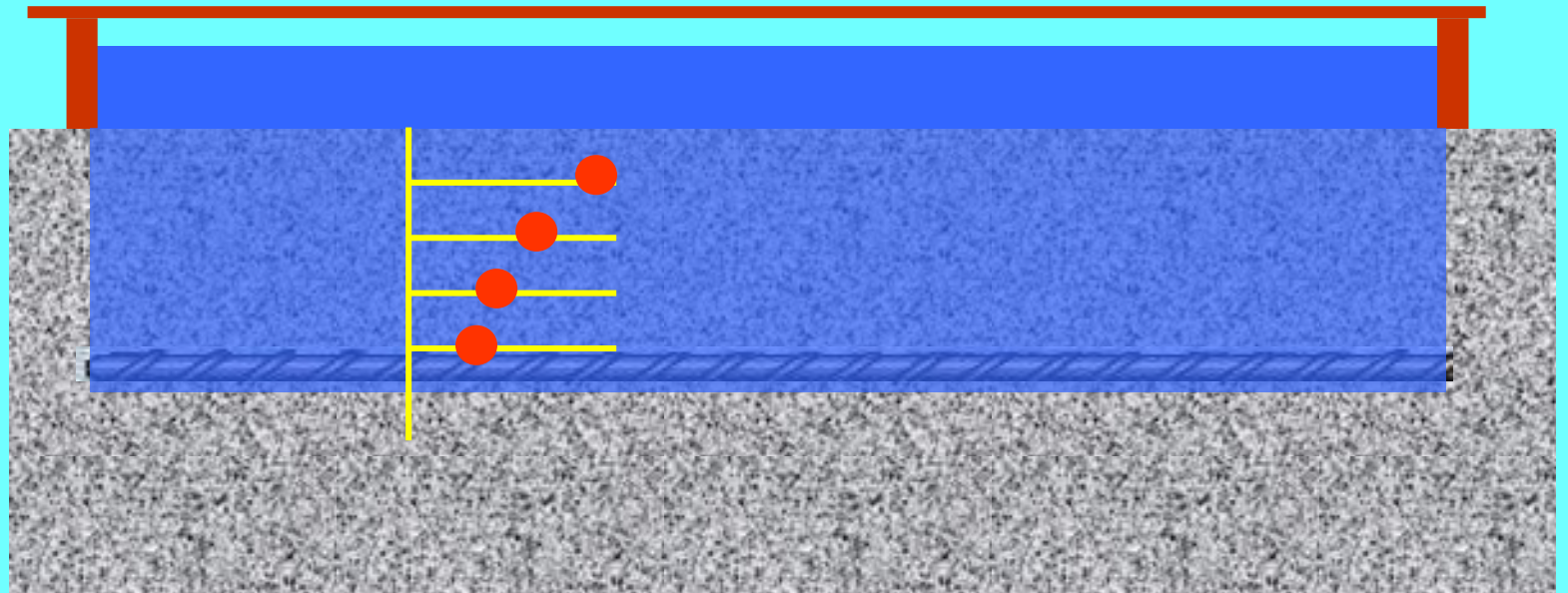
- Deterioration of a material as a result of reaction with its environment-M.G. Fontana
- Metal corrode because they have a strong driving force to return to their natural state



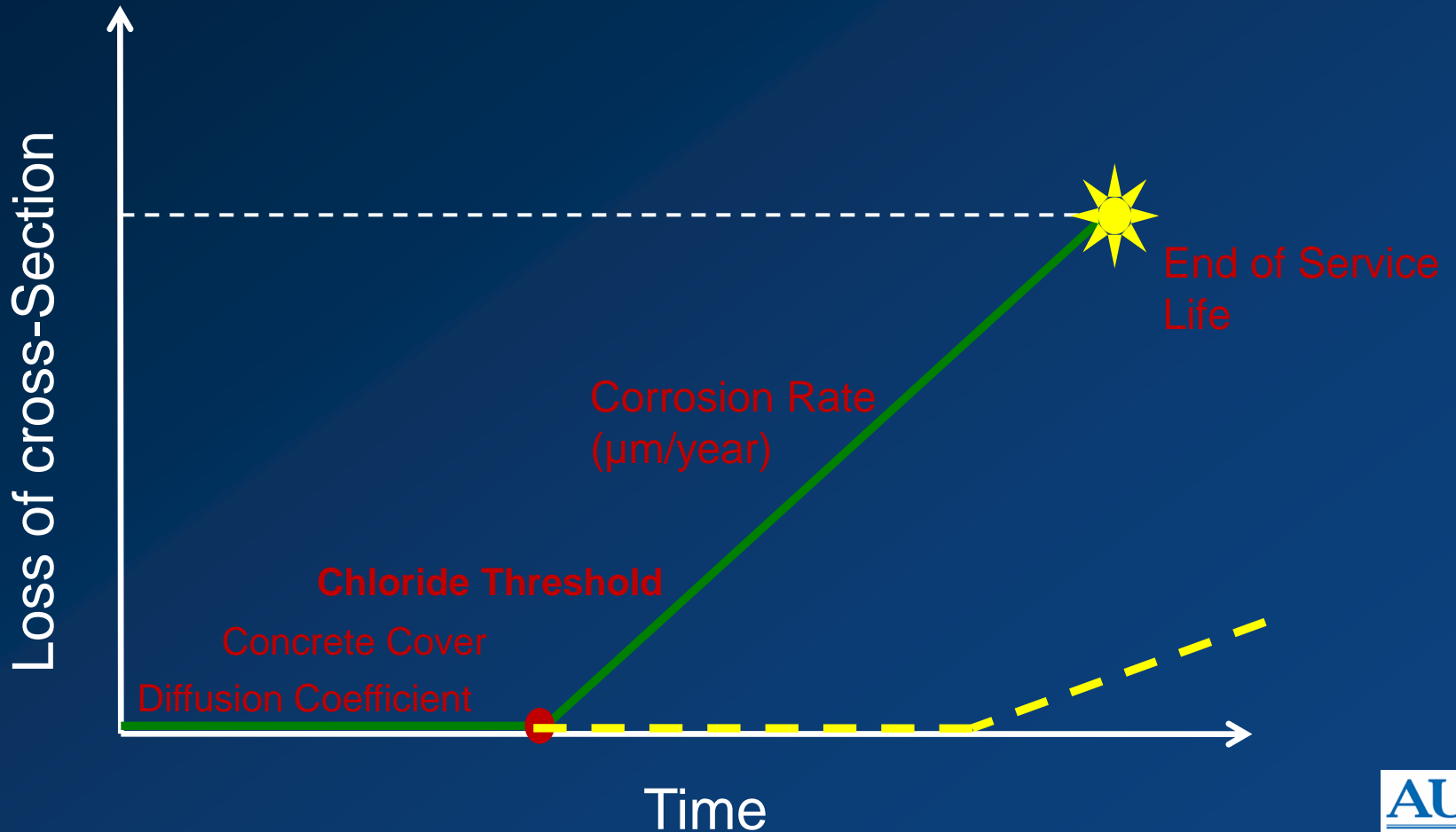




Kyosti Tuuti's Service Life Model



Kyosti Tuuti's Service Life Model



MEDRC Experimental Program

- Selected Concrete Mix Design.
- Laboratory Tests
- Service Life Prediction
- Field Testing Stations



Laboratory Testing Program

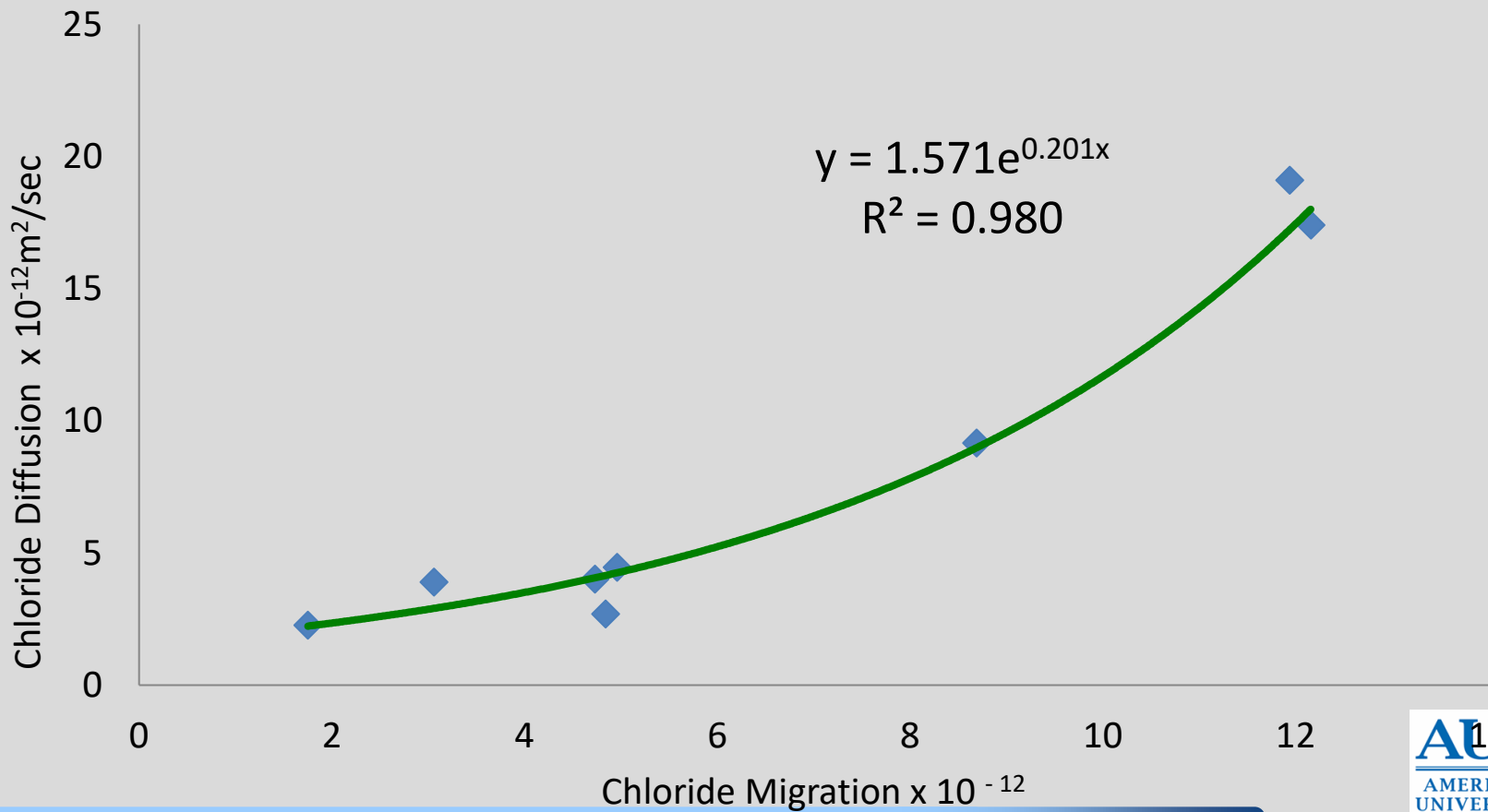
- Standard Durability tests.
- ASTM G 109 Testing Program
- Service Life Monitoring Parameters

ASTM G 109 Specimens



Further Research to Improve our Understanding of SLP

Chloride Migration vs. Diffusion



Conclusions

- Art of durability design is to combine technically suitable methods to achieve most effective solution
- Durability assessment plan is required to match the design with environmental conditions
- Corrosion is the main durability factor leads to deterioration of concrete structures
- Gulf region is the most corrosive location in the world
- Structural design of major structures currently include durability design required to achieve the design service life
- Use of corrosion protection systems such as corrosion inhibitors extend the service life of structures as well

Thank you

For the most up-to-date information please
visit the American Concrete Institute at:
www.concrete.org



American Concrete Institute

دائما تتقدم

THANK YOU



Concrete



**Facilities
Management**



**Geotechnical
& Engineering**



HVAC R



**Offsite
& Modular**



**Project
Management**



Solar



Stone Design



Technology



**Urban Design
& Landscape**