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Durable and Damage Resistant High Performance Fiber Reinforced Bridge Structures

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Problems with many current bridge structures: **Deterioration**

Example #1: Bridge Columns

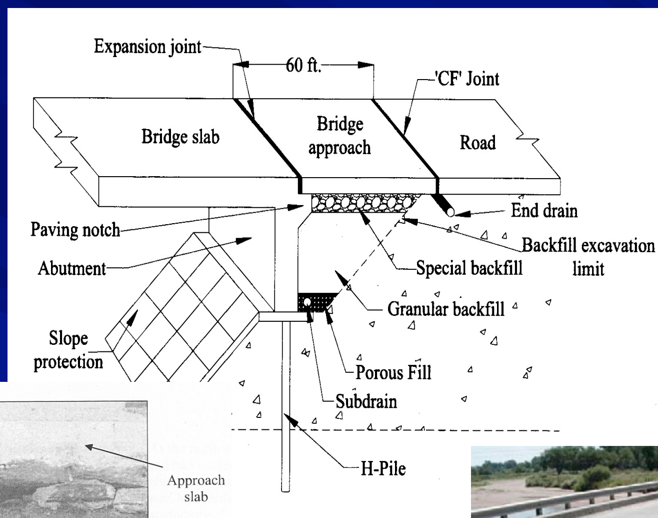
(ASR) *Environmental Damage* (Corrosion)

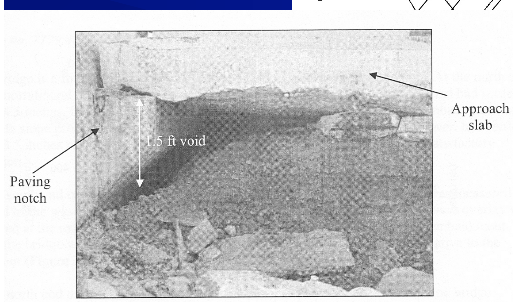
Seismic Damage

Deterioration caused by

both environmental and seismic loading conditions.

Problems with many current bridge structures:
Deterioration
Example #2: Bridge Approach Slabs





Deterioration caused by:

<u>both</u> environmental & mechanical loading conditions.

Mechanically induced

Truck loading

Soil Consolidation and wash out

Fatigue

Environmentally induced

Corrosion

Frost Action

Alkali Silica Reaction

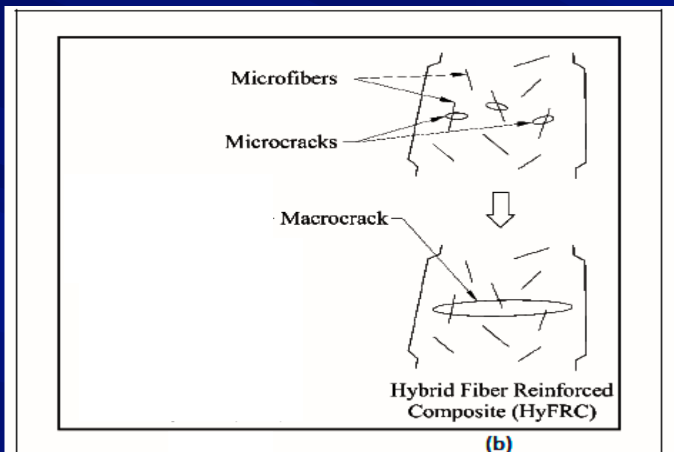
Salt Scaling

High Performance Hybrid Fiber Reinforced concrete (HyFRC) composite

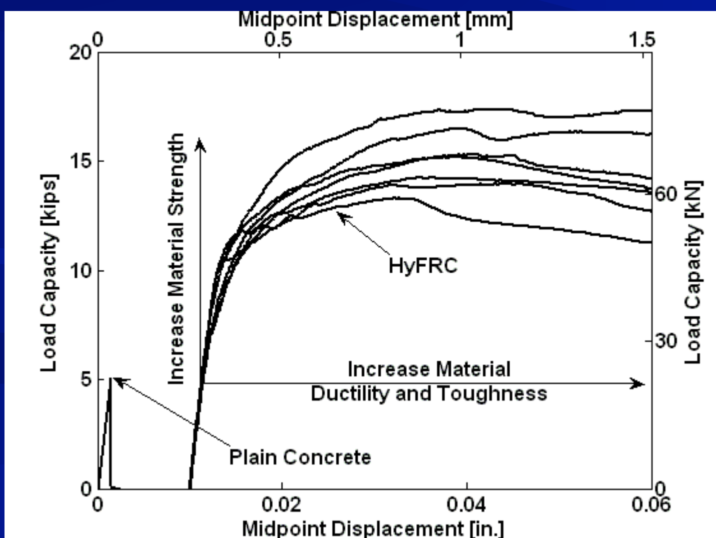
- Enhances durability and damage resistance of bridge structures when exposed to both environmental and mechanical/seismic loading conditions
- Extends Service Life and Sustainability of bridge structures

HyFRC

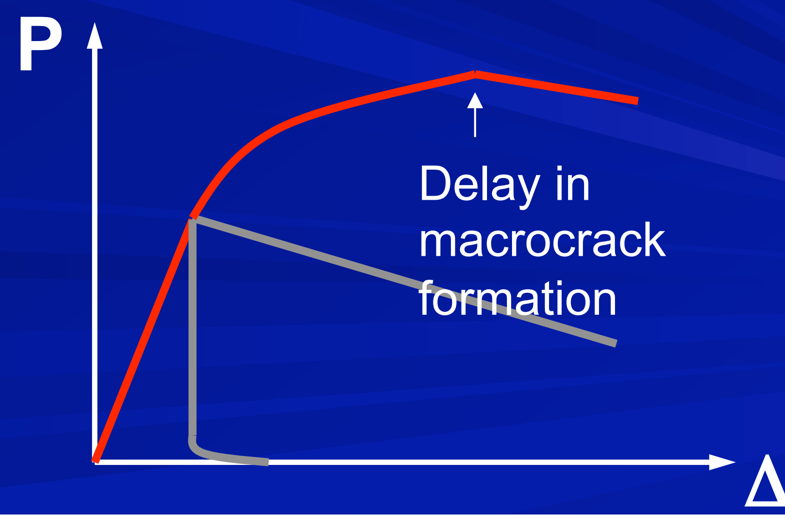
HyFRC: concrete matrix with 9.5mm CA; 1.5 vol% fibers; contains both micro & macrofibers for multi-scale crack control



	RECS 15x8	ZP305	RC-80/60-BN
Material	PVA	Steel	Steel
Length [mm]	8	30	60
Diameter [mm]	0.04	0.55	0.75
Aspect Ratio [L/d]	200	55	80
Elastic Modulus [GPa]	42	200	200
Tensile Strength [Mpa]	1600	1100	1050
Volume Fraction [%]	0.2	0.5	0.8
Fiber Spacing [mm]	0.79	6.89	7.43



Beam size: 6"x6"x24"



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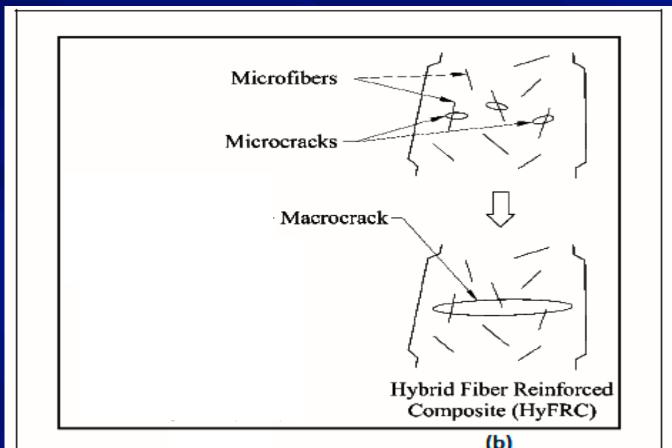

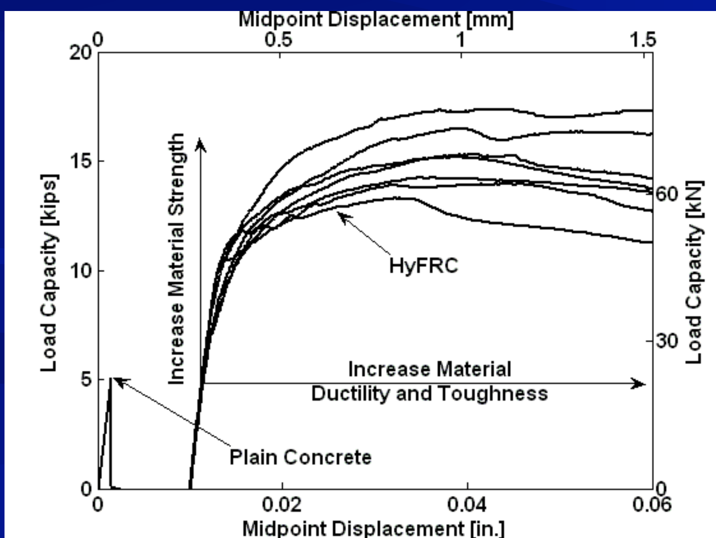

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- 1st generation of HyFRC:
- Bridge Approach Slabs for Area III (CalTrans)
- 2nd generation of HyFRC:
- Self-compacting HyFRC: Bridge Columns (PEER)
- 3rd generation of HyFRC:
- Service Life enhancement and Reduction in Carbon Footprint of Highway Structures (FHWA)

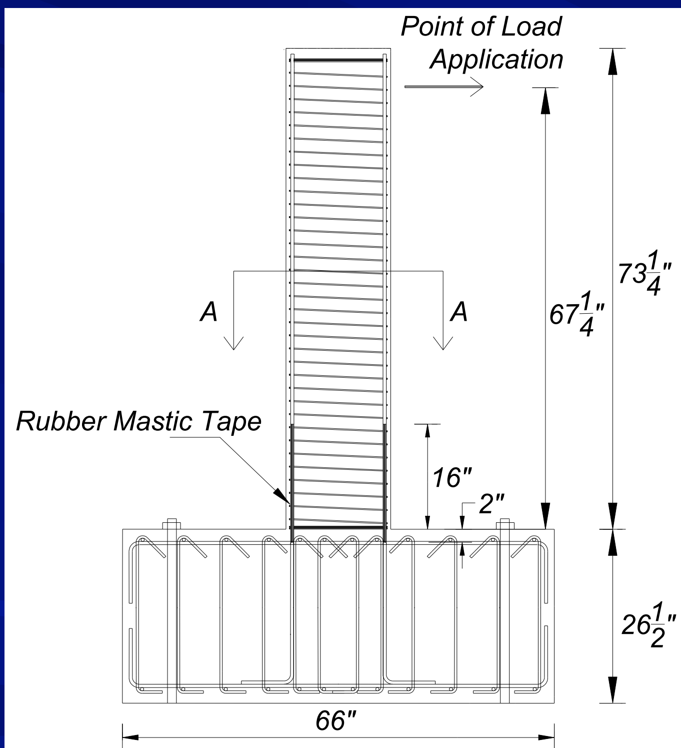
Example #1: Damage Resistance of Bridge Columns exposed to Seismic Loading

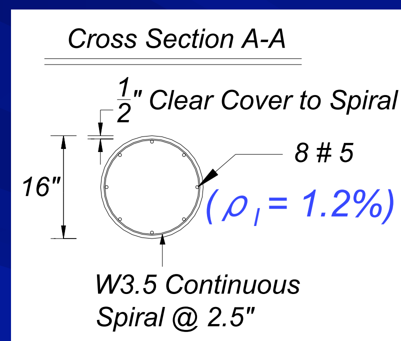
Bridge Columns with self-compacting HyFRC (SC-HyFRC)

PEER funded project (Ostertag& Panagiotou)

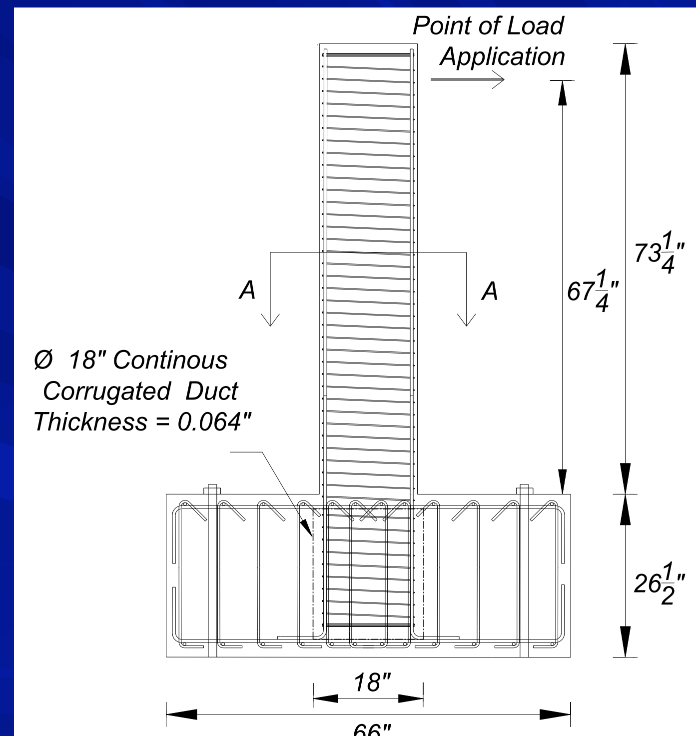
SC-HyFRC TEST SPECIMENS

- *1:4.7 Scale Specimens*
- *Aspect Ratio, H / D = 4*
- *Axial Load Ratio, $N / f'_c A_g = 0.1$*





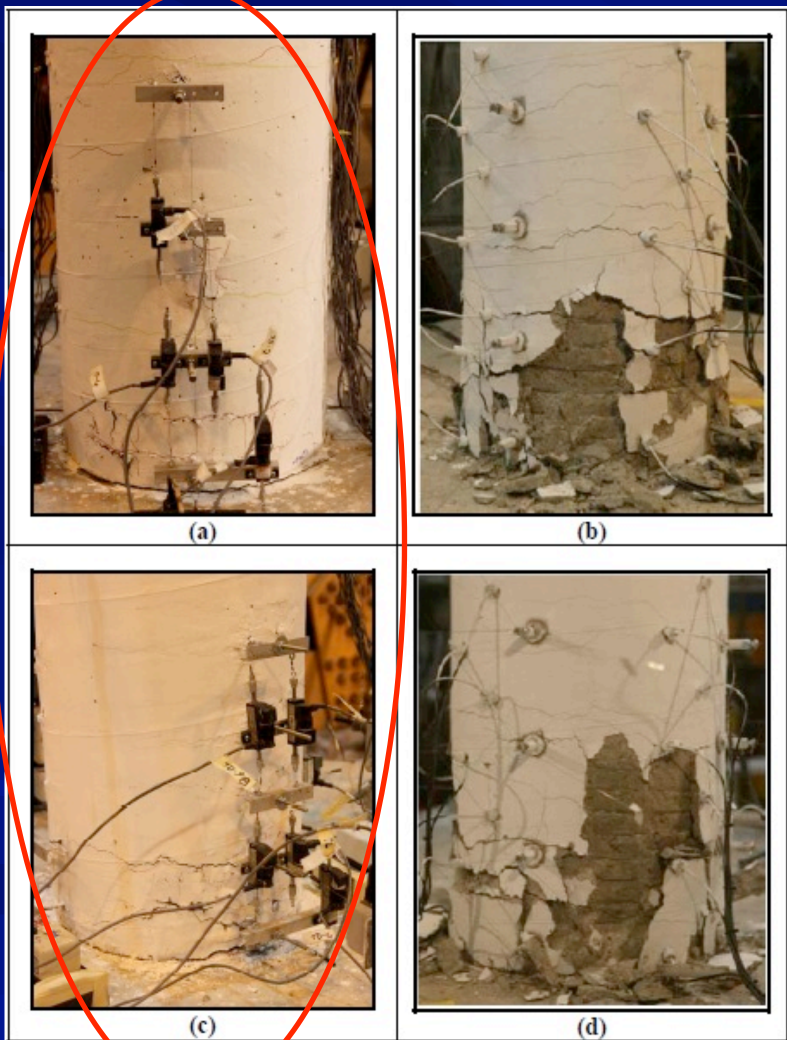
(ρ_v = 0.37%)



Designed to rock at column/foundation interface

Designed for plastic hinge formation

SPALLING & DAMAGE Resistance in SC-HyFRC Bridge Columns compared to conventional concrete columns



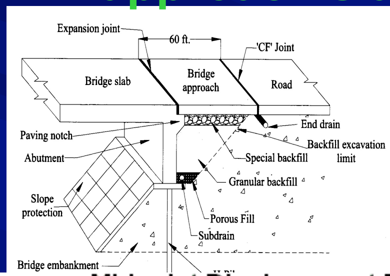
TS-1(a), TS-2 (c); *Conv. Concrete*
ρ_v= 0.37%; *ρ_v= 0.7%*

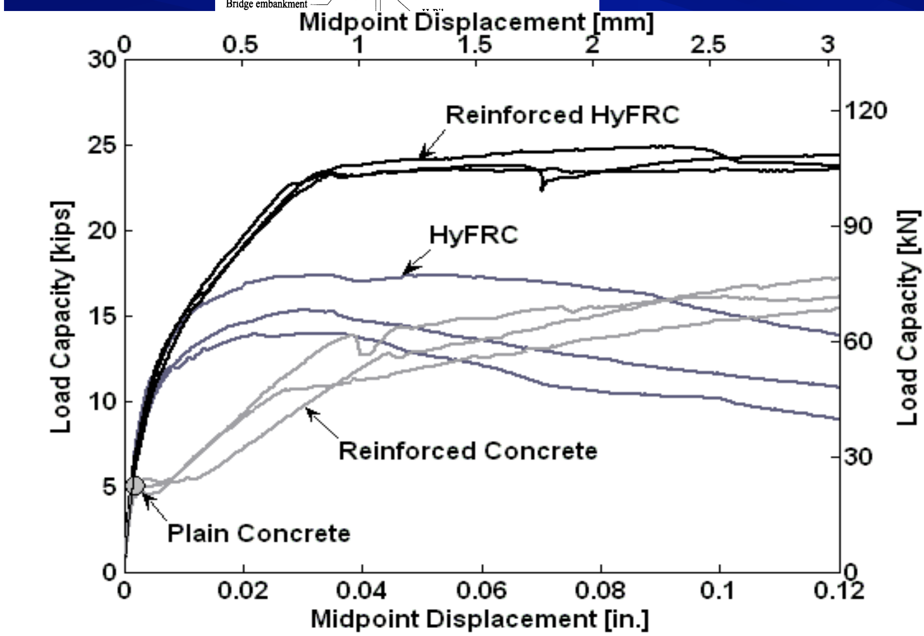
- *Damage resistance of SC-HyFRC Columns (a) and (c) , compared to conventional Concrete Columns (b) & (d) after being subjected to approx. same drift ratio of 4%*
- *In SC-HyFRC columns spalling of cover occurs only locally and is delayed up to 3.6% drift ratio despite half the transverse reinforcement ratio, (ρ_v), 0.37% vs. 0.7%).*

SC-HyFRC columns: Ostertag and Panagiotou (PEER report 2011/106)
Conv. Concrete Columns: Terzic et al, (2009)

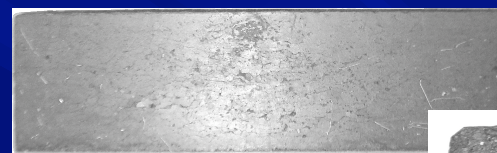
Example #2:
Damage Resistance of HyFRC bridge approach slabs exposed to both mechanical & environment loading conditions

Flexural Performance of ½ scale bridge approach slabs





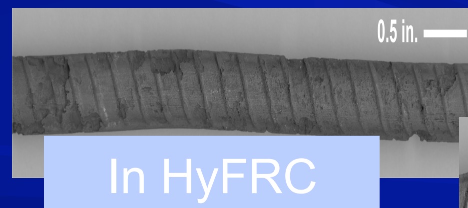
Frost resistance

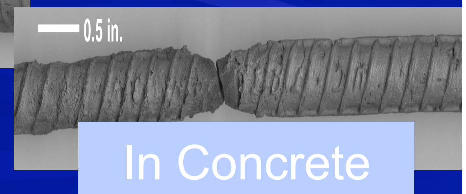


HyFRC after 220 cycles

Concrete after 50 cycles

Corrosion resistance

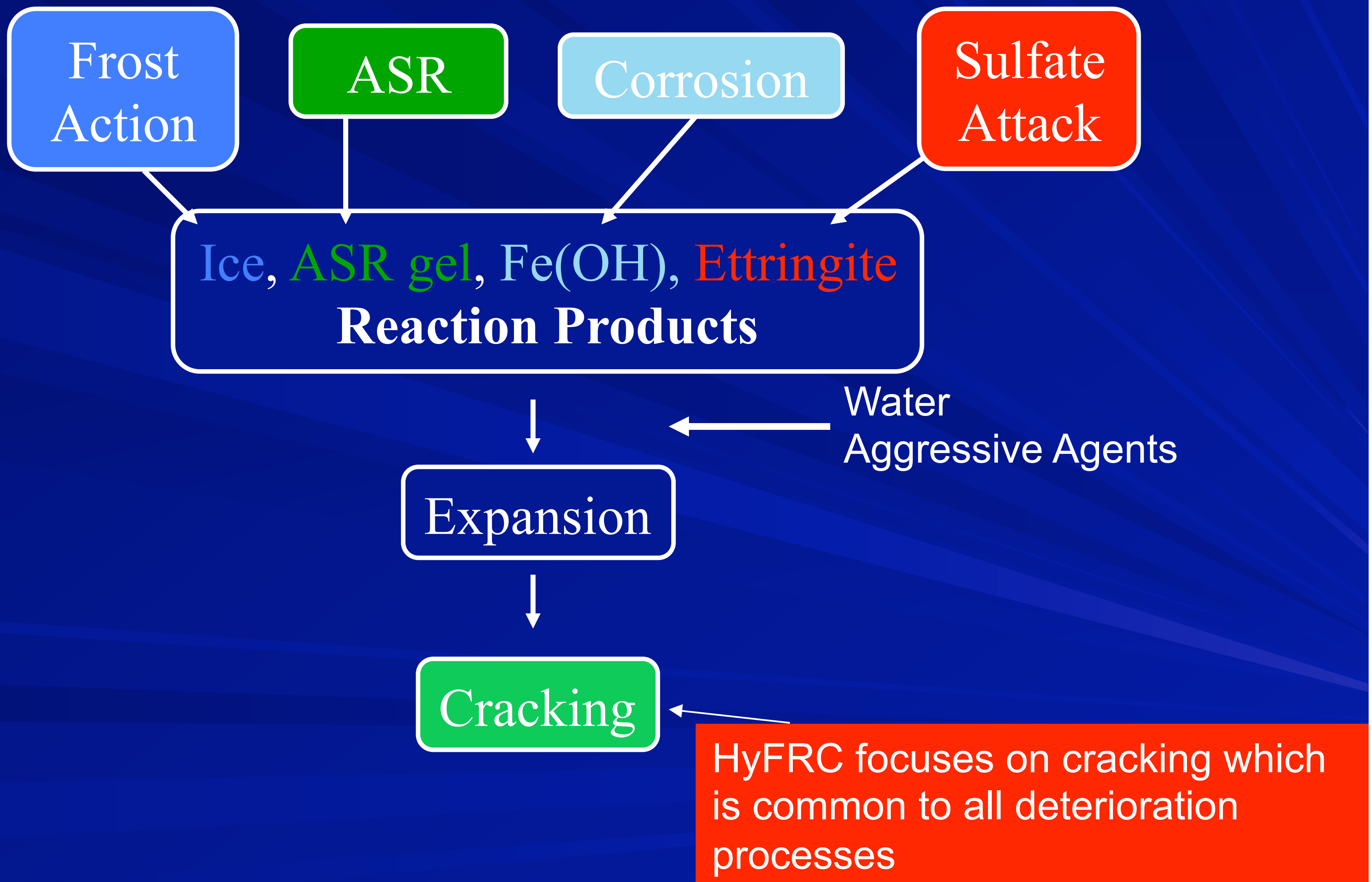




CalTrans Report No. CA09-0632, 2008

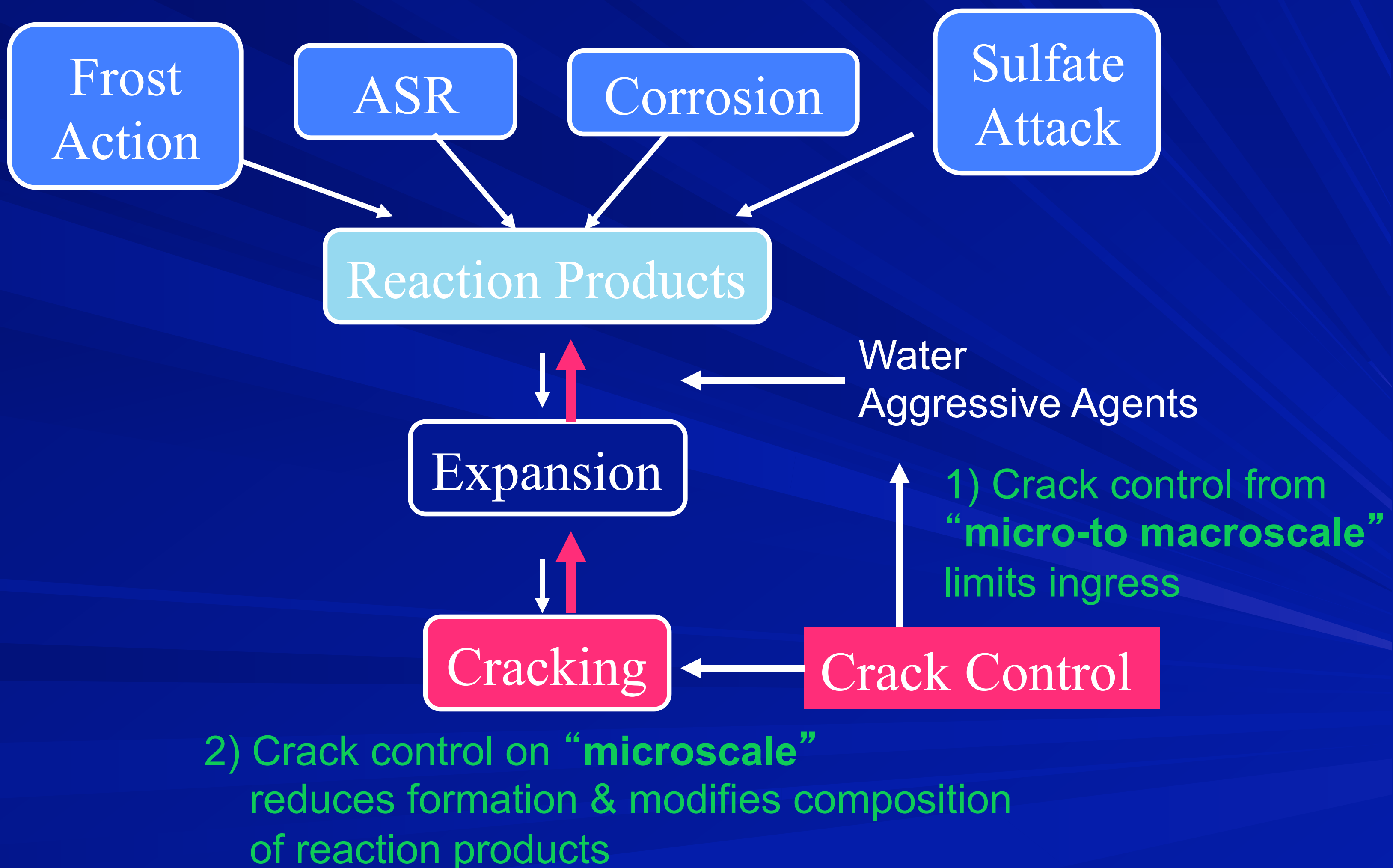
HyFRC provides Holistic Approach to Durability of Bridge Structures

Processes responsible for Deterioration of Concrete Bridge Structures

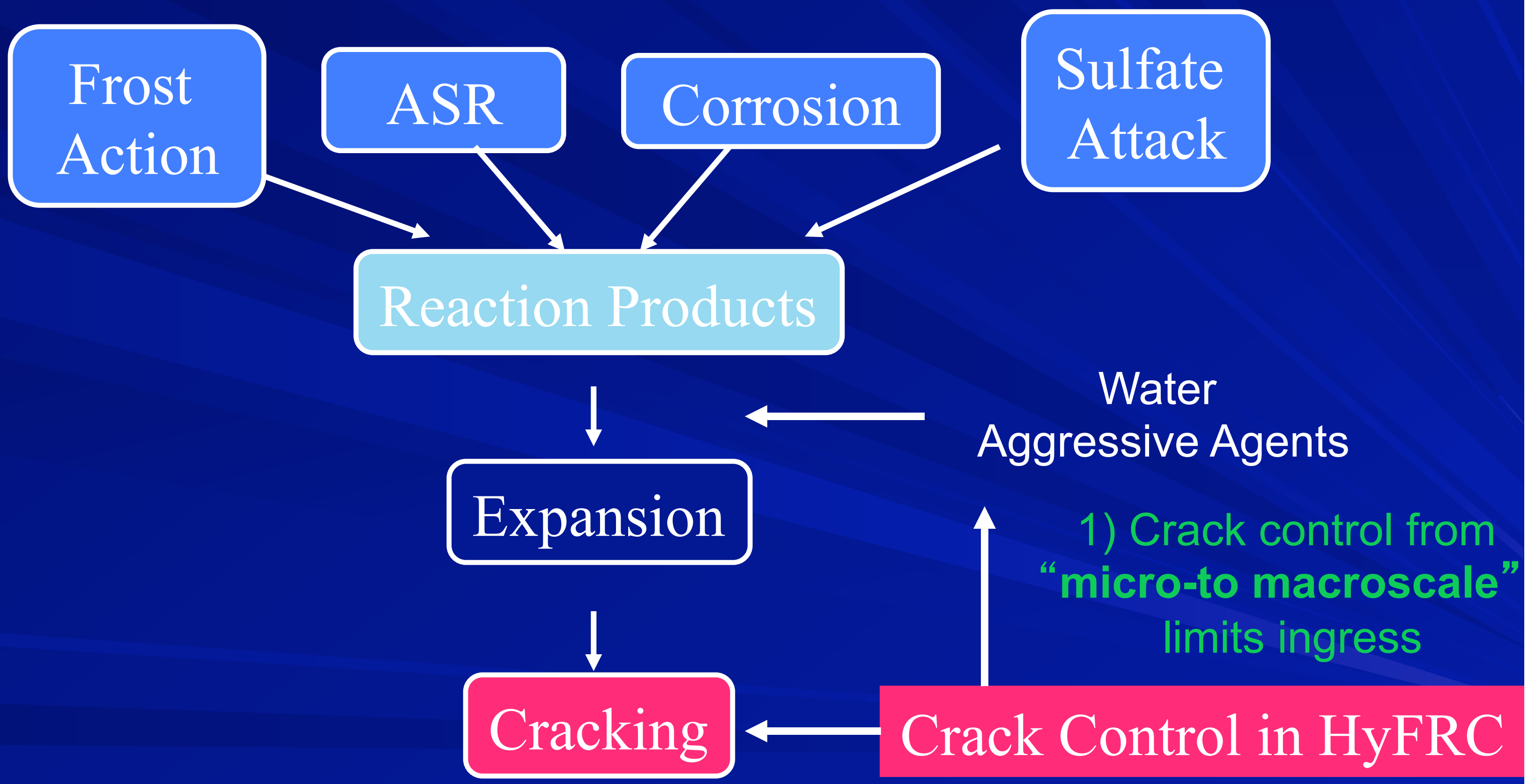


Enhancing Durability of Concrete Structures

(Mitigate Expansive Deterioration Processes through multi-scale crack control in HyFRC)

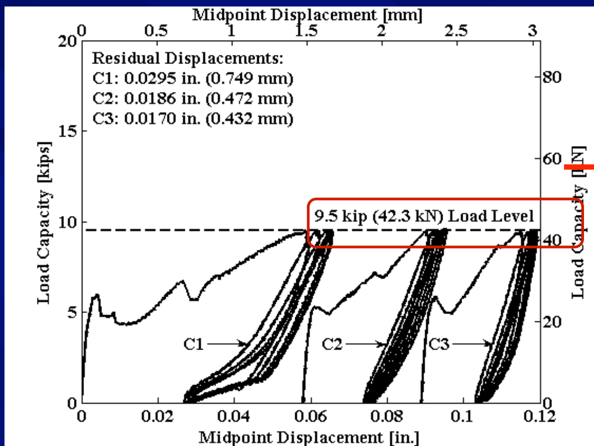


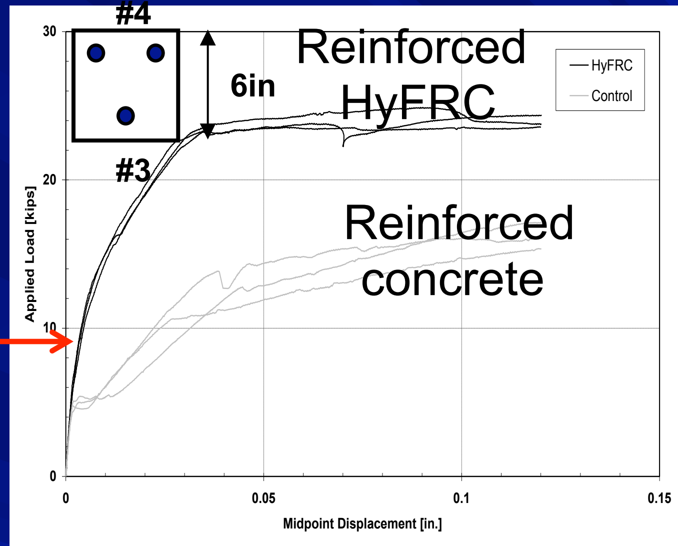
Mitigation of Expansive Deterioration Processes through multi-scale crack control



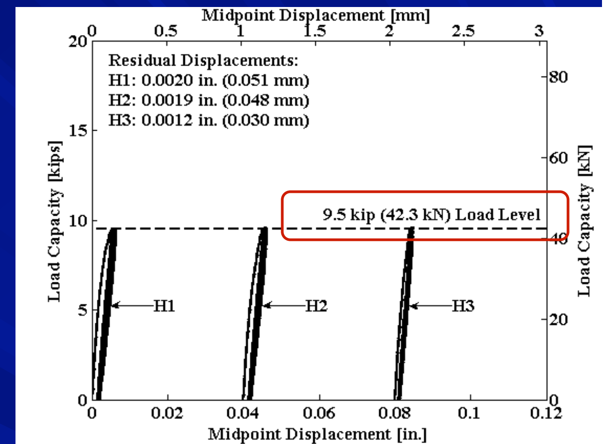
HyFRC limits ingress of aggressive agents into concrete which extends the damage initiation phase

Reinforced Concrete

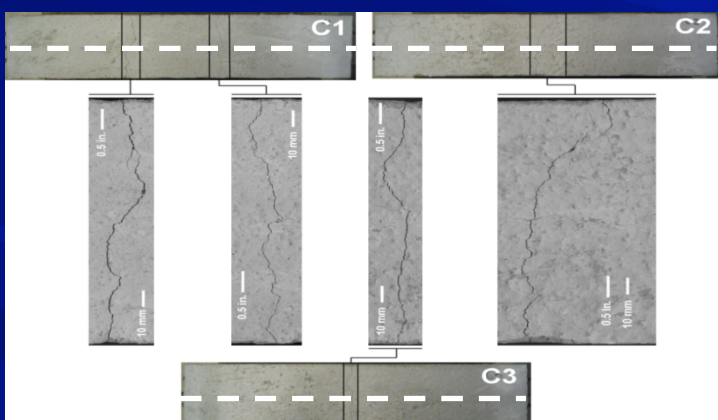




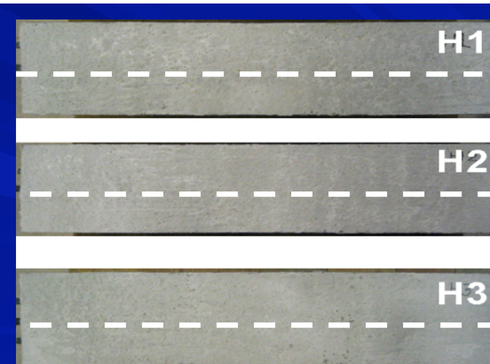
Reinforced HyFRC



Flexural Performance of ½ scale bridge approach slabs



Macrocrack formation after 5 cycles of **9.5** kip loading

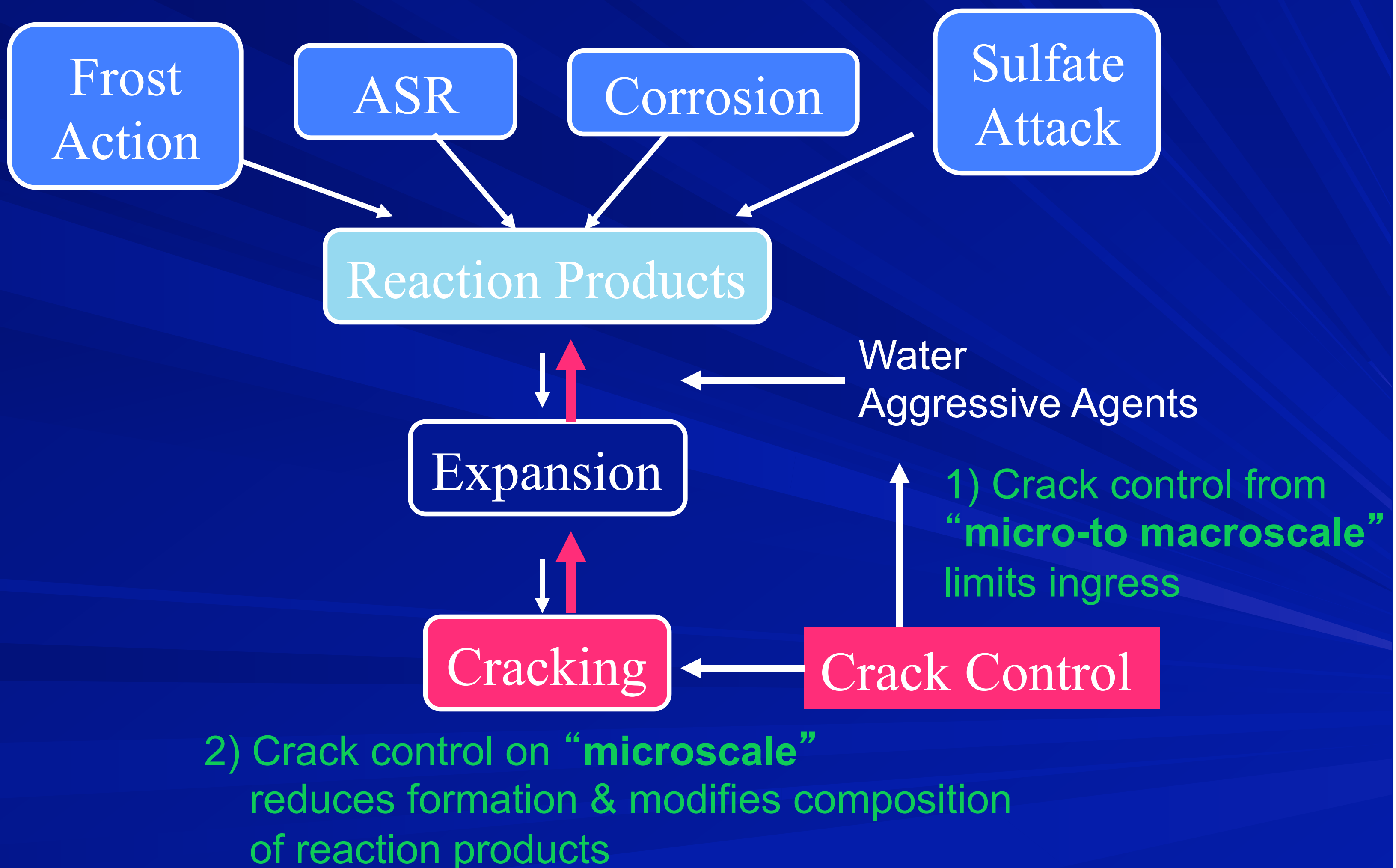


No crack formation after 5 cycles at 9.5 kips

Ostertag and Blunt, FraMCoS-7 Jeju Korea, 2010
Blunt and Ostertag, ACI J. Engrg. Mech., 2009

Enhancing Durability of Concrete Structures

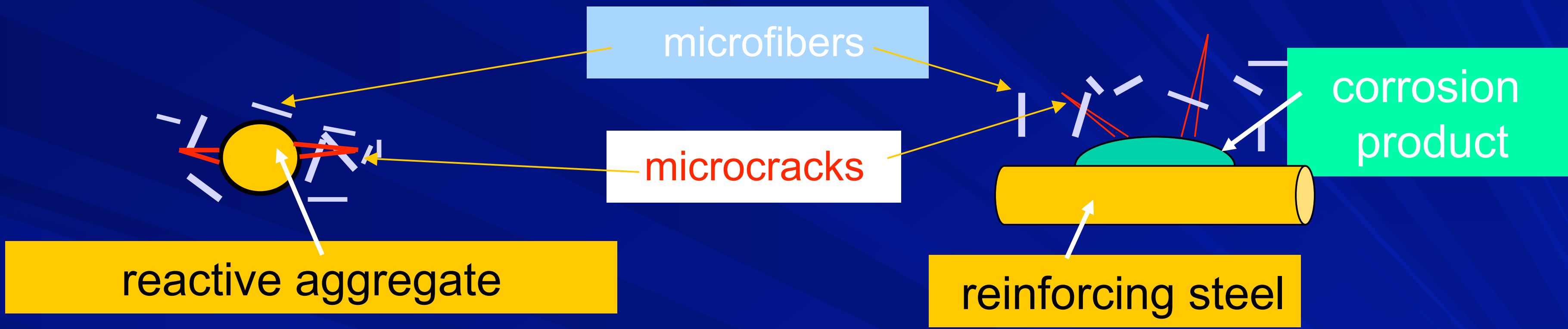
(Mitigate Expansive Deterioration Processes through multi-scale crack control in HyFRC)

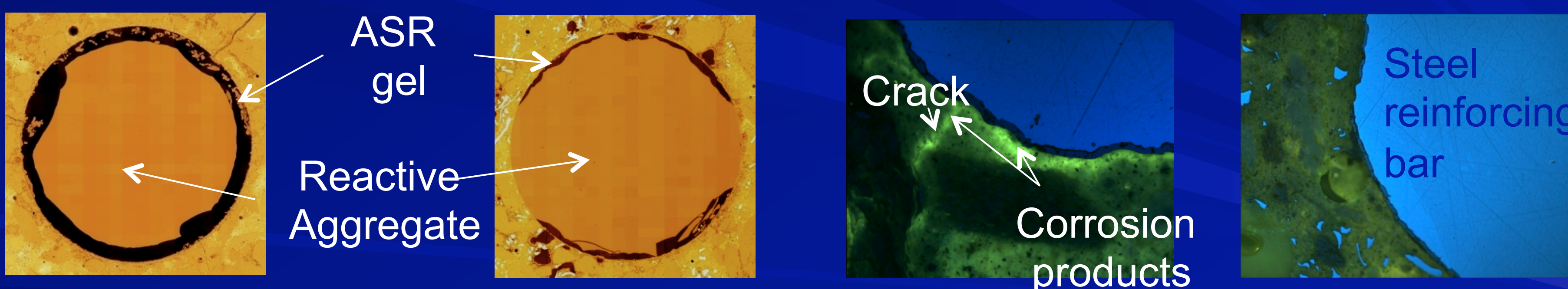


Crack control on microscale reduces formation of expansive reaction products

Alkali silica reaction

Corrosion





No crack control

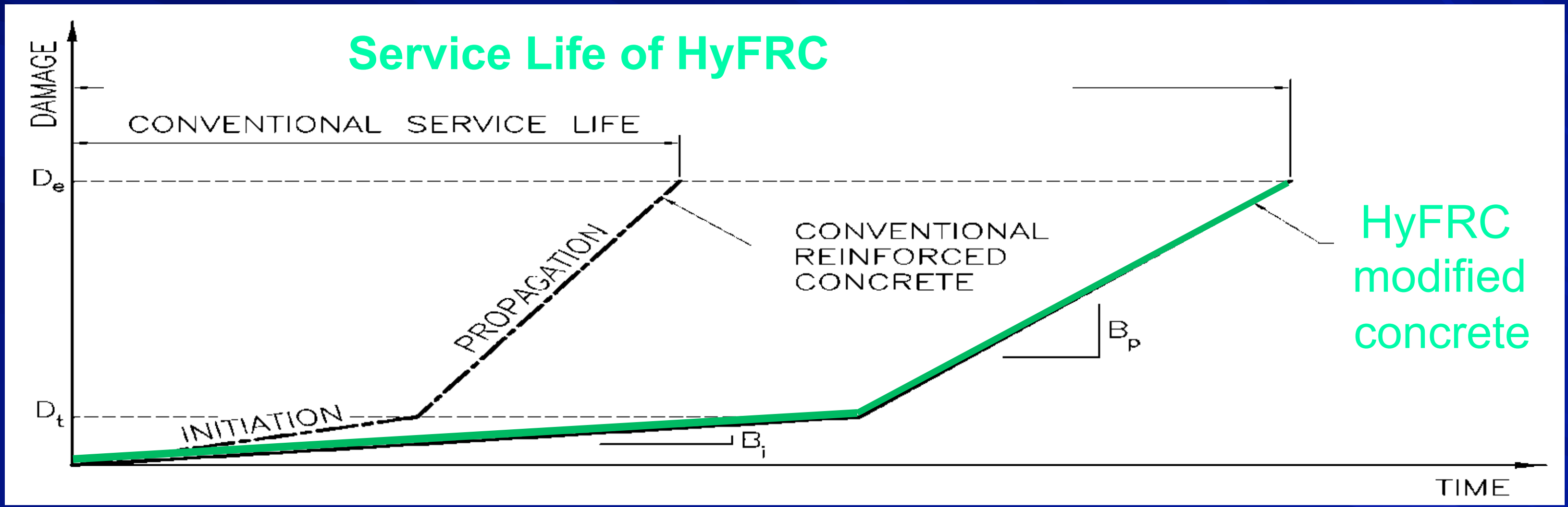
With microcrack control

No crack control

With microcrack control

Service life enhancement due to HyFRC

HyFRC extends both the initiation phase and slows down the propagation phase of damage



Initiation Phase is extended due to crack resistance **which limits ingress of aggressive agents into the concrete**

Propagation Phase is slowed down due to microcrack control which **reduces formation & modifies composition of reaction products**

Research NEEDS:

Whereas i) Mechanical properties of plain HPFRCCs have been studied and documented,

ii) Durability enhancement investigated and confirmed

- Few studies exist on synergy between HPFRCC matrix and steel rebar.
- Need Model development and establish design guidelines
- Need additional large scale tests to verify damage resistance and performance enhancement of HPFRCCs in CIP and ABC applications

Thank you for your attention