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Impact of PCE-Based High-Range Water Reducers on Precast/Prestressed Concrete Operations

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BASF Construction Chemicals

Outline

- **High-Range Water Reducers (HRWRs)**
  - Why are they Needed?
  - Chemistries
  - Recent Developments
- **Application of HRWRs**
  - Flowing Concrete
  - Self-Consolidation Concrete
- **Benefits of HRWRs in Precast/Prestressed Concrete**

Levels of Concrete Slump

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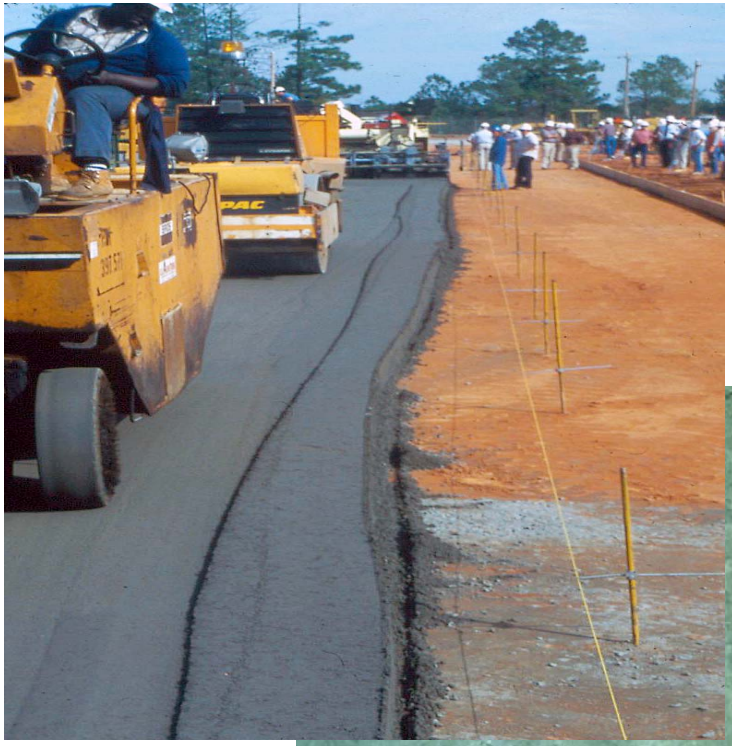
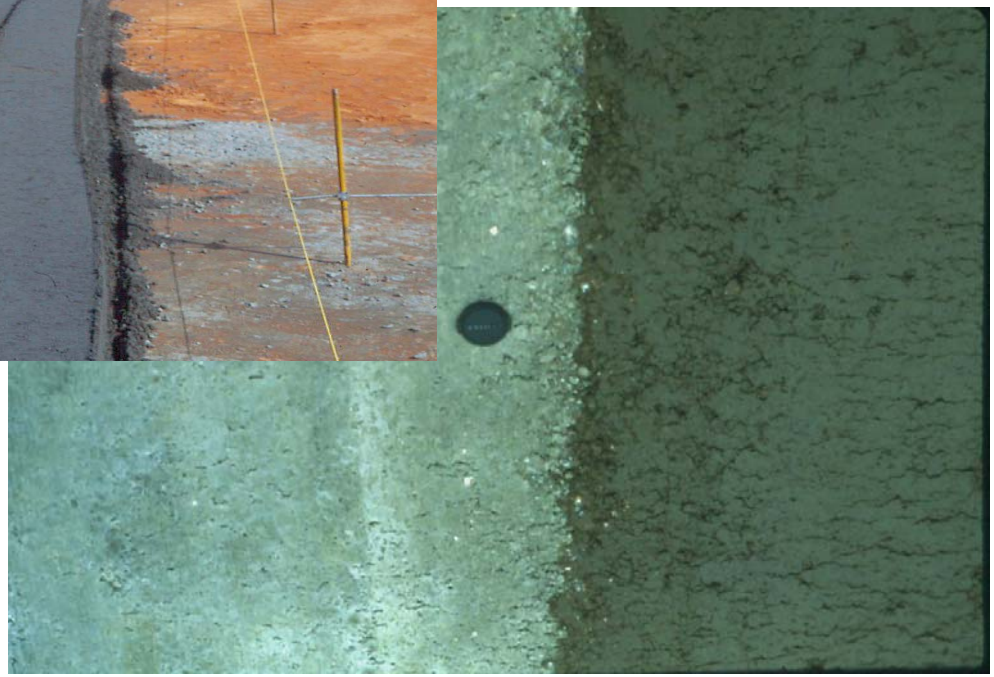
No / Negative





Levels of Concrete Slump

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No / Negative

Low

Moderate

Benefits of Increasing Slump

- Ease of Placement & Consolidation
- Improved Finishability

Consolidation

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The most common method of consolidation is vibration.

- Liquefies mortar fraction of the concrete
- Reduces internal friction between aggregate particles
- Vibration is two stage process
  - ➢ Concrete slumps under gravity
  - ➢ De-aeration of mortar
- When vibration stops friction returns

Internal

External

Consolidation

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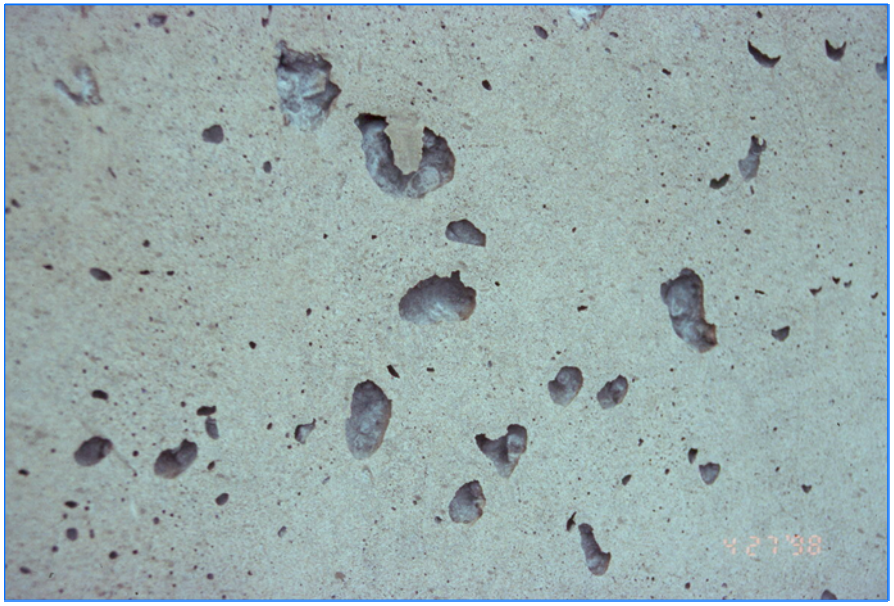
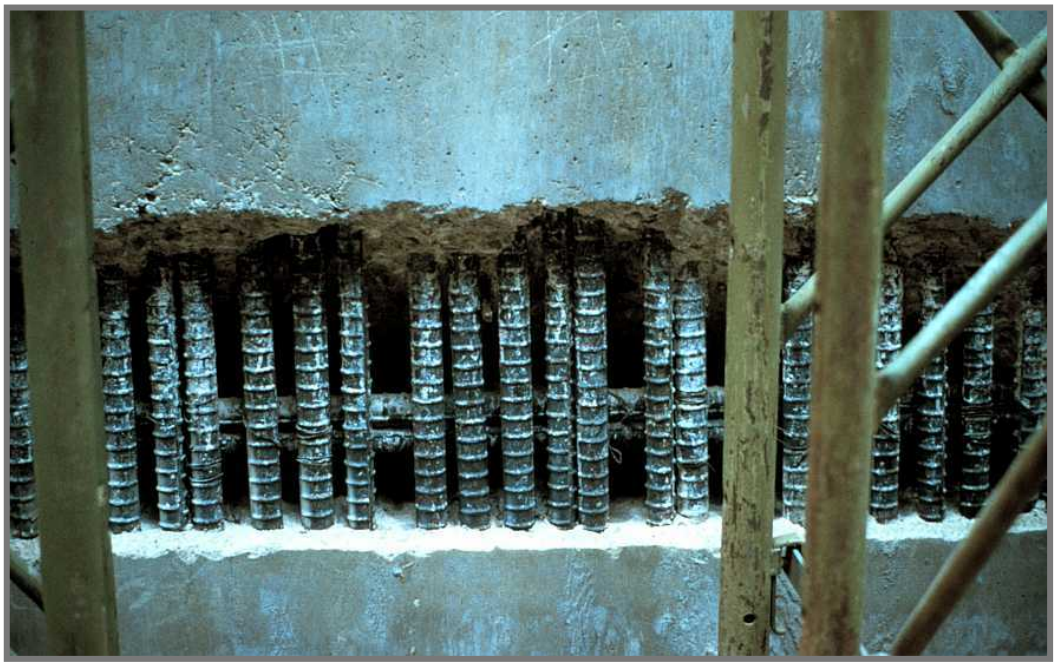
Consolidation

Surface Air Voids (Bug Holes)



Honeycomb

Voids



Levels of Concrete Slump

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High (Flowing)

Good HPC… Poor Consolidation!

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Good HPC… Poor Consolidation!

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Levels of Concrete Slump

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Self-Consolidating

Options for Increasing Concrete Slump

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Most effective way...

"…..is to use a water-reducing admixture, particularly, a high-range water reducer."

High-Range Water Reducers (HRWRs)

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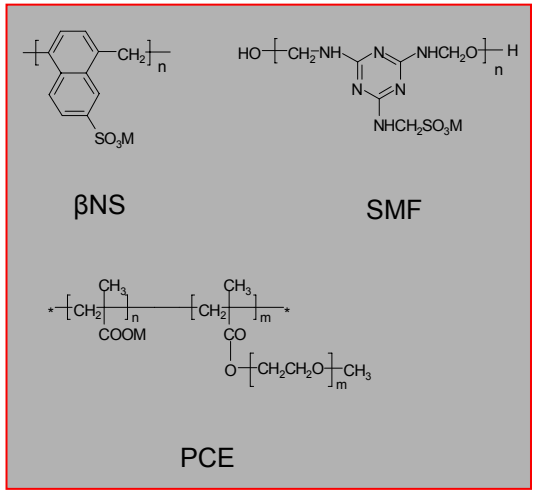
- Introduced in late 1970s.
- Permit use of low mix water content (low w/cm).
- Enable the production of high slump concrete.
- Help to minimize consolidation-related defects.

HRWR Chemistries

- Modified lignosulfonates (MLS)
- Sulfonated Melamine Formaldehyde Condensates (SMF)
- Sulfonated Naphthalene Formaldehyde Condensates (βNS)
- Plocarboxylate-Ether (PCE)



Dispersants

Basic Dispersant Mechanism
Electrostatic Repulsion

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- HRWR molecules absorbed on cement
- Cement particles get negative charge
- Cement particles repel and disperse
- Effect of negative charge diminishes with hydration
- Stiffening occurs

Steric Hindrance Mechanism - PCEs

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- HRWR molecules absorbed on cement
- Cement particles get negative charge
- Cement particles repel and disperse
- Effect of negative charge diminishes with hydration
- Comb-like fingers keep cement grains dispersed longer
- Stiffening occurs

PCE Molecules are Engineered !!!

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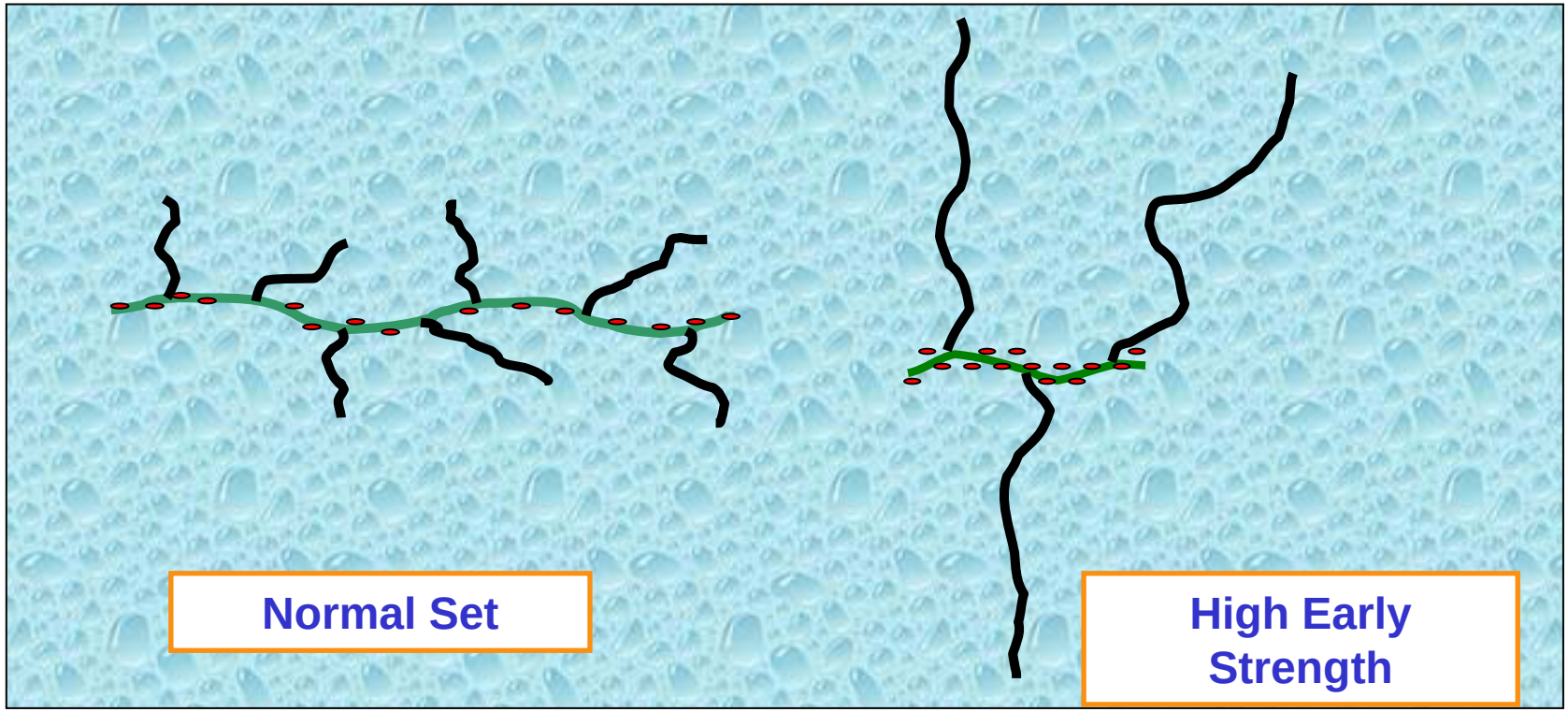
Molecules of polycarboxylate ether with very flexible chains carrying negative functional groups and side chains



Glenium® molecules

PCE Molecules are Engineered !!!

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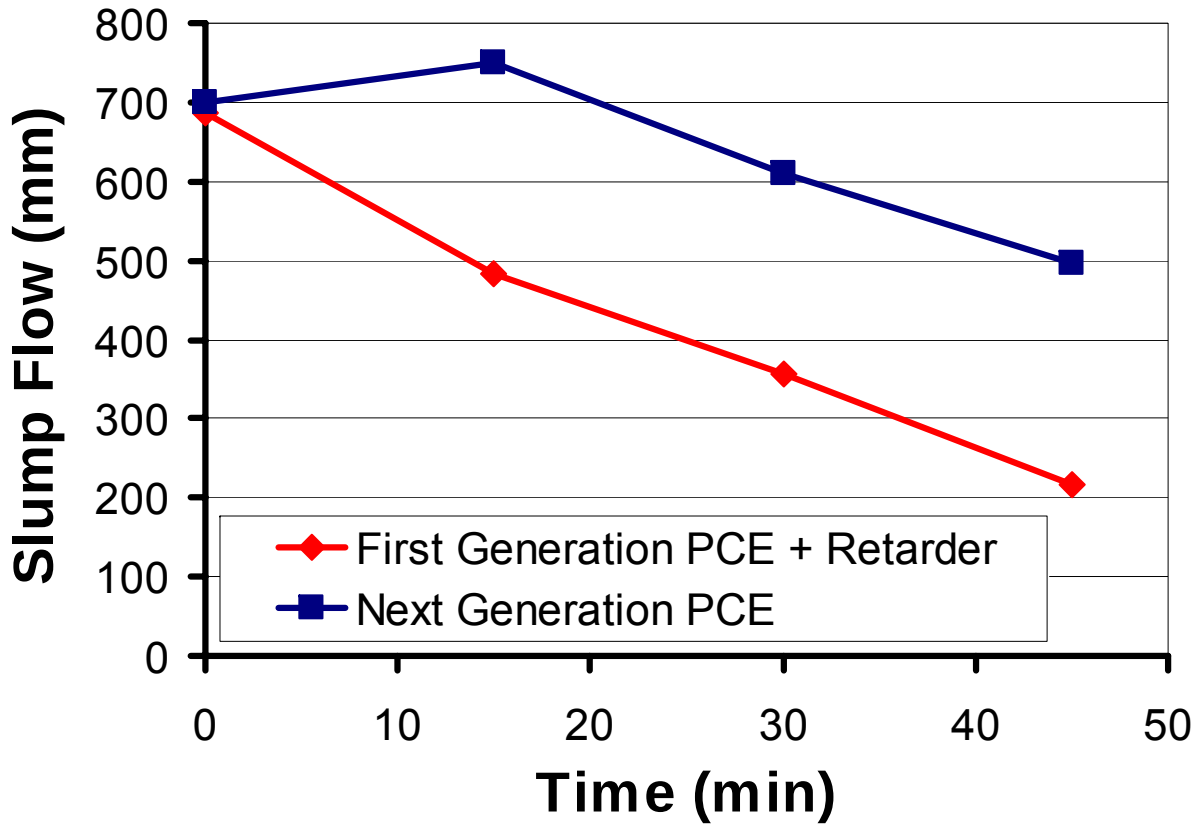
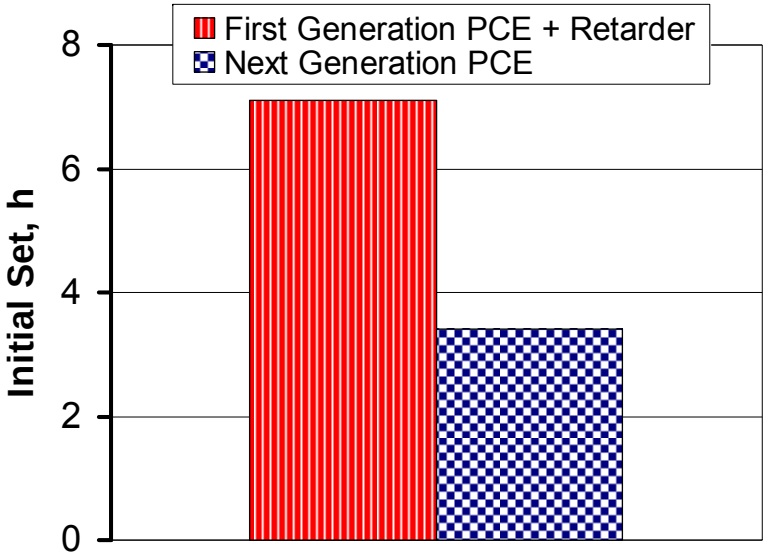
Next Generation PCE HRWRs…

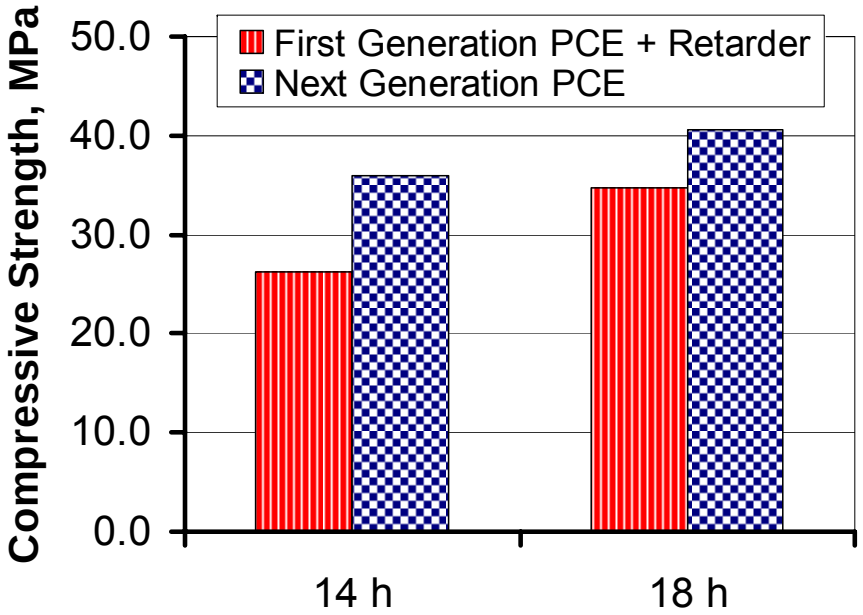
- Tailored for regional cements.
- Provide exceptional slump retention, without the use of a retarding admixture.

Slump Retaining PCE HRWRs



Slump Retaining PCE HRWRs





Slump Retaining PCE HRWRs

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Benefits…

- Consistency in concrete production.
- **Improve overall quality of in-place concrete.**

PCE-Based HRWRs

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Have facilitated...

.....the production and use of
Self-Consolidating Concrete

Self-Consolidating Concrete

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Benefits of SCC:

- Fluid and stable concrete mixtures
- Trouble-free and versatile concrete placement
- Self-consolidation in formwork without vibration
- Reduced repair and rework
- Improved/optimized surface appearances
- Enhanced engineering properties

Self-Consolidating Concrete

The benefits of SCC are derived from its high fluidity and stability and they can be categorized under the following:

- **Production & Energy Savings**
- **Improved Safety & Working Conditions**
- **Improved Aesthetics**

Benefits of Using SCC

…Production & Energy Savings

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- **Faster rate of placement & increased productivity**
  - reduced casting time / potential for more pieces per day
  - faster truck turn-around
  - earlier job completion
- **Elimination of (or reduced) vibration**
  - more efficient use of labor (permits re-deployment)
  - less wear and tear on equipment (vibrators & forms)
  - reduced power usage
- **Improved surface finish & aesthetics**
  - reduced rework & repair

Precast Concrete Double-Tee

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1 Lead
2 Vibrators
2 Finishers
1 Edge Finisher

2 Rakers
2 Shovelers
1 Bullfloat/Confilm

11 Laborers

1 Lead
0 Vibrators
2 Finishers
1 Edge Finisher

1 Raker
1 Shoveler
1 Bullfloat/Confilm

7 Laborers

Precast Concrete Double-Tee

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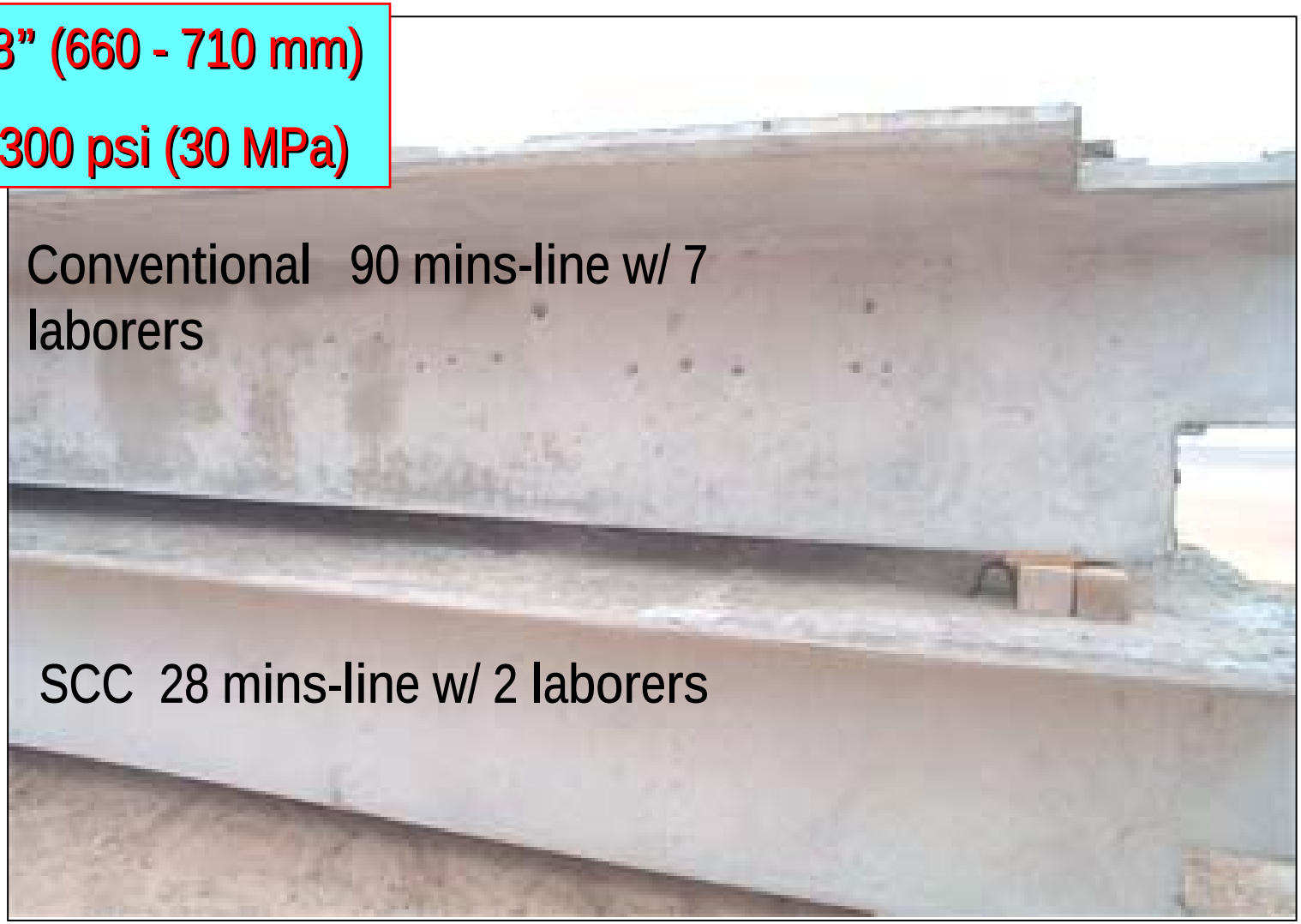
Double-Tee Production

Spread 26-28” (660 - 710 mm)

16 hours - 4,300 psi (30 MPa)



Patching to Improve Aesthetics

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Benefits of Using SCC

…Production & Energy Savings

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Concrete Ingredient	Cost / m^3		
	Conventional Concrete	SCC Mixture (no Fly Ash)	SCC Mixture (with Fly Ash)
Cement	$35.10	$40.28	$31.65
Fly Ash			$ 3.92
Coarse Aggregate	$ 8.21	$ 6.89	$ 6.75
Fine Aggregate	$ 7.00	$ 7.23	$ 7.10
Conventional Admixtures	$ 4.11	$ 0.25	$ 0.25
PCE HRWR		$ 8.76	$ 8.76
VMA		$ 0.58	$ 0.58
TOTAL	**$54.42**	**$63.99**	**$59.01**

Double-Tee Beam Production Analysis

Benefits of Using SCC

…Production & Energy Savings

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Placement	Conventional Concrete	SCC Mixture
Number of Workers	13	11
Placement Time	2.5 h	2.0 h
Overtime*	0.5 h	--
Total Man-hours	42.25 man-h	22 man-h
Labor per Double-Tee	5.28 man-h	2.75 man-h
Labor Savings	--	**47.9 percent**
Patching		
Number of Workers	2	1
Patching Time	8 h	8 h
Overtime*	1 h	1 h
Total Man-hours	19 man-h	9.5 man-h
Labor per Double-Tee	2.38 man-h	1.18 man-h
Labor Savings	--	**50 percent**

Not including productivity increase from labor re-deployment.

Double-Tee Beam Production Analysis

Benefits of Using SCC

…Production & Energy Savings

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Double-Tee Beam	Conventional Concrete	SCC Mixture
Materials Cost	$ 98.09 / m^3	$ 101.36 / m^3
Placement Crew	8	5
Placement Time	--	~ 60 percent reduction
Patching Crew	2	--
Vibrator Cost Savings	--	**~ $10,000 / yr**
Standard Vault		
Materials Cost	$ 71.93 / m^3	$ 81.09 / m^3
Placement Crew	5	2
Placement Time	--	--
Patching Crew	1	--
Vibrator Cost Savings	--	**~ $5,000 / yr**

Production Labor / Costs for Various Precast Elements

Benefits of Using SCC

…Production & Energy Savings (Brazil)

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COMPANY 'A'				
STEP	CC		SCC	
	Labor	Costs (R$ / m^3)	Labor	Costs (R$ / m^3)
Concrete	0	142.46	0	177.29
Concrete mixing	1	3.43	1	3.43
Concrete transportation	1	15.49	1	15.49
Demolding agent application	3	10.66	3	10.66
Placement	5	26.70	2	5.34
Finishing	4	7.03	2	1.41
Repairs	2	14.55	0	0.00
TOTAL	**16**	**216.89**	**9**	**210.19**

Production Costs in Brazilian Plant (Tutikian et al.)

Benefits of Using SCC

…Production & Energy Savings (Brazil)

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COMPANY 'B'				
STEP	CC		SCC	
	Labor	Costs (R$ / m^3)	Labor	Costs (R$ / m^3)
Concrete	0	715.23	0	805.15
Concrete mixing	2	6.86	2	6.86
Concrete transportation	2	20.16	2	20.16
Demolding agent application	2	5.81	2	5.81
Placement	9	47.78	4	9.56
Finishing	5	8.78	2	1.76
Repairs	3	21.58	0	0.00
TOTAL	**23**	**819.34**	**12**	**842.43**

Production Costs in Brazilian Plant (Tutikian et al.)

Benefits of Using SCC

…Production & Energy Savings (Brazil)

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Brazilian Precast Operations...

…..not accounting for equipment cost savings and increased productivity from labor re-deployment, use of SCC technically and economically feasible.

Benefits of Using SCC

…Improved Safety & Working Conditions

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- **Reduced noise (vibration eliminated or reduced)**
  - less headaches
  - easy on the “hearing”
- **Less physical effort required for placement**
  - employees stay “fresh” longer
- **Reduced accident potential (less cables)**
  - falling off walls/formwork
  - wrenching/twisting back
  - electrocution
- **Contributes overall to a better work environment**
  - worker satisfaction

Benefits of Using SCC

…Improved Aesthetics

Benefits of Using SCC

…Improved Aesthetics

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Benefits of Using SCC
…Improved Aesthetics

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- **Enabled by fluidity of SCC mixtures**
  - displaces air from forms
- **Influenced by Viscosity of SCC mixture**
  - low viscosity SCC provides better finish
- **Influenced by Placement Technique**
  - mock trials highly recommended
  - may require slight modification to reinforcement detail, etc. to facilitate placement

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SCC Applications

Precast/Prestressed Concrete

Aesthetics / Architectural Details

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Effect of Mixture Viscosity on Flowability

Non SCC

SCC

Aesthetics

Jersey Barrier with Conventional Concrete

Placing SCC in Jersey Barrier Form

Aesthetics

Jersey Barrier with SCC

Aesthetics / Architectural Details

Aesthetics / Architectural Details

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In Summary…

- PCE-based HRWRs are facilitating the production of high-performance concretes that meet the demands of concrete professionals today.

- The use of Self-Consolidating Concrete (SCC) is providing significant operational benefits in concrete construction, particularly, in precast / prestressed concrete operations.

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Thank You!

Questions ?