

“Self Consolidating Concrete”

Let it Flow.....

Presented By



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Self Consolidating Concrete (SCC)

- SCC - what is it, where did it come from
- SCC Mix Design
 - Applications
 - Raw materials
- WIIFM (or the Benefits of SCC)
 - Properties
 - SCC Test Methods
 - Producing SCC – examples
 - Case Studies

Self Consolidating Concrete (SCC)

“A highly flowable, yet stable concrete that can spread readily into place and fill the formwork without undergoing any consolidation and without undergoing significant separation”

Khayat, Hu and Monty



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Self Consolidating Concrete

SCC has unique benefits over flowing concrete:

- **Self Placement:** *the need for vibration can be eliminated* because SCC is highly flowable concrete that will change shape under its own weight to self-level and self-consolidate within formwork
- **No Segregation:** SCC is a flowable, yet highly cohesive material with *no segregation and significantly reduced bleeding*
- **No Blocking:** *SCC can pass freely through narrow openings and congested reinforcement* without aggregates “blocking” behind obstructions and stopping the flow of concrete

SCC History

Japan

- SCC was developed from technologies used in underwater concrete placement in 1988 by Prof. Okamura at the University of Tokyo.
- In Japan, use of **viscosity modifiers** as a cohesive aid to enable SCC production was researched by academics in conjunction with major contractors, who then further developed their own systems and test methods for SCC.
- The initial driver for SCC was concern over the effect of poor concrete placement on long term concrete durability in Japan, particularly in complex, thin walled sections in heavily reinforced buildings where achieving proper consolidation was a major difficulty

SCC History

Europe

- SCC has also been adopted in Europe, particularly Scandinavia which is now widely regarded as being the most advanced in SCC adoption.
- In Europe the availability of fine powder materials, such as limestone power and pozzolans, led to the development of SCC based on the **“powder method”**. Viscosity modifiers are also used to produce consistent, reliable SCC.
- European motivations for using SCC include increased potential for reduced vibration, and automation in precast factories, thus increasing worker productivity and limiting vibration health and safety issues

Self Consolidating Concrete Mix Design

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Raw Materials

- Cementitious Types and Volumes
 - High fine powder content is required for most SCC mixes (these can include inert powders such as limestone powder)
 - Cementitious contents can be reduced for less demanding applications
 - Use of pozzolans (GGBF slag or flyash) is highly recommended

Raw Materials

- Water/Cementitious Ratio
 - Water content is determined by flow requirements, and not by strength (SCC mixes are overdesigned for most applications)
 - Typically under 0.40 w/c ratio is recommended for high performance SCC mixes. W/C ratio can be increased where appropriate

Raw Materials

- Aggregates (Combined)
 - Use non gap-graded materials
 - Moisture contents must be known and controlled

Self Consolidating Concrete Benefits

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Benefits

- Eliminate vibration
 - Reduce noise levels and **improve the plant environment** for employees and neighbors
 - Improve **labor safety and productivity** with self leveling, self consolidating concrete that requires less manpower to place and finish
 - Reduce **capital cost and maintenance** on formwork and vibration equipment

Benefits

- **Improve concrete consolidation**
 - Improve consolidation around dense reinforcement
 - Fill areas impossible to reach with internal poker vibrators
- **Improve concrete finish**
 - Reduce repairs and sack rubbing required
- **Increase flexibility in design and orientation of formwork**
 - Place concrete in unique shaped molds that could not be used for conventional concrete

Added Productivity



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Self Consolidating Concrete Applications

- Horizontal elements
- PC/PS elements - Dense Reinforcement - Spacing less than 1.5 inches (40 mm)
- Highly reinforced PC/PS elements - Reinforcement Spacing greater than 1.5 inches (40 mm)
- Architectural Concrete

Self Consolidating Concrete Properties

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Hardened Properties

- **Compressive and Tensile Strength**
 - Early strength (1 day) similar to slightly higher than a mix with the same cement content and water to cement ratio
 - 28 day strength similar to higher than a mix with the same cement content and water to cement ratio

Hardened Properties

- Durability (Freeze/Thaw testing ASTM C666)
 - Similar to conventional superplasticized concrete
 - Despite high flowability SCC concrete can be air entrained and meet requirements for freeze-thaw durability. See ACI Material Journal article on air entrained SCC (Oct 2000 issue)

Hardened Properties

- Shrinkage (Length Change ASTM C157)
 - Numbers range from 0.02 to 0.05, similar to other high cementitious mixes

Self Consolidating Concrete Test Methods

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Testing

- DOT concerns
 - Air content
 - Slump [flow]
 - Vibration
 - Consolidation, uniform distribution of aggregates
 - Shrinkage

Testing

Current Test Methods for Segregation Resistance of SCC

- Visual Stability Index (VSI)
 - Based on slump flow test – ASTM C 1611
- Column Segregation Test - ASTM C1610
- Penetration Test – ASTM C 1712

Testing

Visual Stability Index (ASTM C1611)

- Provides a means for assessing segregation prior to placement
- A qualitative & a highly subjective parameter

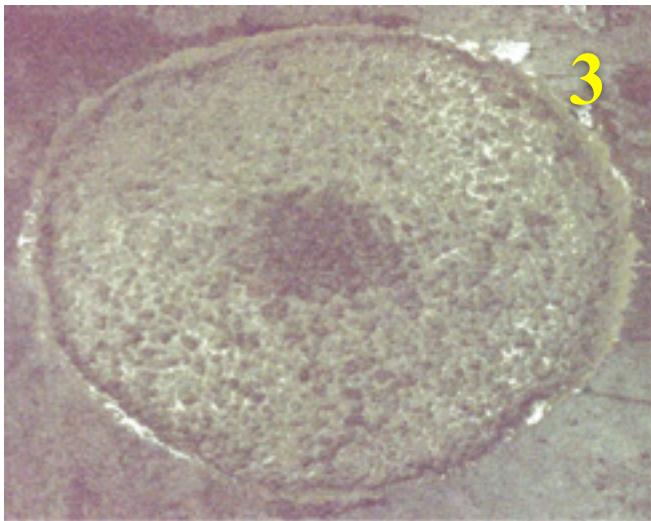


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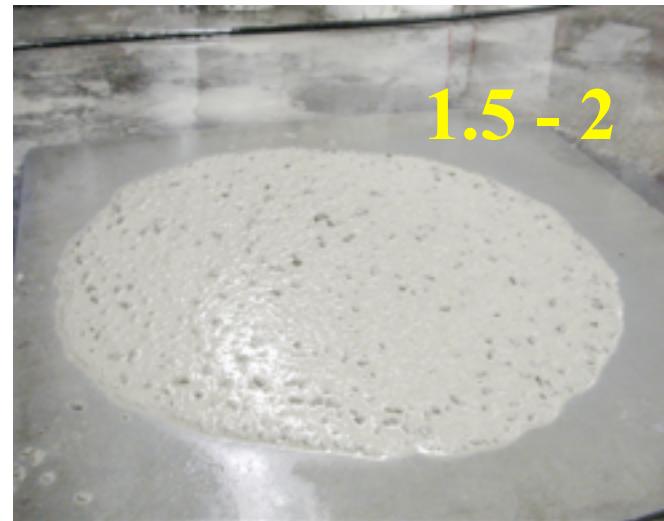


0.5 - 1

Visual Stability Index (VSI)



3



1.5 - 2

Testing

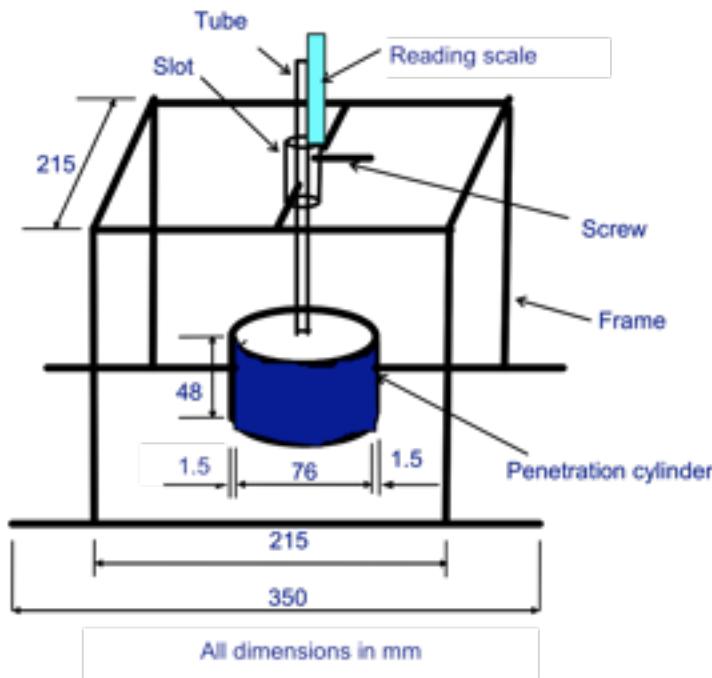
Column Segregation (ASTM C1610)

- Provides a useful quantitative parameter for assessing SCC static segregation
- A labor-intensive test; not suitable for a rapid assessment prior to placement



Testing

Penetration Test (ASTM C1712)



Testing Program

Test Parameters

- Slump flow & VSI according to ASTM C1611
- Percent static segregation (S) according to ASTM C1610
- Penetration depth (P_d) ASTM C1712

 **Compare Penetration Depth (P_d) with Static Segregation (S) and VSI**

Testing Program

Test Procedure



Measurement of
penetration depth
(ASTM C1712)



Slump flow &
VSI assessment
(ASTM C1611)



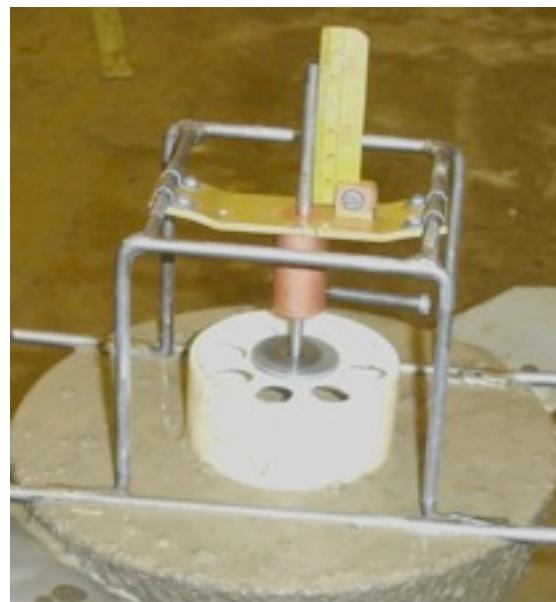
Column segregation test
(ASTM C1610)

Testing Program

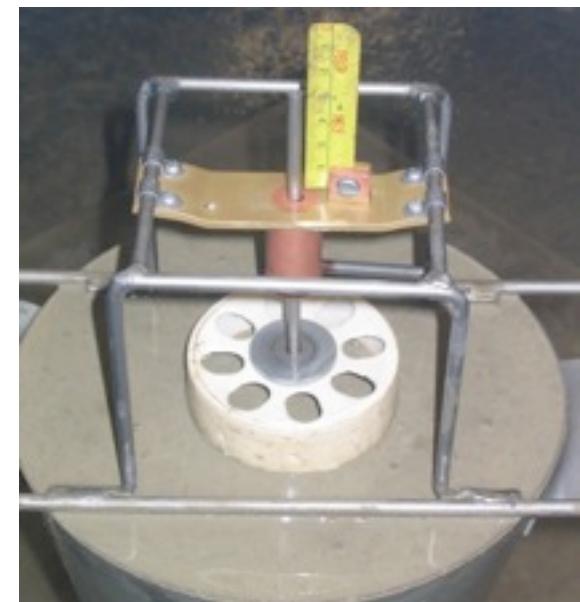
Penetration Depth (PD) and Different Stability Levels



Highly Stable
($PD \leq 10 \text{ mm}$)



Stable
($10 \text{ mm} < PD \leq 25 \text{ mm}$)



Unstable
($Pd > 25 \text{ mm}$)

Testing Program

Conclusions

- A rapid test, Penetration Test, is a reliable and useful test for assessing the segregation resistance of SCC mixtures **both in the laboratory and the field**.
- A stability classification is developed based on the measured penetration depth of the test apparatus.
- The Penetration Test provides a **quantitative** basis for decision-making regarding acceptance, modification or rejection of the SCC mixture **prior to placement** in the field.

Producing Self Consolidating Concrete

- SCC has many benefits, but may require some changes in mix design and production methods
- SCC is not a prescription mix, it is a **CUSTOMIZED MIX** that is influenced by:
 - Application
 - Available raw materials
 - Economics

SCC: The Real Thing

- Watch for high flow, no bleed uniform aggregate distribution



SCC in Precast Applications

- Precast and Pre-stressed application:
 - From Double Tee's and bridge beams to septic tanks and manholes
- Compressive strength ranging from 3,500 to 14,000 psi
- Chloride permeability as low as 630 coulombs
- Shrinkage as low as 0.032%



SCC in Precast Applications



Lifting molds

Note fine edge detail and smooth form finish



SCC in Precast Applications

Which surface looks better? This?



SCC in Precast Applications

Or This?



SCC in Precast Applications

Now, That's Fine Detail!



Case Studies

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National Museum *for the* American Indian

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Project Description

- National Museum for the American Indian
- Part of the Smithsonian Institution
- Designed by Architects in an intent “to resemble a solid piece of rock carved over time by wind and water”.
- The building has no right angles. Everything is highly symbolic and non-repetitive.
- Inaugurated in 2004

Project Considerations

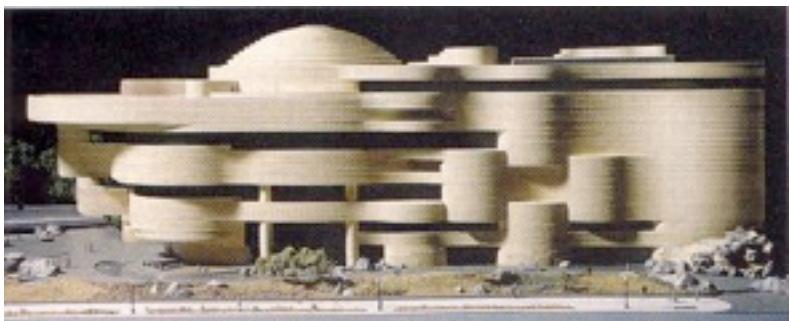
- Problems with Conventional Concrete
 - Columns could not be vibrated properly
 - Requirements for monolithic pours and steel congestions
 - Extensive repair work with conventional mix
 - Specialty forms, no right angles, all custom build
 - Forms blowing out due to excessive use of vibrators
 - Concrete is exposed
- SCC was used for the majority of the project (>3,000 cu.yd.)
 - Turnaround times of forms was reduced from 5 to 2 days
 - Improved surface finish



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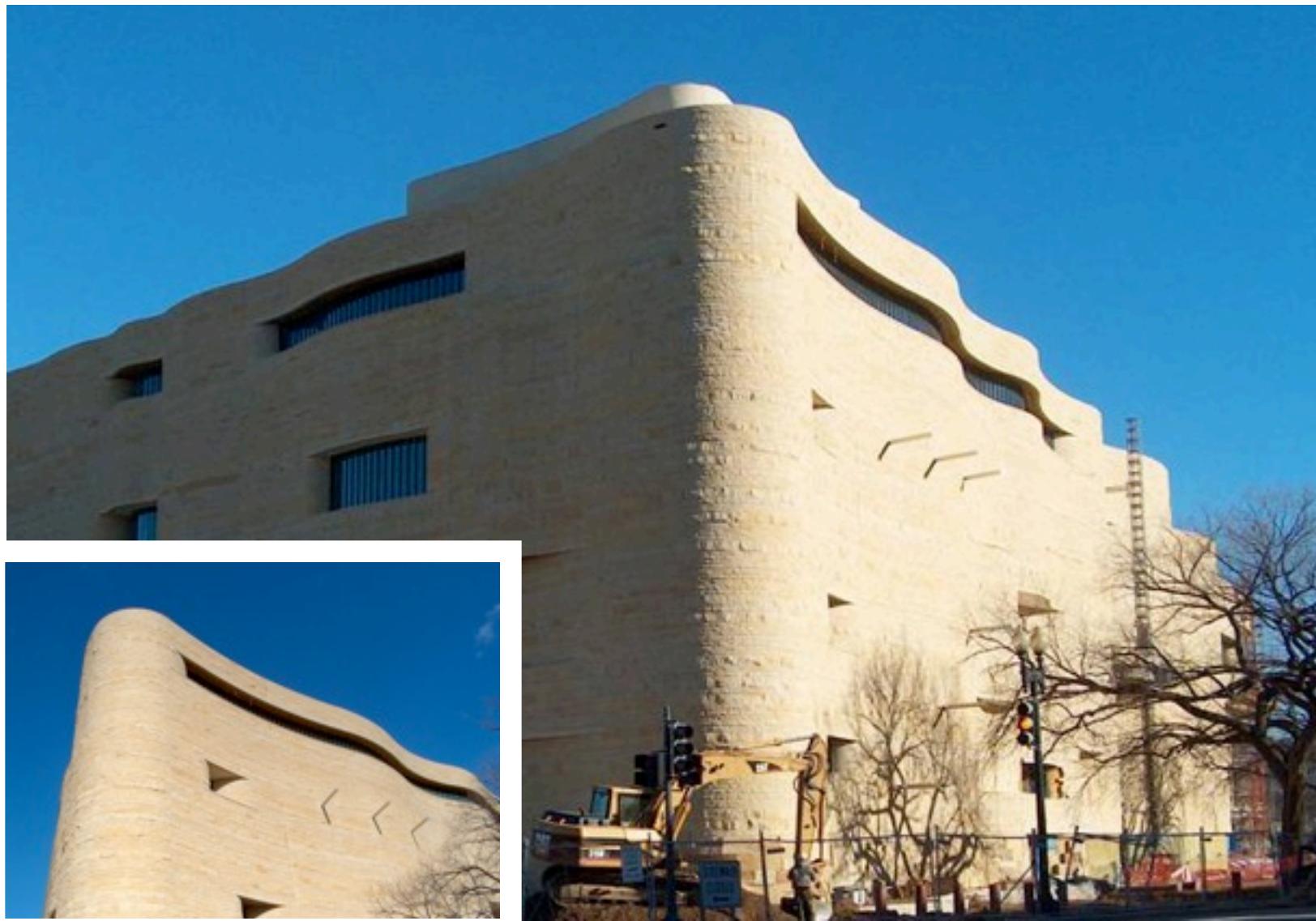
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Comcast Building

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Project Description

- Time: Start Fall 2005
Concrete placement completion end of 2006
- Location: JFK Boulevard and 18th street
Philadelphia, PA
- Concrete volume :
SCC application - 40 000 cu.yds – center core construction
- Three different mix designs used
 - 10,000 psi
 - 8,000 psi
 - 6,000 psi

Project Considerations

- The ready-mix producer was approached with the request to supply SCC, with consistent performance and minimum variation.
- Concrete was pumped vertically to approximately 500ft (167 meters). Total pumping height in the last construction phase was be approximately 900 vertical feet (300m).
- Strengths (field cured cylinders)
 - Compressive
 - 7 day – 8560 psi
 - 28 day – 12,720 psi
 - 56 day Flexural – 1560 psi

Project Considerations

- Benefits of using SCC :

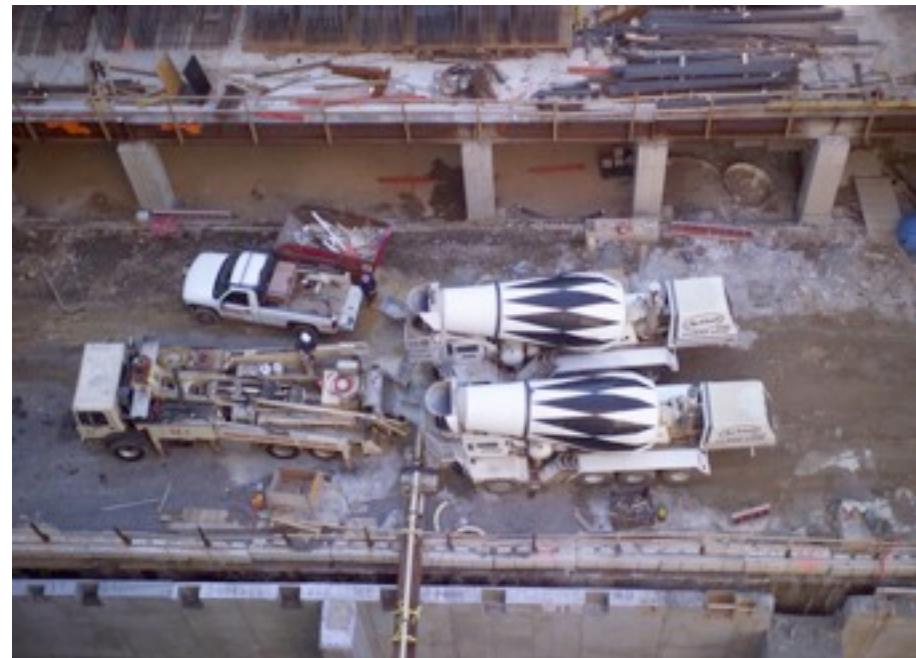
- End User :

- Simplified construction method cutting on construction time
 - Faster concrete placement, easier pumpability
 - Ability to achieve full compaction in intricate areas with heavy steel reinforcement
 - Reduced labor cost
 - Reduced patching and rework



Project Considerations

- Benefits of using SCC :
 - Concrete producer :
 - Faster truck turnaround due to shorter discharge time into pumps.
 - Ability to produce consistent high quality concrete





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Thank You

Any Questions?

The Pennsylvania Aggregates and Concrete Association
Greatly Appreciates the Efforts Made by the Below
Companies in Providing This Presentation

