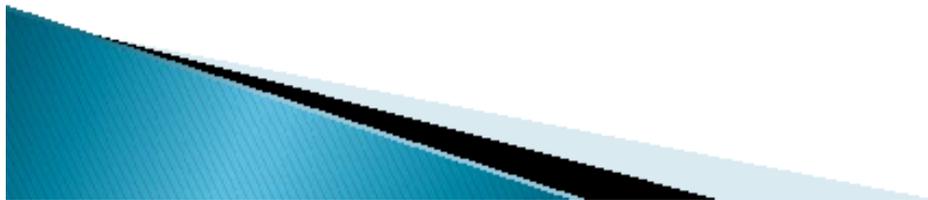




*DESIGNING MARINE CONCRETE FOR
THE CBBT PARALLEL THIMBLE SHOALS TUNNEL LINING SEGMENTS
WITH 300+ YEAR SERVICE LIFE FOR
DURABILITY, LONGEVITY, SUSTAINABILITY AND RESILIENCE*



ECS Design Technology Today



- *MARINE DESIGNS / SCC*
- *LONGEVITY 300+ YEAR SERVICE LIFE*
- *DURABILITY / NO CORROSION*
- *LOW SHRINKAGE / CRACK FREE*
- *MASS DESIGN / THERMALLY CONTROLLED*

LIFE CYCLE OVERVIEW

LIFE CYCLE OF MARINE CONCRETE STRUCTURES / HAMPTON ROADS

- ✓ MMM BRIDGE TUNNEL / JAMES RIVER CROSSING = 75+ Years Service Life;
 - ☐ Completed 1992
- ✓ JORDAN BRIDGE / ELIZABETH RIVER CROSSING = 120+ Years Service Life;
 - ☐ Completed 2012
- ✓ MID-TOWN TUNNEL / ELIZABETH RIVER CROSSING = 150+ Years Service Life;
 - ☐ Completed 2015
- ✓ CHESAPEAKE BAY BRIDGE TUNNEL SEGMENTS = 300+ Years Service Life.
 - ☐ Work in Progress





Monitor-Merrimac Memorial Bridge-Tunnel (I-664)

- 3.2-mile-long South Trestle
- 4,800-foot long tunnel.

- 75+ YEAR SERVICE LIFE
- START OF *CONCRETE DURABILITY AND LONGEVITY*
- COMPLETED 1992



JORDAN BRIDGE (120+ YEAR SERVICE LIFE)



- ***MASSIVE 10 FT THICK LOW WATER PIER CAPS***
- ***CHANNEL EYE RINGLETS 10' X 15' X 50' MASS SEGMENTS TO PREVENT DAMAGE FROM SHIP IMPACT***
- ***LINK BETWEEN CHESAPEAKE AND PORTSMOUTH, VA***
- ***COMPLETED 2012***

MID-TOWN TUNNEL / ELIZABETH RIVER CROSSING 150+ YR SERVICE LIFE

COMPLETED YEAR 2015
2ND CONCRETE TUNNEL BUILT IN US



CBBT — THIMBAL SHOALS PARALLEL CROSSING **Chesapeake Bay Bridge Tunnel**



300+ YEAR SERVICE LIFE
TUNNEL SEGMENT LINING CONCRETE

MODELING 300+ YEAR SERVICE LIFE



WHAT IS REQUIRED?

- 1) **CONCRETE DESIGN STRENGTH, psi;**
- 2) **DURABILITY, LONGEVITY, AND NO CORROSION;**
- 3) **VERY LOW RAPID CHLORIDE PERMEABILITY;**
- 4) **VERY LOW DRYING SHRINKAGE / NO CRACKS;**
- 5) **SCM's (GBFS & Silica Fume);**
- 6) **CHEMICAL ADMIXTURES;**
- 7) **MODERATE CEMENTITIOUS FACTORS.**

ECS USES RECYCLED MATERIALS



- **Cement I/II Production Consumes:**

- *Waste Oil*
- *Used Tires*
- *Contaminated Soil*
- ***CBBT - 55.0% of Total Cementitious***

- **Concrete (Uses SCM's):**

- ***CBBT - 40% GBFSlag, Grade 120***
- ***CBBT – 5 to 8 % Silica Fume***
- ***ASR & Sulfate Resistant***



MR Credit 4: Recycled Content

ECs USES REGIONAL MATERIALS



- *Manufacture and extract concrete materials within 500 miles;*
- *Supports the Regional Economy;*
- *Reduces Impacts of Transportation;*
- *Reduces use of Fossil Fuels;*
- *Sustainable and Resilient*



MR Credit 5: Regional Materials

DESIGN OVERVIEW



- *Longevity & Durability > 300+ Year Service Life Concrete?*
- *Portland Cement – Type I/II*
- *Supplementary Cementitious Materials (SCM)*
 - *GBFS, Grade 120 High Reactivity*
 - *Silica Fume- Greatly lowers permeability*
- *Air Entraining Admixture – F/T Durability*
- *Accelerating PCHRWR Admixture / Type F*
- *Very low permeability <100 Coulombs @ 28 Days*
- *Very low Drying shrinkage (<0.35)*
- *Very low **Water permeability** / 42 Days @ 116 lbs. pressure*

PORTLAND CEMENT

- Portland cements have special properties for specific uses and are Divided by types.
- While each type is similar in manufacture, they differ in raw materials, proportions, and/or fineness.



7. 31. 2002



8. 1. 2002



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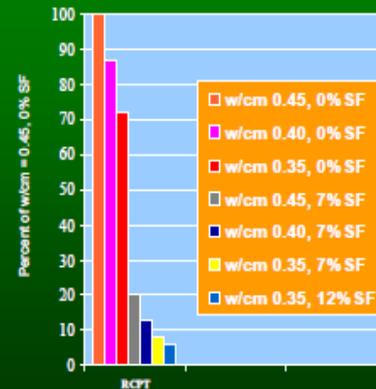


SILICA FUME (MICRO SILICA)

- By-product of producing silicon metal or ferrosilicon alloys
- Ultra fine silica (85-96%) between 50 and 100 times finer than Portland Cement
- Specific Gravity is 2.25
- Blueish Black in color
- Excellent for high strength concrete
- Excellent for Lowering Permeability
- **2 x Finer than Tobacco Smoke**



Silica Fume - Low Permeability



SLAG CEMENT...WHAT IS IT?



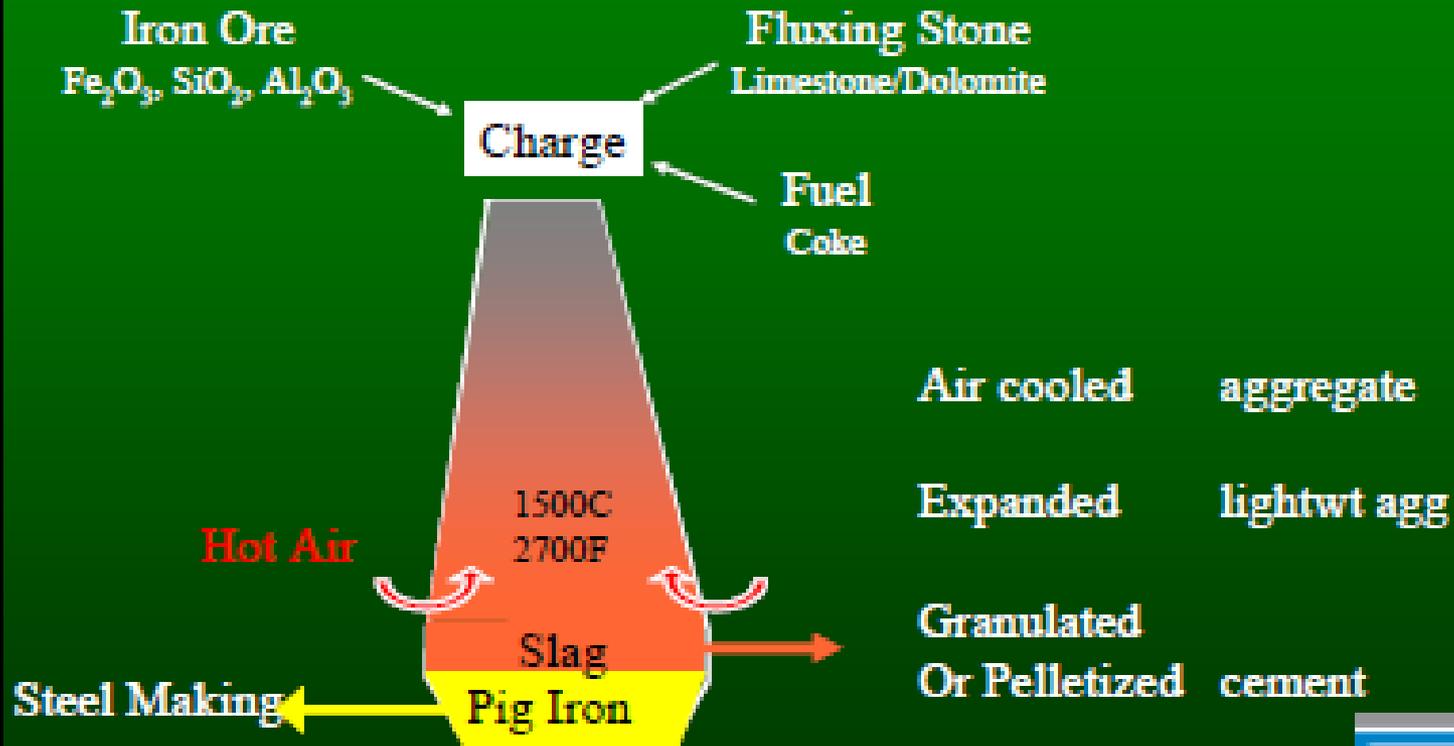
- By-product of the Steel manufacturing process;
- Non-metallic, consisting mostly of silicates and alumina silicates of Calcium
- Greatly Improves the Performance of Cement
- Supplementary Cementitious Material (SCM)

GGBFS
(Ground Granulated Blast Furnace Slag)



Slag - Manufacture

Iron Blast Furnace



GBFS ACTIVITY INDEX – ASTM C989



ASTM Minimum Requirements

Grade	Activity	7 Day	28 Day
80	Low	---	75
100	Moderate	75	95
120	High	95	115

Strength Activity Index = % of Compressive Strength with Portland cement

QUALITY AGGREGATES



- Fine - Consists of natural sands, manufactured sands, or crushed stone.
 - Grading < 3/8 inches
 - 300+ yr. CBBT Design – ASTM C33 - Natural Sand

- Coarse - Consists of one or a combination of natural gravels, crushed limestone, or quarry rock.
 - Grading 3/8 to 1 1/2 inches
 - 300+ yr. CBBT Design – ASTM C33 – #8 Stone

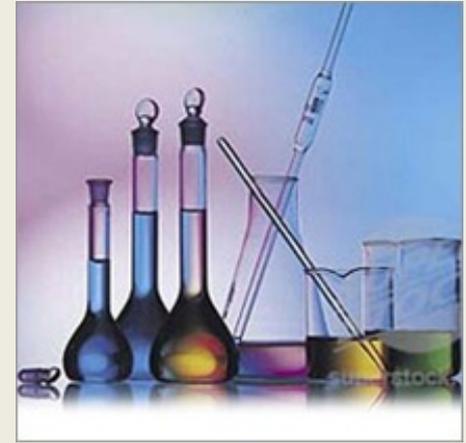
AGGREGATE CHARACTERISTICS / VERY IMPORTANT

- Particle Shape
- Surface Texture
- Absorption
- Strength
- Hardness
- Toughness
- Porosity
- Specific Gravity
- Unit Weight
- Durability



ADMIXTURE TYPES

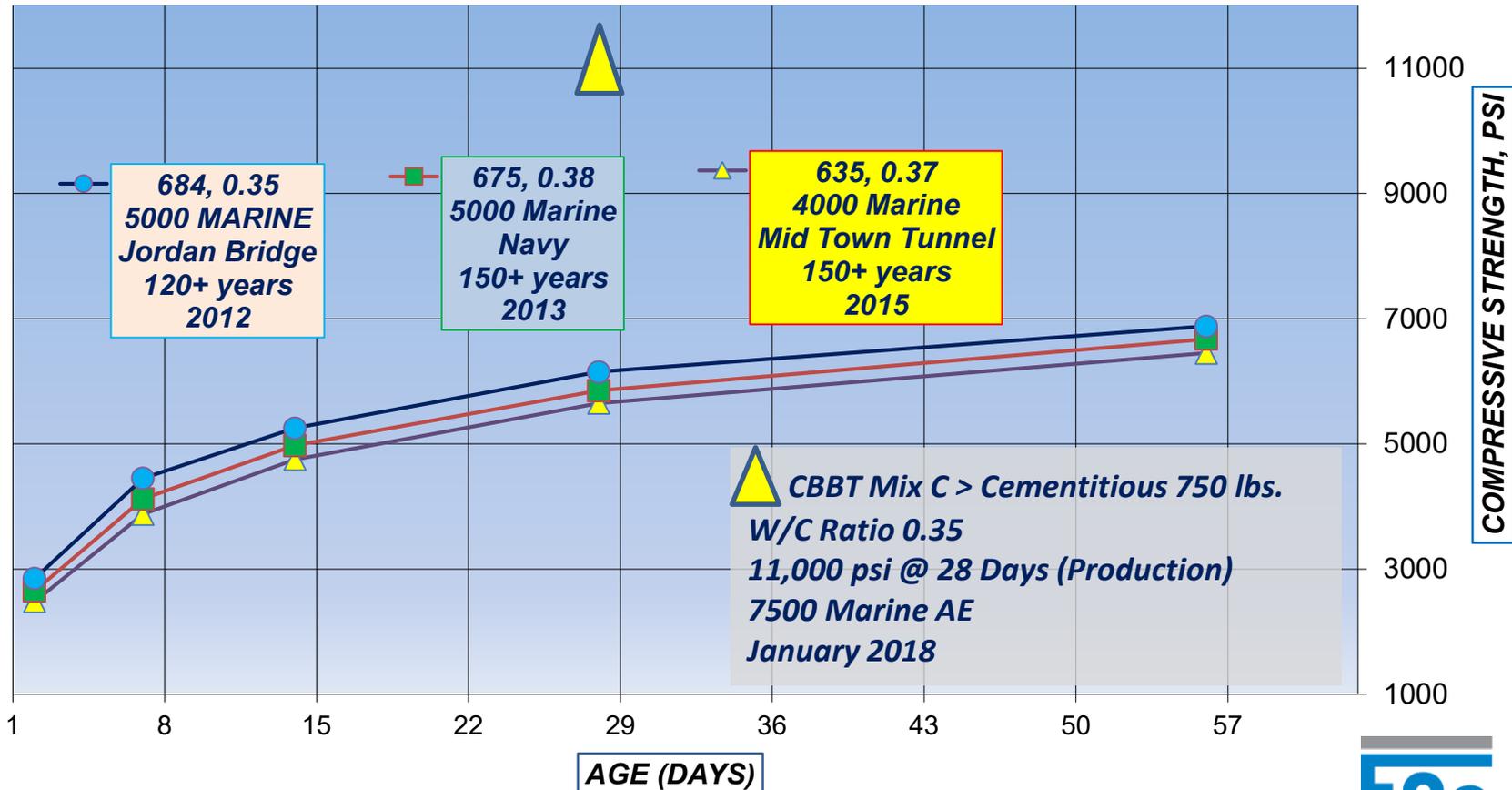
- Accelerators
- Retarders
- Air Entrainment
 - (CBBT Mix uses Sika AEA-14)
- High Range Water-Reducers (HRWR)
 - (CBBT Mix uses Accelerating PCHRWR = Sika Viscocrete 6100)
- Viscosity Modifiers (SCC)
- Others
 - Corrosion Inhibitors
 - Anti Wash-out
 - Shrinkage Reducers
 - Water-Repellent Admixtures



STRENGTH MATURITY CURVE - PERFORMANCE BASED DESIGNS

(Cementitious & W/C Ratio)

Marine Concrete Compared to High Performance
CBBT Tunnel Segment Lining Mix C



COMPRESSIVE STRENGTH TESTING WITH 400,000 LBS. MACHINE



STOP
THINK
ACT
REFINE

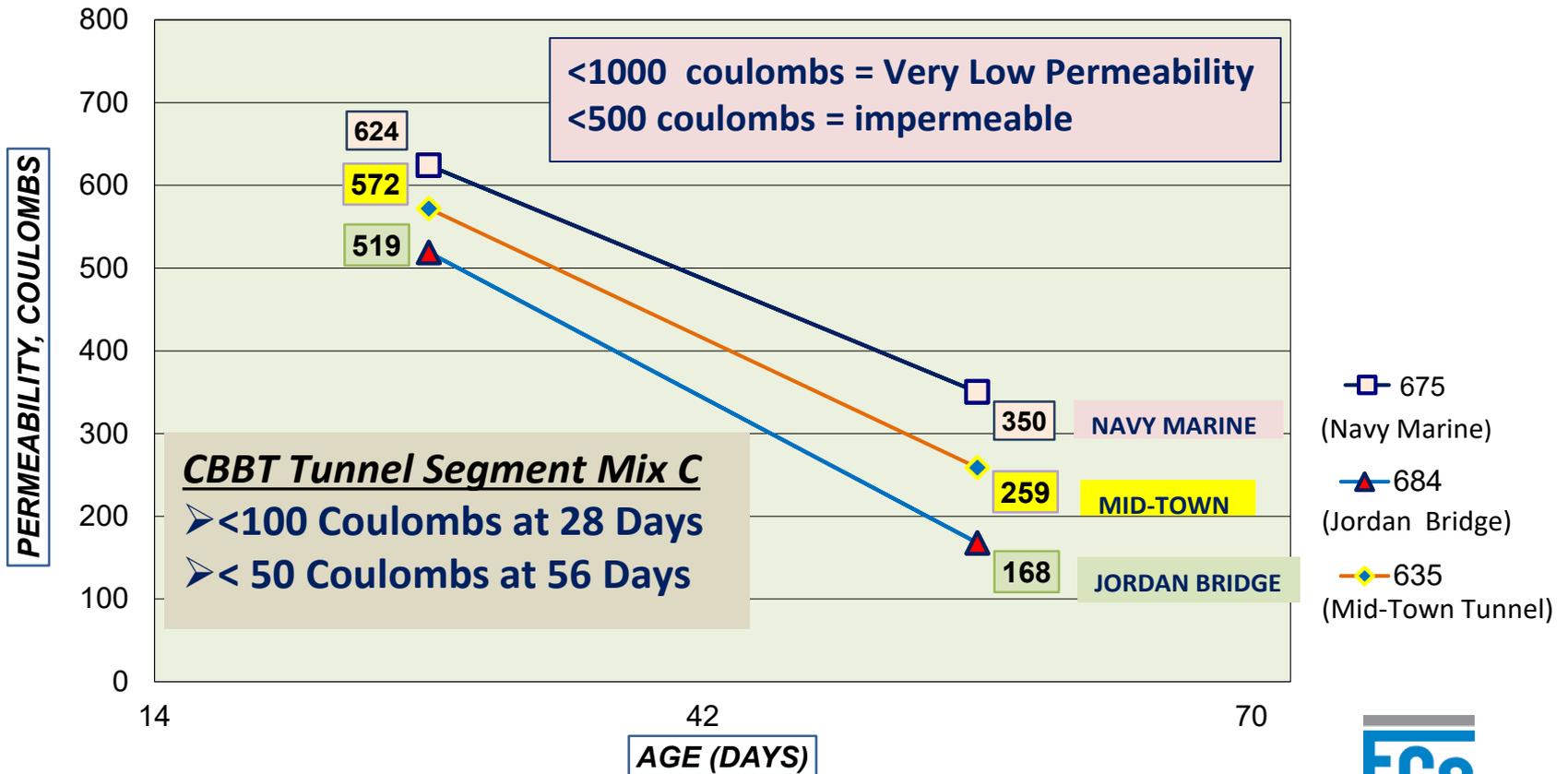
CBBT 300+ Year Service Life, (w/c 0.35)



- 28 Day Design Strength ($F'_c = 7500$ psi)
- Required 28 Day Strength ($F'_{cr} = 9000$ psi)
- Laboratory strengths Achieved:
 - ✓ 28 Days = 11,000 psi
 - ✓ 56 Days = 13,000 psi
- VTM 112 Rapid Chloride Permeability / ASTM C1202
 - ✓ Achieved <100 Coulombs at 28 Days
< 50 Coulombs at 56 Days
 - ✓ < 500 Coulombs is Impermeable
- No Reinforcing Steel for Corrosion
 - ✓ 300+ Years No Corrosion
- 2 1/4" 4D Stainless Steel Fibers @ 65 lbs. per CY;
 - ✓ Bekaert / Slinky Company
- Low Drying Shrinkage / No Cracking
 - ✓ Achieved < .016% Average Change)
 - ✓ .035 Required
- Supplementary Cementitious Materials (SCM)
 - ✓ 40% GBFS Grade 120 High Reactivity
 - ✓ 5 to 8% Silica Fume
- Coarse Aggregate size: 1/2" maximum 3/8" nominal max
- Fine Aggregate: Natural Silica Sand

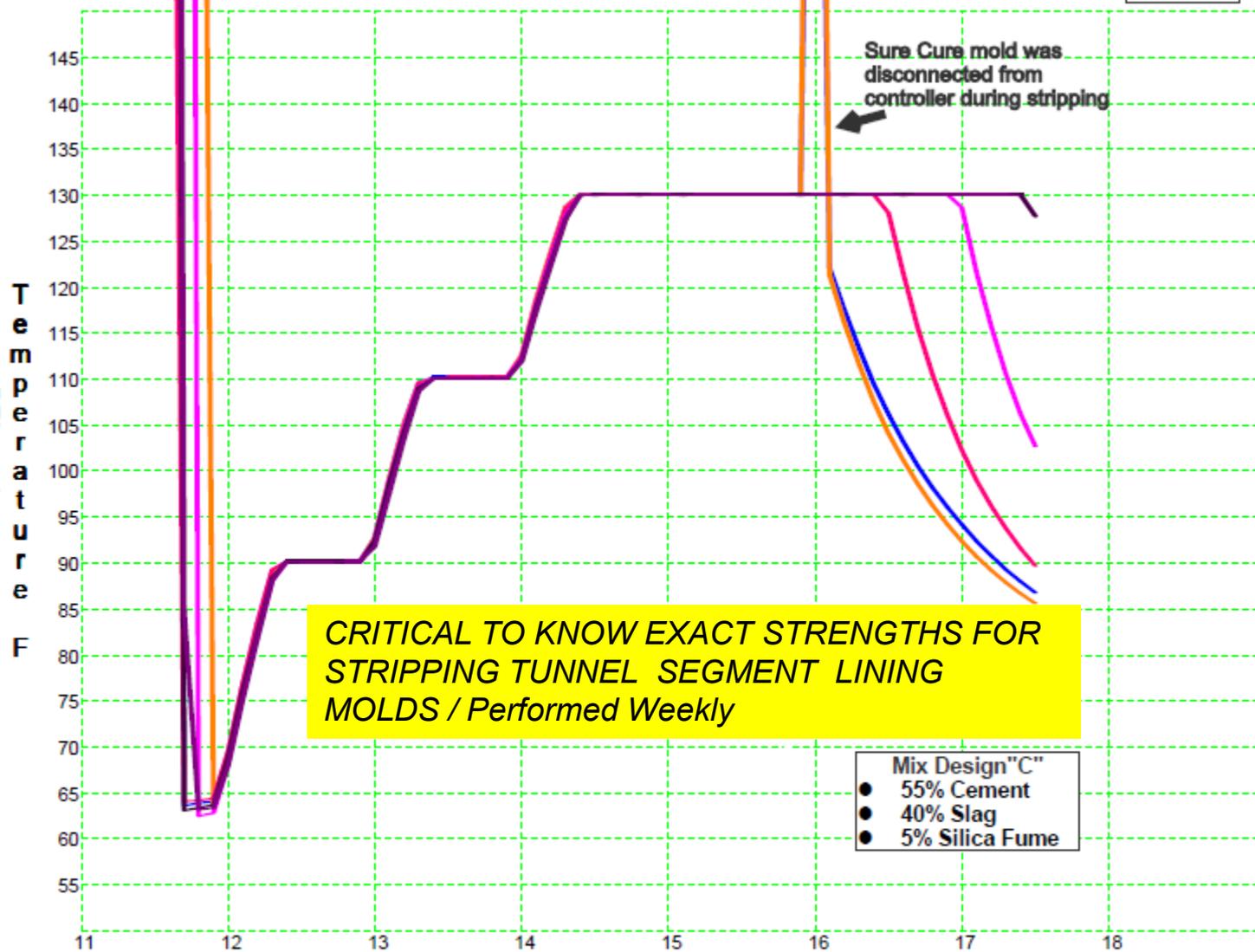
Mid-Town Tunnel / Jordan Bridge / Navy Marine Stadium

Rapid Chloride Permeability Curve



Channel 1, 2, 3, 5, 7, 8

3/12/2018



CRITICAL TO KNOW EXACT STRENGTHS FOR STRIPPING TUNNEL SEGMENT LINING MOLDS / Performed Weekly

Mix Design "C"
● 55% Cement
● 40% Slag
● 5% Silica Fume

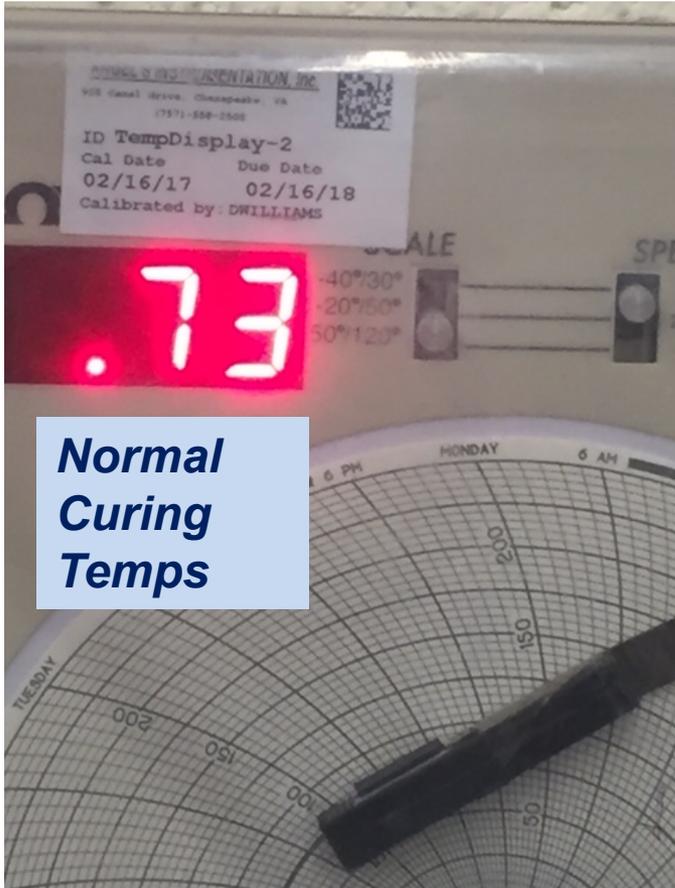


VTM 112 / ASTM C1202 (RAPID CHLORIDE PERMEABILITY)
Designed for low perms to prevent **Osmotic intrusion**
of contaminants such as **Sulfates** and to prevent moisture
intrusion so **Alkalis** do not go into solution Attacking the
siliceous minerals in the aggregates.



ASTM C157 (DRYING SHRINKAGE)
Designed to be **Crack Free** in the
structure eliminating intrusion of
contaminates through the cracks





**Normal
Curing
Temps**



Curing is Critical with Tunnel Lining Segments

- Especially at least 85+% Humidity
- Temperature ranges of
- INITIAL at 90 Degrees F
- MID at 110 Degrees F
- FINAL at 140 Degrees F.



***LABORATORY TRIAL TESTING OF
CBBT – 300+ YEAR MIX C***

PREPARING FREEZE THAW AND DRYING SHRINKAGE BEAMS



A man wearing a white lab coat, a dark safety vest, safety glasses, and orange gloves is working in a laboratory. He is pouring a grey, granular material from a metal scoop into several black rectangular molds arranged on a table. In the background, there are stacks of blue buckets, a white cabinet, and safety signs on the wall. One sign reads 'RIGHT-TO-KNOW INFORMATION' and another says 'MATERIAL SAFETY DATA SHEETS'. A handwritten note on the wall says 'Be's Doo Comp's Clo's'.

**CASTING INVERSE
CARBONATION
RESISTANCE BEAMS**

PREPARING TO START MIX
PROPORTIONING WITH
HIGH ENERGY MIXER



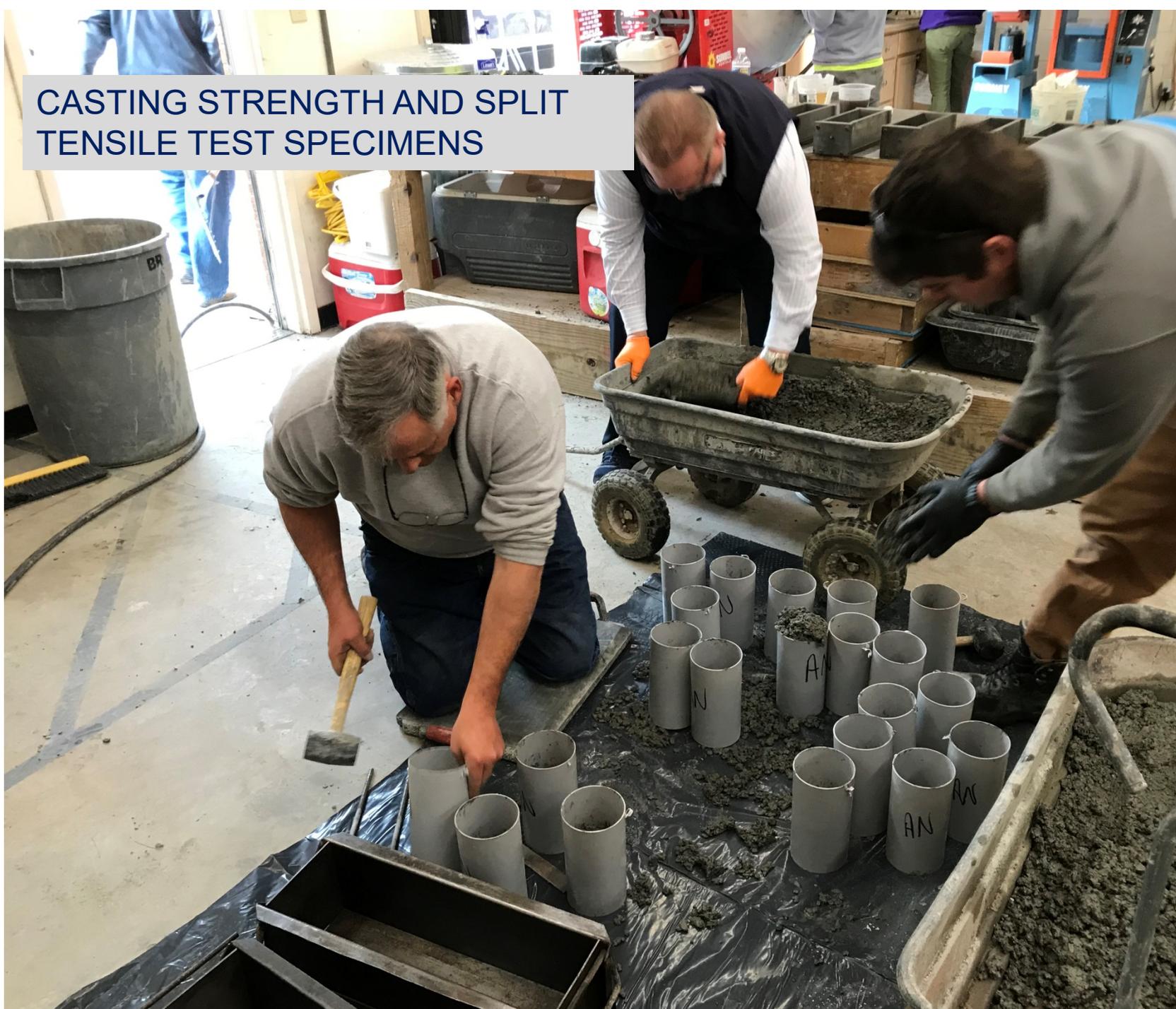
A group of people in a workshop are weighing raw materials. In the foreground, a man in a blue hoodie and orange cap stands with his back to the camera. To his right, a woman in a light blue shirt is pouring material from a brown bag into a blue bucket on a scale. Another person in a maroon shirt is also pouring from a bag into a bucket. In the background, a man in a dark jacket is bent over, and another man in a grey hoodie is standing near a workbench. The workshop contains various tools, equipment, and materials. A sign on the wall reads "CAUTION RADIOACTIVE MATERIALS". A bag of "Sikacrete 950DP" is visible on the floor.

WEIGHING RAW MATERIALS
IN THE DESIGNS

RUNNING PLASTIC UNIT
WEIGHT TEST AFTER
FINAL MIXING



CASTING STRENGTH AND SPLIT TENSILE TEST SPECIMENS





*Casting Beams for Freeze / Thaw Durability
ASTM C666 (300 Cycles) and ASTM C157 Drying
Shrinkage (< 0.035)*

**PROPER LOCATION OF 4D BEKAERT
STAINLESS STEEL FIBERS FOR
PRIMARY REINFORCEMENT**

FIBER DISTRIBUTION
TYPICALLY 140+ COUNT



*CSI Tunnel Systems Performing Fiber Count
checking for Proper Fiber Distribution*





FIBER WASHOUT

- Measure .5 Cubic Feet
- Magnetically Remove 4D Fibers
- Dry Fibers / Calculate %

**CBBT – 300+ YEAR DESIGN
CHEMICAL RESISTANT TO
ALKALI SILICA REACTIVITY & SULFATE
ATTACK**

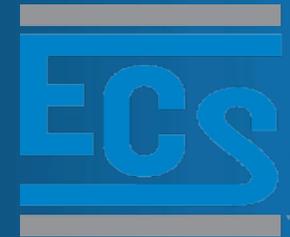
DESIGNED TO ELIMINATE
ALKALI SILICA REACTIVITY
& SULFATE ATTACK



What is Alkali Reactivity?



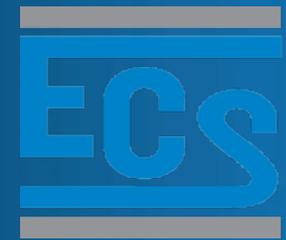
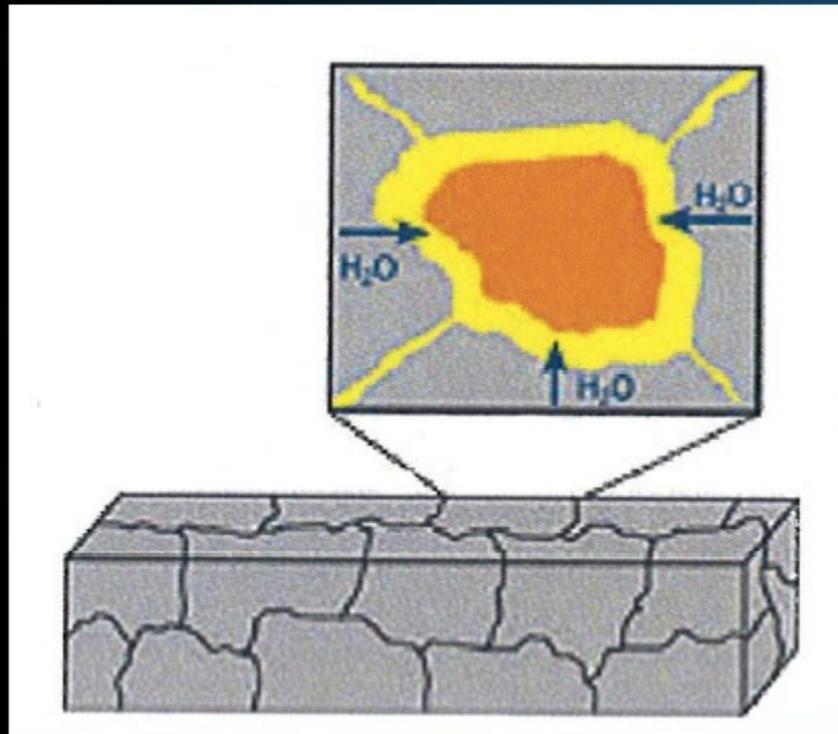
**BOWSER
MORNER.**



What is Alkali Reactivity?



**BOWSER
MORNER.**



**CBBT – 300+ YEAR DESIGN
MANUFACTURING OF TUNNEL
SEGMENT LININGS**





















The Thimble Shoal Channel Tunnel.mp4 - Shortcut.lnk

THANK YOU