

# Specifying Novel Materials and Admixtures

## Innovation Obstacles in Construction Materials

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# “O, brave new world, that has such people in it.”

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- Shakespeare, The Tempest

# Seeing the future is not so easy

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- ◉ In 1876, Western Union decided that telephones would never replace telegram messengers.
- ◉ In 1971, AT&T turned down the opportunity to run the Internet as a monopoly.
- ◉ In 1980, Ma Bell concluded that cell phones would never replace landlines.

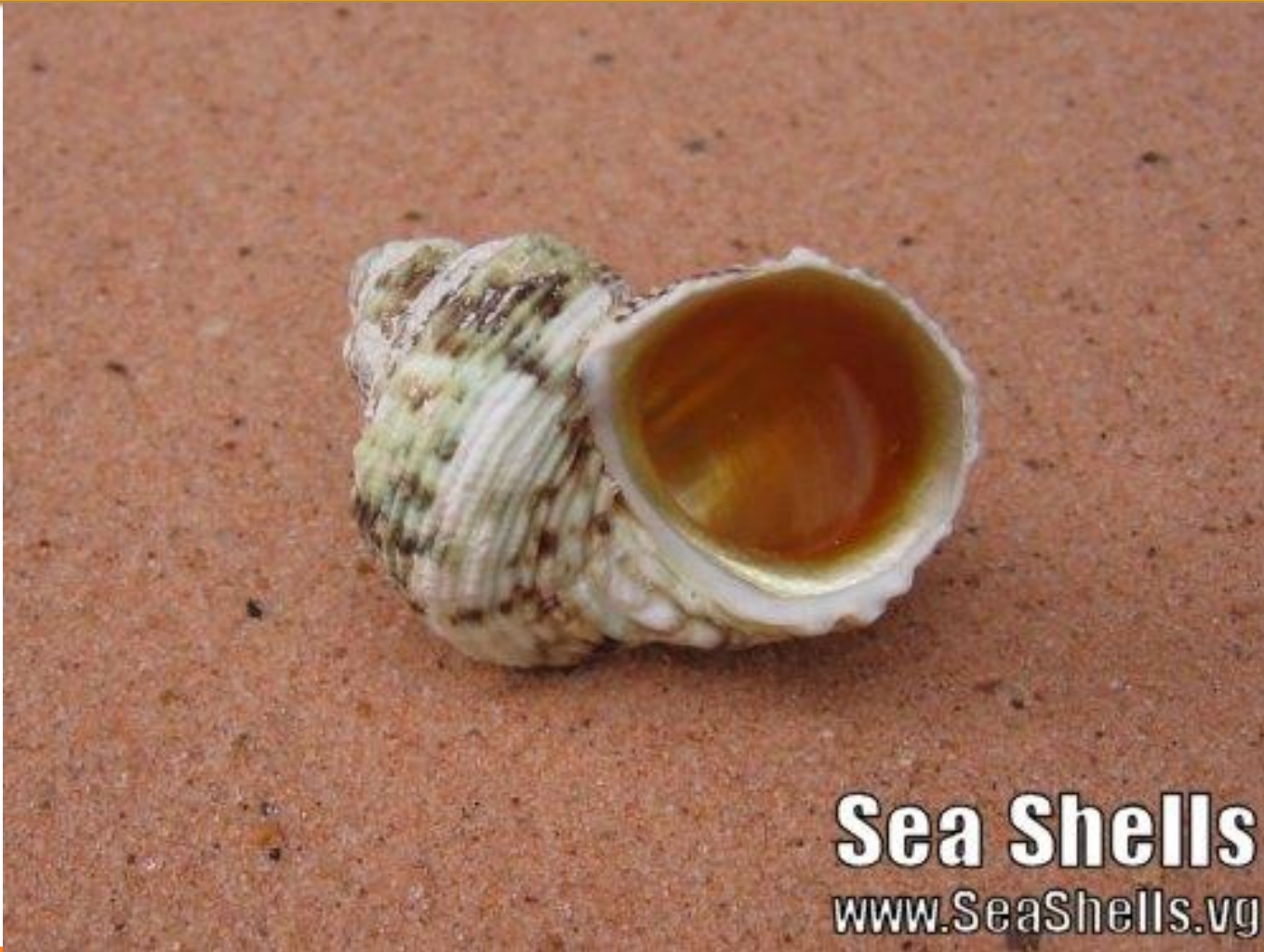
# Pity the Poor Clam

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- Over many millions of years, nature has devised schemes to combine seemingly incompatible building-blocks —
- 'soft' organic proteins and
- 'hard' inorganic particles of calcium carbonate — in a manner that produces composite materials with the unusual combination of high strength, hardness and toughness.

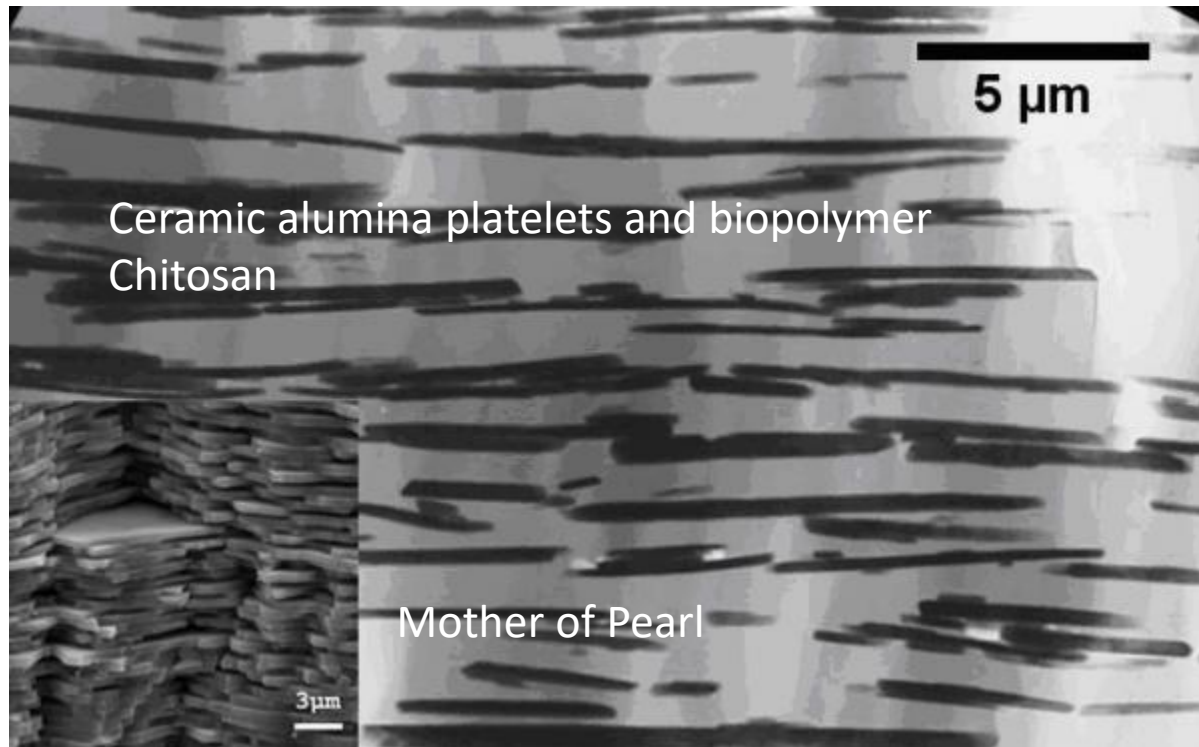
# Youngs Modulus 250-260 GPa

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# 25 percent elongation at failure

- ETH Zurich (2008, March 10). New Composite Material Is Almost Better Than Mother-of-pearl. *ScienceDaily*.







# 1938 ACI Convention

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“Before we can expect findings of research to be adopted and made part of current engineering practice, it is necessary that they be understood, abstracted and molded into a form usable by the practitioner”

Frank T Sheets, President, PCA



# The Current System for Concrete Specification

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- Specification is prepared which lays out all requirements
- A submittal is prepared to address those requirements
- Testing Laboratories are hired to check what is being supplied is what was submitted.
- There are no problems so everything is great.

# Failures

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- A failure occurs for only 2 reasons:
- The contractor did not follow the specification, or
- The specification was in error

Bryant Mather

# Spearin Doctrine

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- 1918 Supreme Court Decision

# Concrete has a split personality

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- Its durability is important
  - It is a structural material
  - It needs to be constructed
- 
- There is no hierarchy of these requirements.  
All three need to be met



# Obstacles

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- ◉ We are developing new technologies and new materials
- ◉ New processes and new construction methods
- ◉ Doing so not to improve construction or performance - to reduce / eliminate emissions and reduce energy needs
- ◉ History tells us that there will be problems and they will be discovered in practice.



# A lesson from History

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- High Alumina Cement (HAC) differs from Portland cement, being composed calcium aluminates rather than calcium silicates. Its rapid strength development made HAC popular from 1950 to 1970. However, mineralogical 'conversion' sometimes caused reductions in concrete strength and increased vulnerability to chemical attack.
- HAC effectively banned for use in new structural concrete in the UK following a few well publicized collapses in the 1970s.
- primary causes of these collapses were poor construction details or chemical attack, rather than problems with the concrete itself.

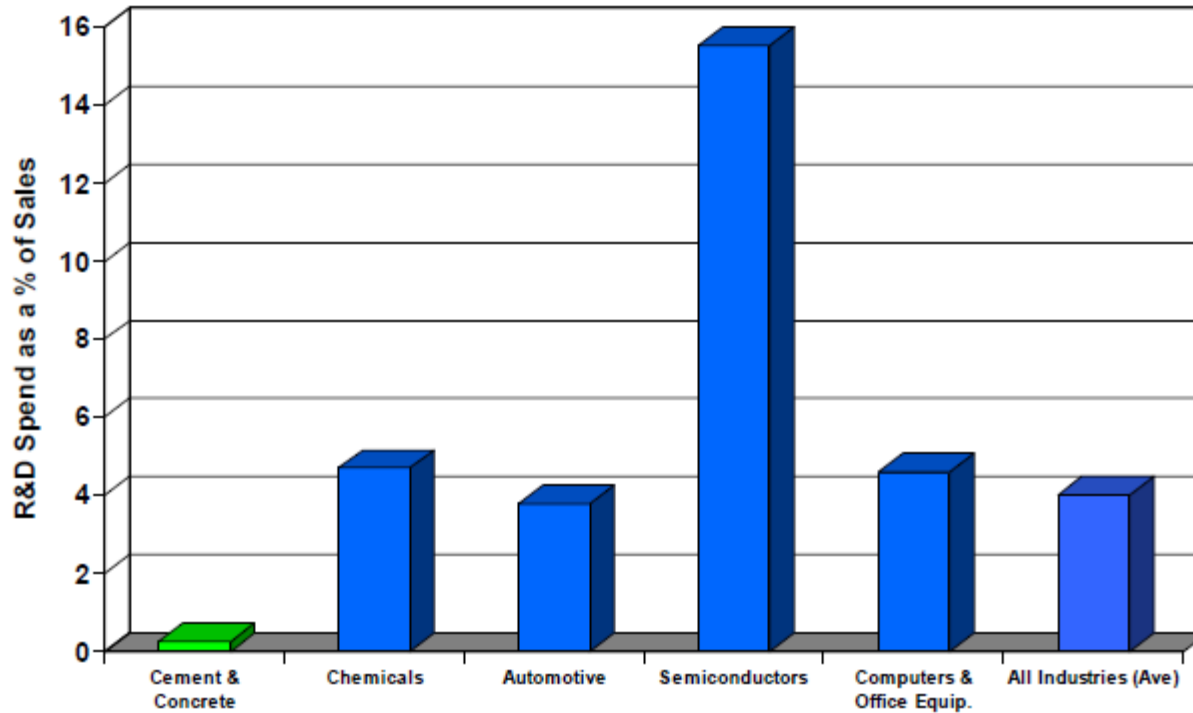
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- Concrete had been in use for a century
  - Alkali Silica Reaction
  - California in the 1940's Stanton
  - Air Entrainment in the 1930's

# Barriers and Issues

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- Lack of adequate R&D funding
- Slow adoption rates of new technologies
- Low level of collaboration for multidisciplinary problems
- Prescriptive vs. performance based standards
- Low level of QC technologies
- Lip service to life-time costs
- *Poor image of cement-based materials !!!*
- .....

## R&D \$'s - Small Numbers!



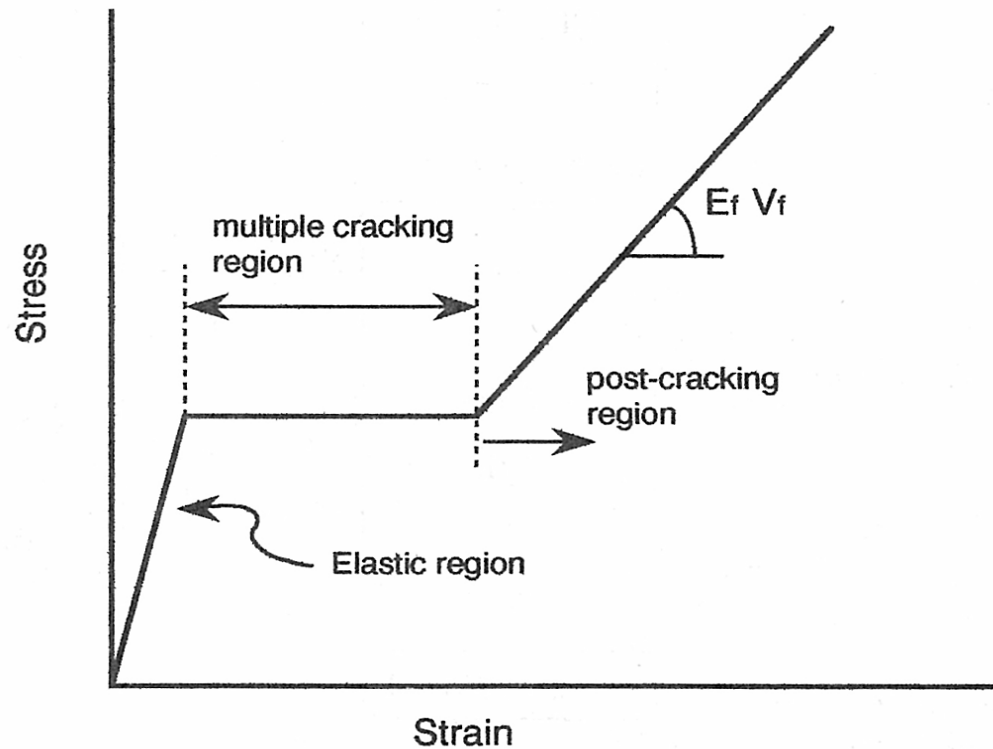
**Little funding for construction research!**

# New Technologies (well kinda new)

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- ◉ Steel Fibers
- ◉ Mixture Design
- ◉ Low Clinker Mixtures
- ◉ No Clinker Mixtures
- ◉ In Situ Mineralization
- ◉ Functional Admixtures
  - Curing without a membrane
  - Frost Resistance without air

# Steel Fibers - ACK Model





# Mixtures : Proportion or Design ?

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## ○ PROPORTIONING

- to adjust in proper proportion or relation, as to size, quantity, etc
- to balance or harmonize the proportions of

## ○ DESIGNING

- showing or using forethought.
  - the act of making designs.
- to prepare the preliminary sketch or the plans for (a work to be executed), especially to plan the form and structure of:

# Slump is not a good indicator of strength



# Unwritten Owner Requirements

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- ◉ Shrinkage
- ◉ Curling
- ◉ Cracking
- ◉ Appearance
- ◉ Longevity

# Constructor Requirements

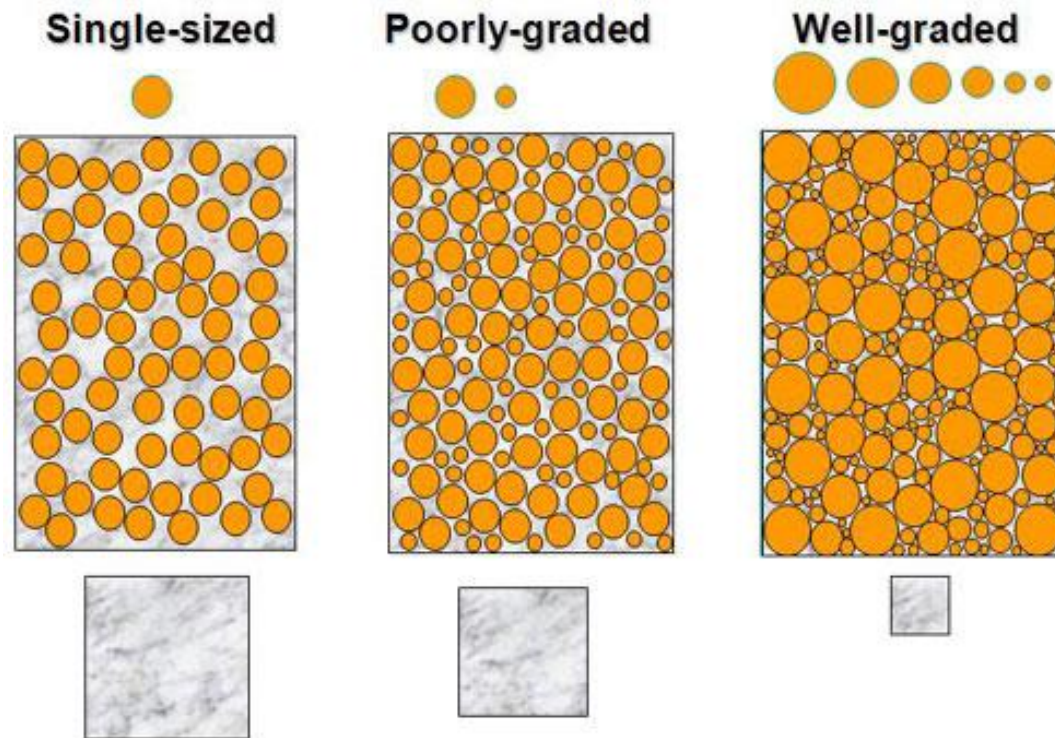
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- ◉ Workability
- ◉ Finishability
- ◉ Setting Characteristics
- ◉ Strength Gain for Stripping and Stressing
- ◉ Cold and Hot Weather





# Gradation vs Paste Content





# Understanding Volumetrics a Different Way

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- ◉ Two types of paste - required and excess
- ◉ Packing can reduce the first to a minimum
- ◉ Gap Graded mixtures pack well - but can segregate
- ◉ Packing models are well developed
- ◉ Control of Gradation is critical
- ◉ Allows improvement of concrete performance



35 Percent Slag  
25 F Ash  
550 Lb/yd<sup>3</sup> Cementitious

SCC with a Slump-flow of 28 inches and  
VSI of zero.

Shaft Diameter 8 feet  
Shaft Depth 135 feet  
Height above Bedrock of this slice 110  
feet  
f'c at 20 days 8500 psi by cores 10000  
psi in-situ

Max Temperature 125 °F at 98 hours  
incoming temperature 65 °F. Maximum  
differential temperature 12 °F

TTOM

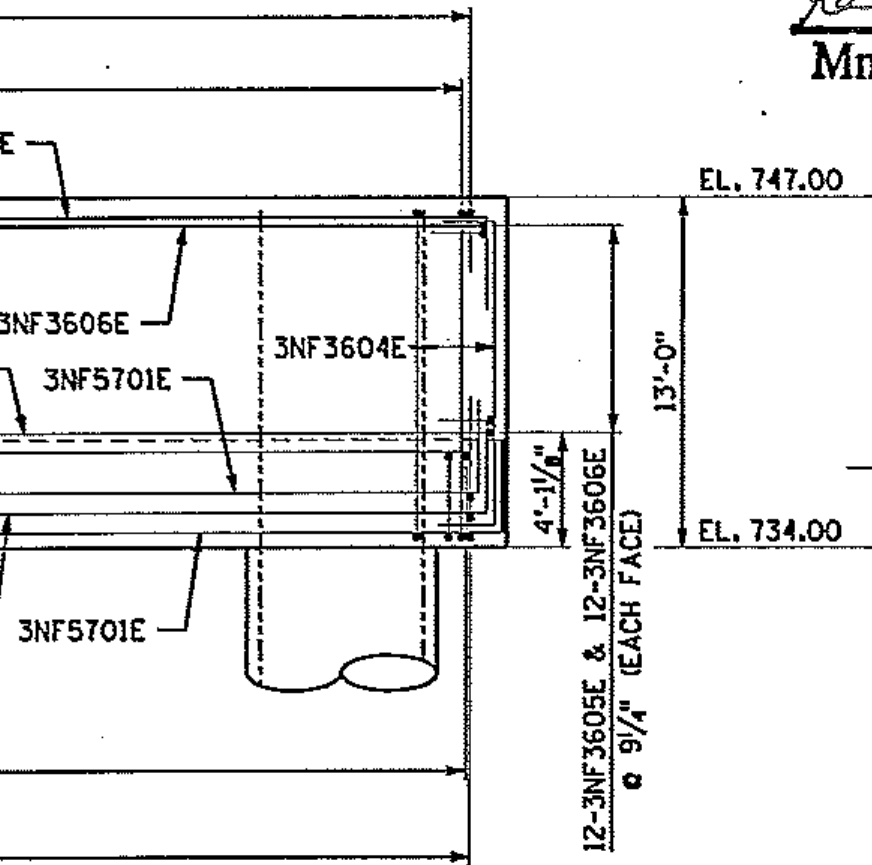
Mn/DOT has reviewed this deliverable and determined that it appears to meet the requirements of the Contract Documents.

*K. D. [Signature]*

1-23-08

Mn/DOT Representative

Date



**RELEASED FOR  
CONSTRUCTION**

FOR ACCEPTANCE

	<p>TITLE:</p> <p>PIER 3 NB FOOTING DIMENSIONS &amp; REINFORCING I</p>	<p>DES: CF</p> <p>CHK: ZYC</p>	<p>DR: KJM</p> <p>CHK: DLS</p>		<p>BRIDGE NOS. 27410(NB)</p>
			<p>PR-005</p>		







# Same Concrete -







# Clinkerless Cement

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- ◉ There are binder systems that do not require any Clinker
- ◉ Different materials and different reactions result in hydraulic binders

# Roman Concrete

- Colosseum, aqueducts, Pantheon, Roman baths, etc.
- 300 BC - 476 AD
  - Binder
    - Slaked lime, gypsum and volcanic ash from 79AD eruption of Mt. Vesuvius
  - Aggregate
    - Rock, pumice, ceramic tile, broken bricks and pottery
  - Additives
    - Ash, animal fat, milk, blood, horse hair
- Pozzolan - *pozzolana*
  - named after Pozzouli, a village near Naples, Italy



# Egyptian Concrete

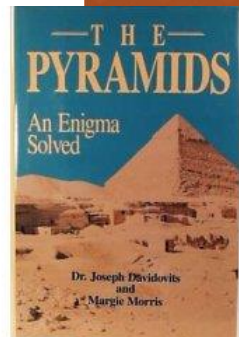
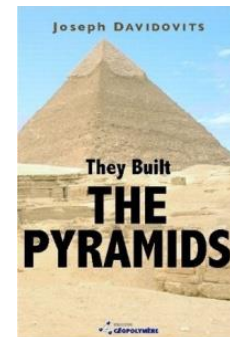
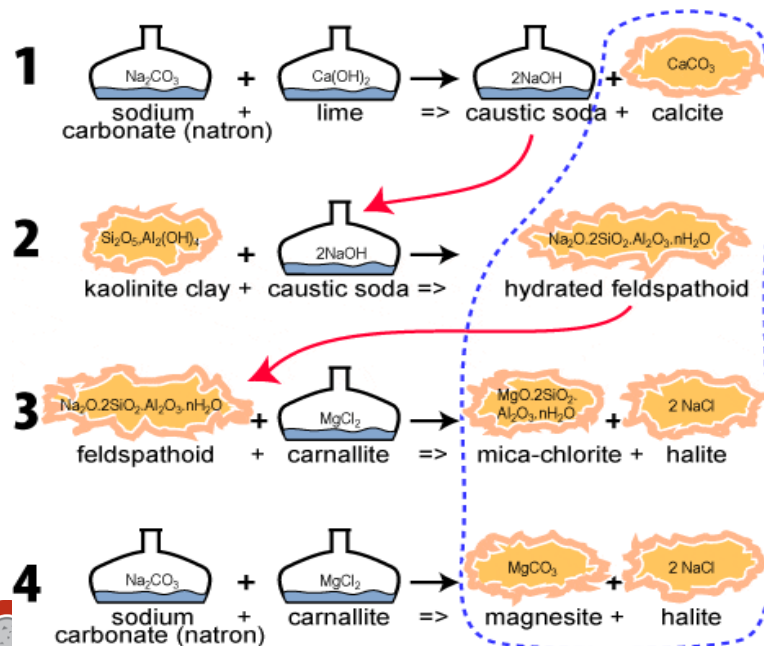
- 3000 BC
  - Mud mixed with straw
  - Lime mortar and burnt gypsum
  - Non-hydraulic



# Great Pyramid of Giza

- Some believe blocks in the Great Pyramid of Giza were cast from an ancient geopolymer formula

- Dr. Joseph Davidovits





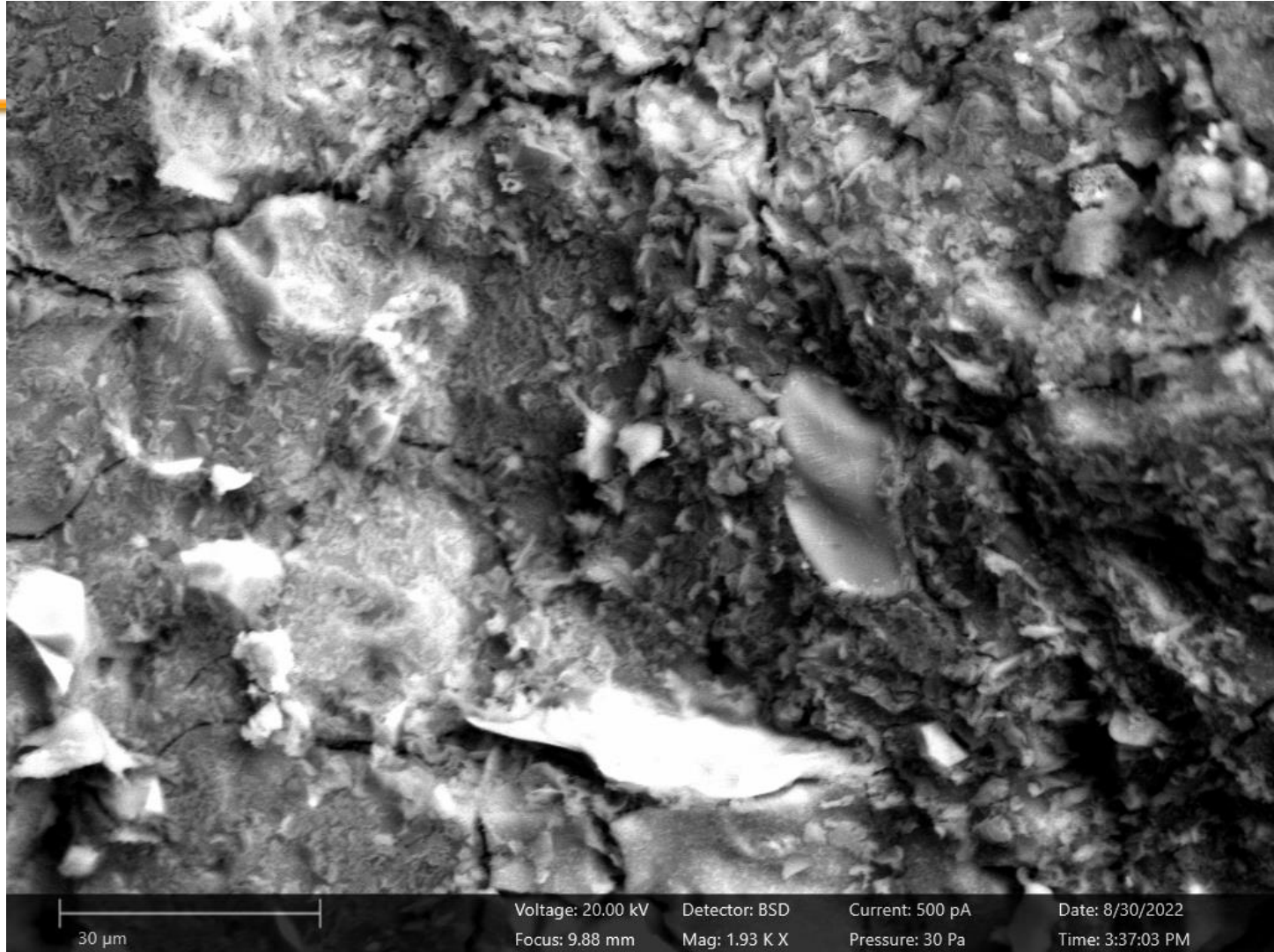


# Alkali-Activated Material

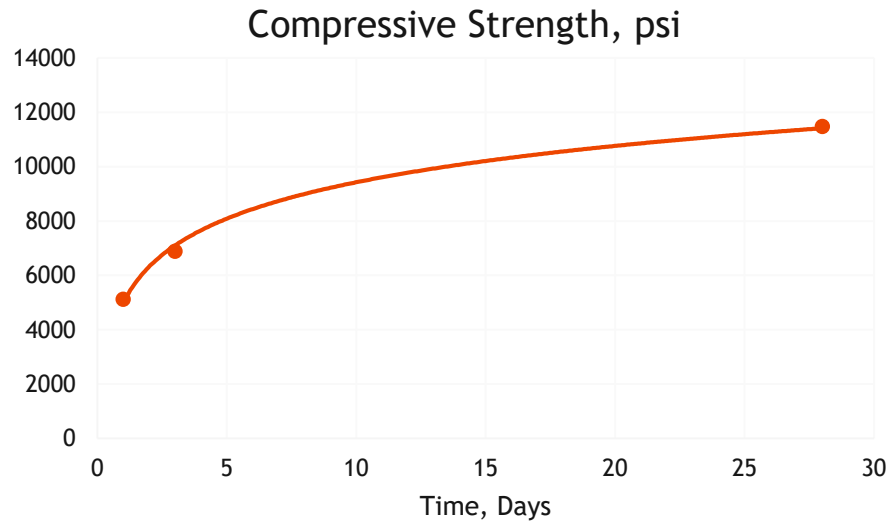
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- ◉ Eliminates the high pH of most
- ◉ Alkali derived from low energy process
- ◉ No Calcination
- ◉ Binder composition is based on post industrial and post consumer waste
- ◉ Solution based hydration results in novel microstructure





# Concrete Mechanical Properties



Modulus of Elasticity 3 days  $6.94 \times 10^6$  psi  
Poisson's Ratio

0.36

$83000 (f'_c)^{1/2}$

Initial Setting 3:15  
Final Setting 5:10

Slump 4 inches (readily available at any slump)

Flexural Strength 7 days 1000 psi

$MOR = 11(f'_c)^{1/2}$

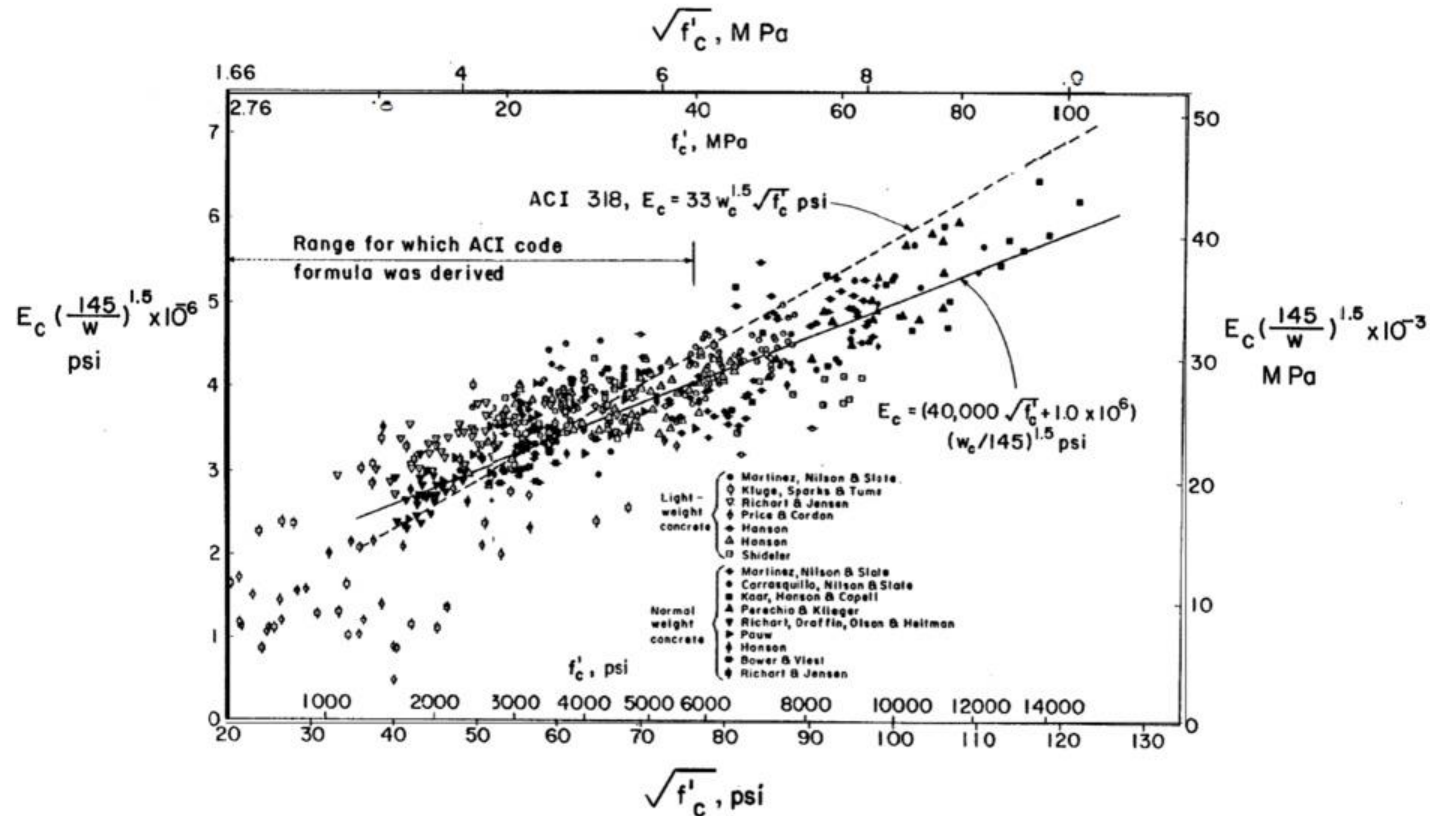


# Production and Durability Design

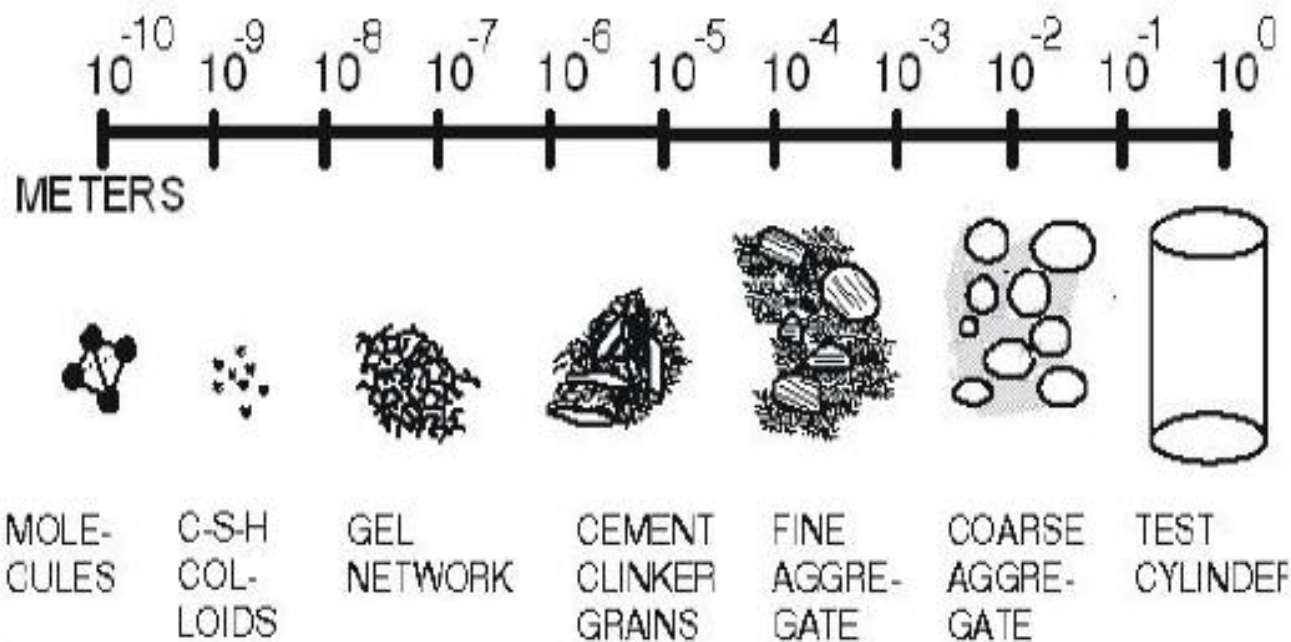
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- ◉ The pH of the concrete is similar to or less than that of portland cement concrete. Normal precautions need to be taken regarding contact of the materials with unprotected skin.
- ◉ Albedo is higher than conventional concrete after some oxygen curing has occurred.
- ◉ KevCo Concrete can be made to be permeable for drainage.
- ◉ KevCo Concrete can be air-entrained using conventional methods and materials.
- ◉ Chloride Ion Resistance RCP equivalent of 200 C passed in ASTM C1202
- ◉ Shrinkage is similar to OPC Concrete without curing the Yummet materials
- ◉ Some efflorescence can be expected where the concrete is in contact with the soil.

# Engineering Practice Requires Simplification



# Concrete Microstructure





# Des Moines Bridge - Liquid Flyash

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## ***Prescription vs. Performance***

- ***US lagging behind Europe / Canada in code development***
- ***I.e. CSA A23.1 class C1 exposure***
- ***Economic advantage of “how” is removed***
- ***Innovation is stifled***
- ***Often meeting the prescription can result in undesirable, unintended consequences***





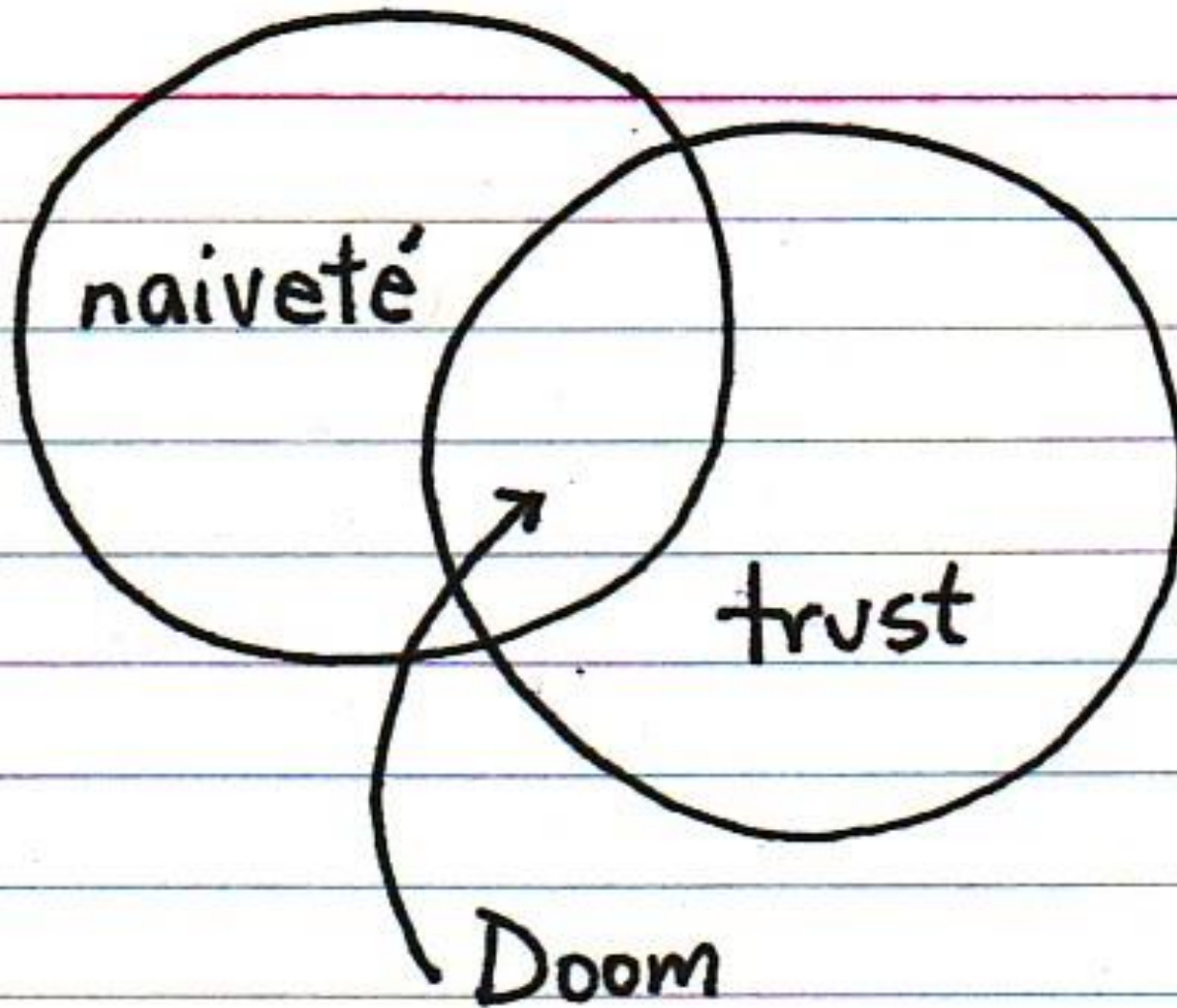
"Here's what I want: Your concrete should pour like Niagara and have the strength of Gibraltar."

# Limestone as a Nucleation Accelerator

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- The one who gets there first wins







# Conclusions

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- ◉ We are making changes in materials at an unprecedented pace
- ◉ Many innovations are being implemented rapidly
- ◉ The EOR may not be able to keep up
- ◉ Performance Specifications need to be used
- ◉ Performance needs to be a shared risk - Warranty

# A plan for Acceptance

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- Testing performed by Contractor
- Cores taken at random in lots
- PWL // QI Acceptance
- Performance Based Acceptance Eliminates a lot of bad situations and allows innovation
- Allows a fair accounting for Risk and Reward



# Hymn of Breaking Strain      Kipling

- The careful texts-books measure (Let all who build beware!) The load, the shock, the pressure Material can bear. So, when the buckled girder Lets down the grinding span, The blame of loss, or murder, Is laid upon the man. *Not on the Stuff - the Man!*
- But in our daily dealing With stone and steel, we find The Gods have no such feeling Of justice toward mankind. To no set gauge they make us,- For no laid course prepare- And presently o'ertake us With loads we cannot bear. *Too merciless to bear.*
- The prudent text-books give it In tables at the end- The stress that shears a rivet Or makes a tie-bar bend- What traffic wrecks macadam- What concrete should endure- But we, poor Sons of Adam, Have no such literature, *To warn us or make sure!*
- We hold all Earth to plunder- All Time and Space as well- Too wonder-stale to wonder At each new miracle; Till, in the mid-illusion Of Godhead 'neath our hand, Falls multiple confusion On all we did or planned. *The mighty works we planned.*
- We only of Creation (*Oh, luckier bridge and rail!*) Abide the twin-damnation- To fail and know we fail. Yet we-by which sole token We know we once were Gods- Take shame in being broken However great the odds- *The burden or the Odds.*
- Oh, veiled and secret Power Whose paths we seek in vain, Be with us in our hour Of overthrow and pain; That we - by which sure token We know Thy ways are true- In spite of being broken. *Because of being broken, May rise and build anew. Stand by and build anew!*

# Thank You

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