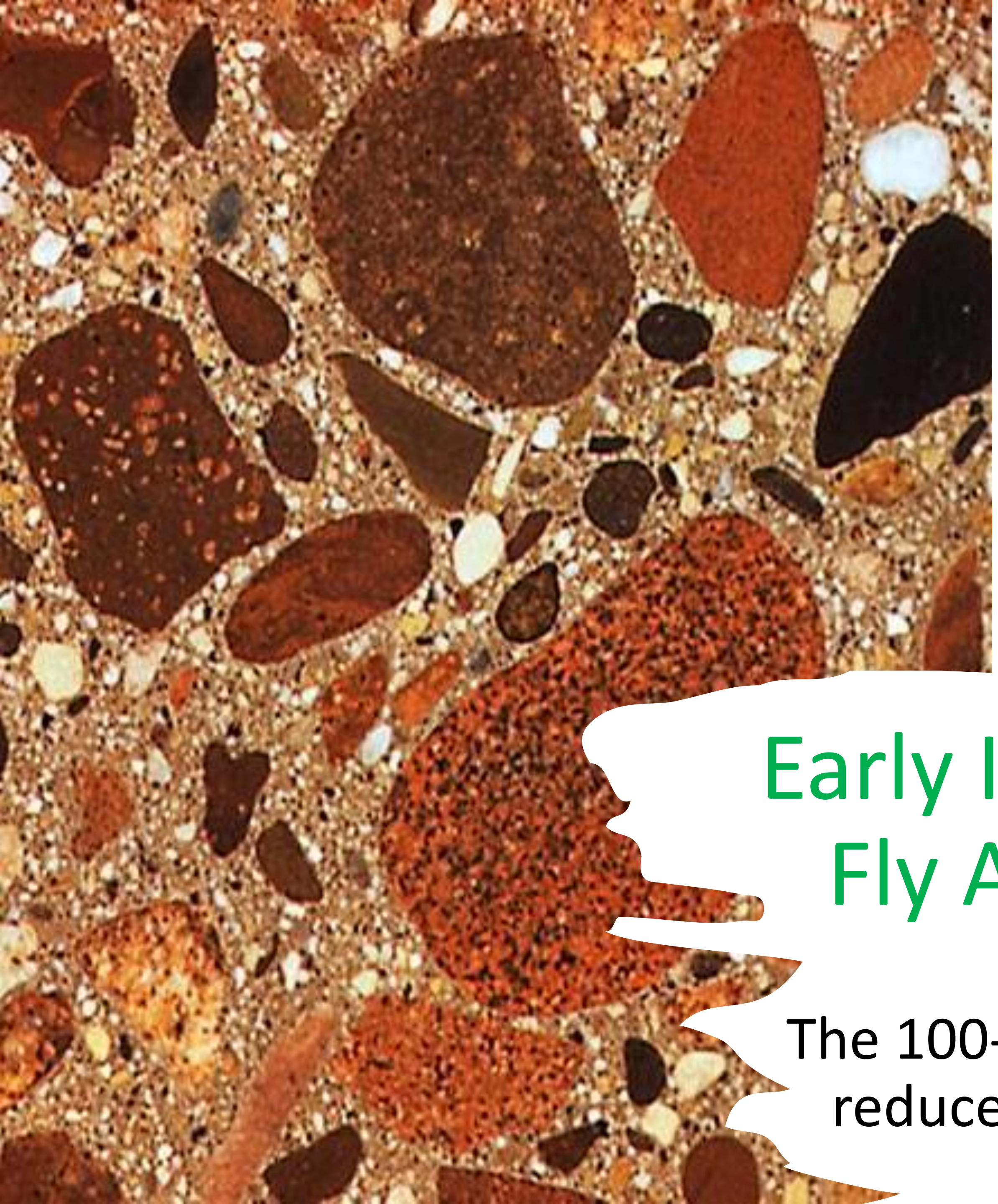


Early Investments in Fly Ash Research

The 100-year Highway and its reduced Carbon Footprint

Ramon Carrasquillo, Ph.D., P.E.

Engineer

Mentor

Colleague

Friend for 40 years

Resource Conservation and Recovery Act (RCRA, 1976)

- EPA Guidelines for Federal Procurement of Cement and Concrete Containing Fly ash (1983)
  - 1st Recovered Material selected by EPA
    - Significant solid waste material by volume
    - Economical to separate and recover
    - Technically proven uses
    - Federal purchasing power must be substantial
- Prior to 1986, 2-3 million tons/yr used in cement or concrete production in US

EPA's Anecdotal Evidence for technically proven uses

- Buildings
  - Sears Tower
  - John Hancock Center
  - McCormick Plane
  - Standard Oil Building
  - Prudential Building
  - Davis-Bessie Nuclear Power Plant
  - Detroit General Hospital
- Federal Infrastructure
  - Hungry Horse Dam
  - Dworshak Dam
  - Libby Dam
  - Tombigbee Riverway locks and dams
  - Central Arizona Aqueduct
  - 200 lane miles of Georgia DOT roads

States were given until January 28th, 1986 to allow Fly Ash in nearly all Highway Concrete

- Federal Procurement
- Minimum 20% by mass of CM
- Risk losing all Fed Transp. $$$

Carrasquillo proposes (1983) : TxDOT Projects 364 and 481

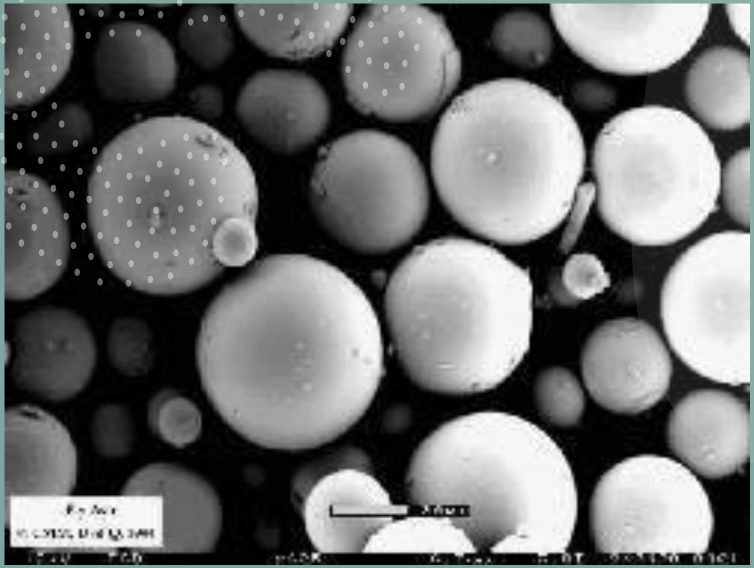
364: Mixture Design with Concrete Containing Fly Ash

481: Durable Concrete Mixtures Containing Fly Ash

- Guidelines for Structural Concrete
- Enduring Pavement Concrete
- Economics
- Design/Construction considerations
- Quality Assurance / Oversight

Results led to greater investments from FHWA, EPRI, NRMCA, SFA, other DOTs in Concrete Containing Fly Ash and Pozzolans

Chemistry is Important



- The chemistry of the cementitious system can resist almost any exposure.
- Fly ash added excellent technical properties in both strength and durability
- Chemistry of fly ash was very important
- Admixture chemistry changes the rules of mixture design

ACI Responds to demand for Guidelines

- ACI 226 Splits
  - ACI 232 - ACI 232
    - ACI 240
  - ACI 233
  - ACI 234

Resilient Infrastructure

Fly Ash was key to extending the life cycle of the nation's infrastructure

- Sulfate Resistance
- ASR Resistance
- Impermeability
- Lower Heat
- Long-Term Strength
- …

Long-Life is not Expensive

- Don’t confuse durable, long-life structures with expensive and special.

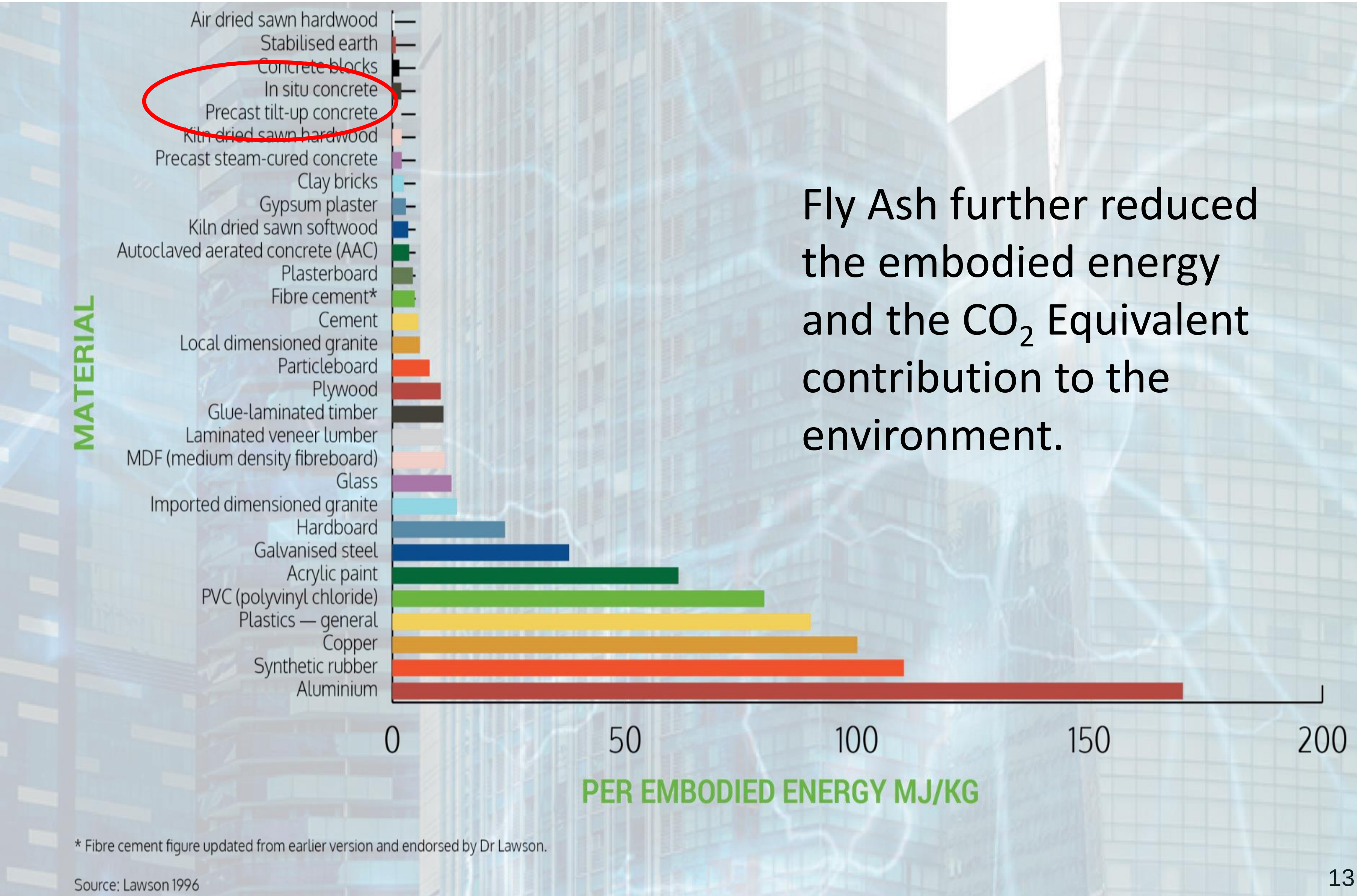
- Well trained crews and quality control is the first step to both economic and excellent concrete.

Long-Life vs. Sustainability

- 12-13 million tons of fly ash per year are used in cement or concrete production in US
- Long Technical Life leads to an even lower lifetime CO_2e footprint

The 100-year highway has 67% deduction in CO_2 and lower life-cycle cost vs. a 33-year highway, and a proportional cost savings.

Embodied Energy



Fly Ash further reduced the embodied energy and the CO_2 Equivalent contribution to the environment.

Ramon Carrasquillo, Ph.D., P.E.

- Concrete is Science and an Art
- Keep learning
- Look Ahead and keep moving

The fundamentals still work and are the core of innovation

Other Impacts of Long-Life

- Long life structures with fly ash reduced the interruption to other commercial enterprises.
- Continuous operations during emergency

Endurance based design with concrete

- Integrated Structural System
  - Concrete Shear walls (inside the building for integrity also see energy savings)
  - Avoid high deflection elements (cantilevers)

- Enduring Materials
  - Continuously reinforce connections
  - Low permeable exposed concrete
  - Low to moderate shrinkage slabs

- Consider how it could be tougher or how it could be quickly restored in a singular event

Passive Energy for Long-Life and operation during bad times.

- Interior thermal mass (concrete) reduces the stress on Mechanical systems and maintains environment during outages (concrete shear walls and floors)

- Hydronic cooling/heating of concrete can be powered with low amp off grid power.

Final Lessons from Ramon

- No matter how long it's been, reach out

- Laugh and have a good story

- Start the next chapter, sooner than later.