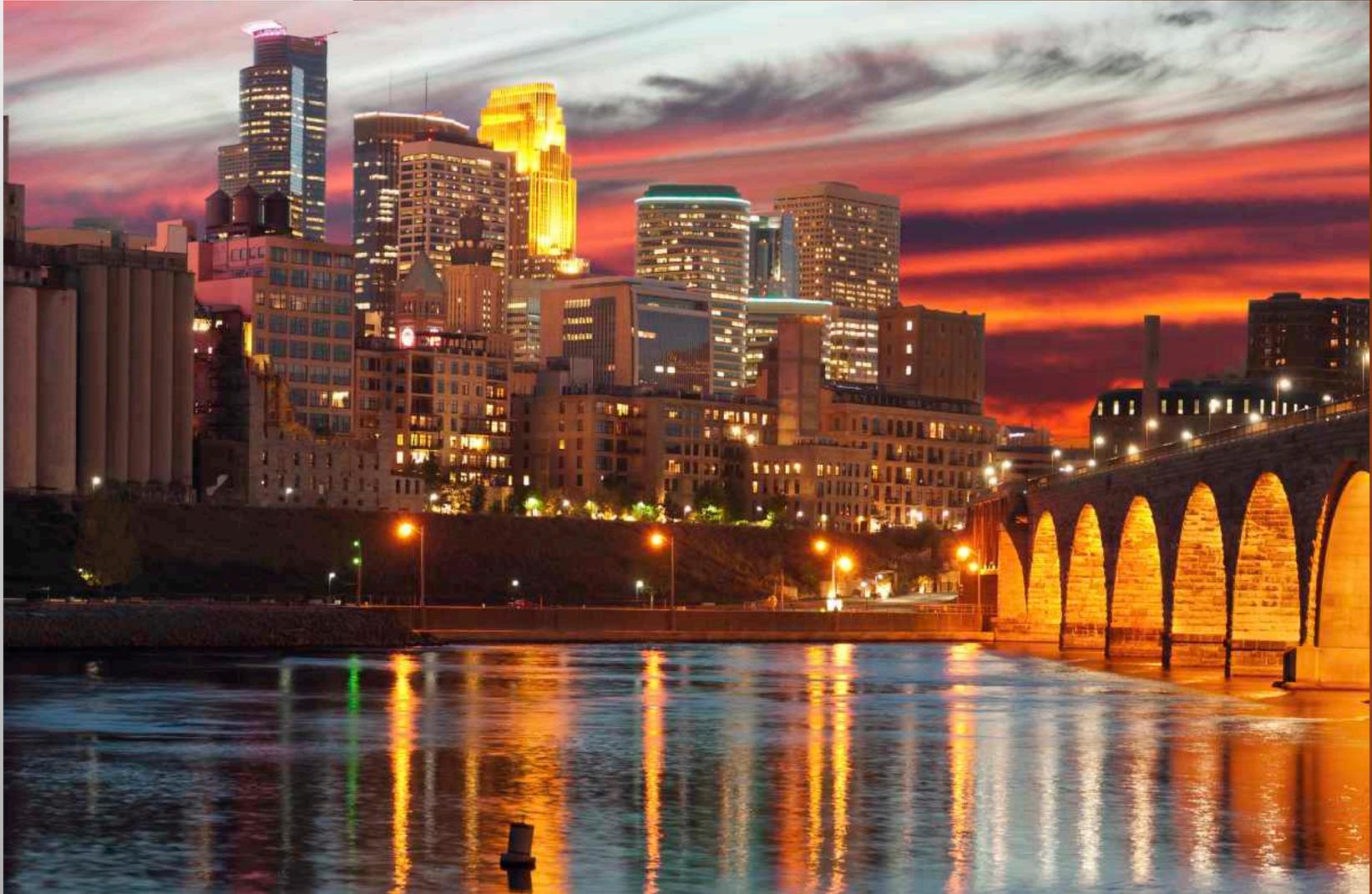


Responsibility for Concrete Construction

ACI 132







DOCUMENTS REFERENCED IN CONTRACT DOCUMENTS

- References to inappropriate external documents can lead to ambiguities that result in conflicts.
- General statements in specifications or contracts requiring compliance with codes are not appropriate unless such responsibility is delegated to a specialty subcontractor.

DOCUMENTS REFERENCED IN CONTRACT DOCUMENTS

- Specifications and Standards are unambiguous. For example, ACI 318 adopts a number of ASTM standard specifications including C94/C94M, *Standard Specification for Ready-Mixed Concrete*
- *Work on (Project Title) shall conform to all requirements of ACI 301-05 published by the American Concrete Institute, Farmington Hills, Michigan, except as modified by these Contract Documents.*
- *Not complete until the checklist is completed.*

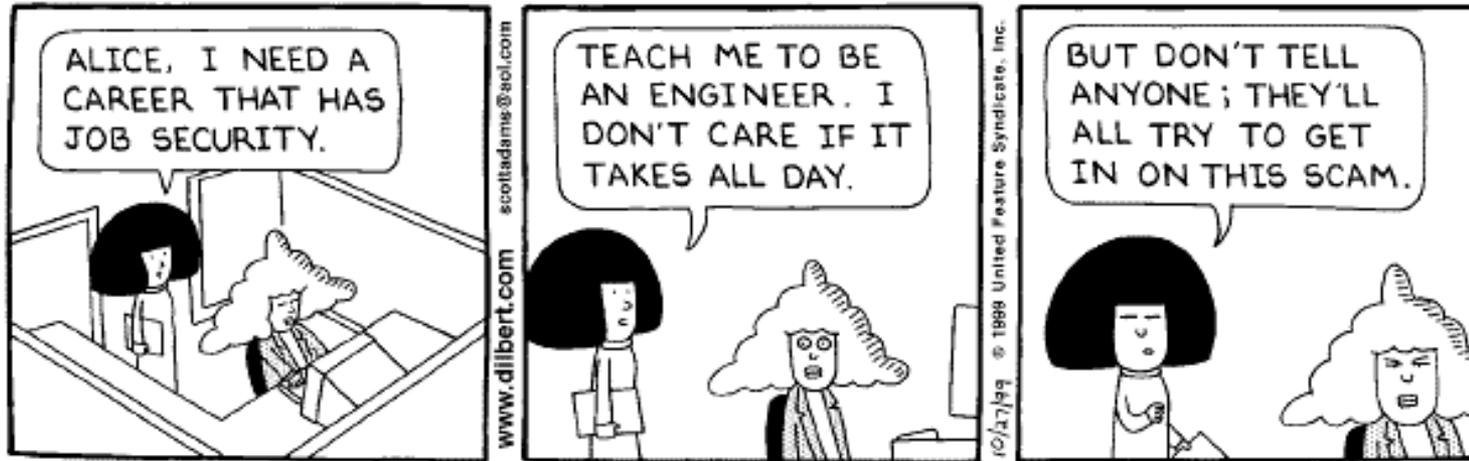
ACI Document Taxonomy

- There are reports, guides, standards, specifications and codes
- Only the last two are in Mandatory Language
- Specifications are written to the contractor and contain a checklist
- Codes are written to the designer and contain a commentary

Clear Intent of Specifications

- The specification has to be read in its entirety. If there are conflicts the need to be clarified (RFI) or the stricter condition applies.
- Ambiguity is decided against the favor of the drafter.

ACI 318 - Written to the Designer



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3.3 CAST-IN-PLACE CONCRETE

A. Mix Design

1. Mix design(s) shall be prepared by an independent testing agency in accordance with ACI 211 and ACI 318.
2. Concrete exposed to weather shall contain 5% to 7% entrained air.
3. Maximum 5" slump for slab-on-grade concrete with a water/cement ratio no greater than 0.55.
4. Submit mix designs to the Engineer at least 14 days prior to placing concrete.

B. Material

1. Portland cement shall conform to ASTM C150, Type I.
2. High early strength cement shall conform to ASTM C150, Type III.
3. Use only one brand of cement through out project.
4. Regular weight aggregate shall conform to ASTM C33. Light weight aggregate shall conform ASTM C330.

-
- CHAPTER 4 - OWNER
 - CHAPTER 5 - LICENSED DESIGN PROFESSIONAL
 - CHAPTER 6 - GENERAL CONTRACTOR
 - CHAPTER 7 - DESIGN/BUILDER
 - CHAPTER 8- SUBCONTRACTOR
 - CHAPTER 9 - SPECIALTY ENGINEERS AND SUBCONTRACTORS

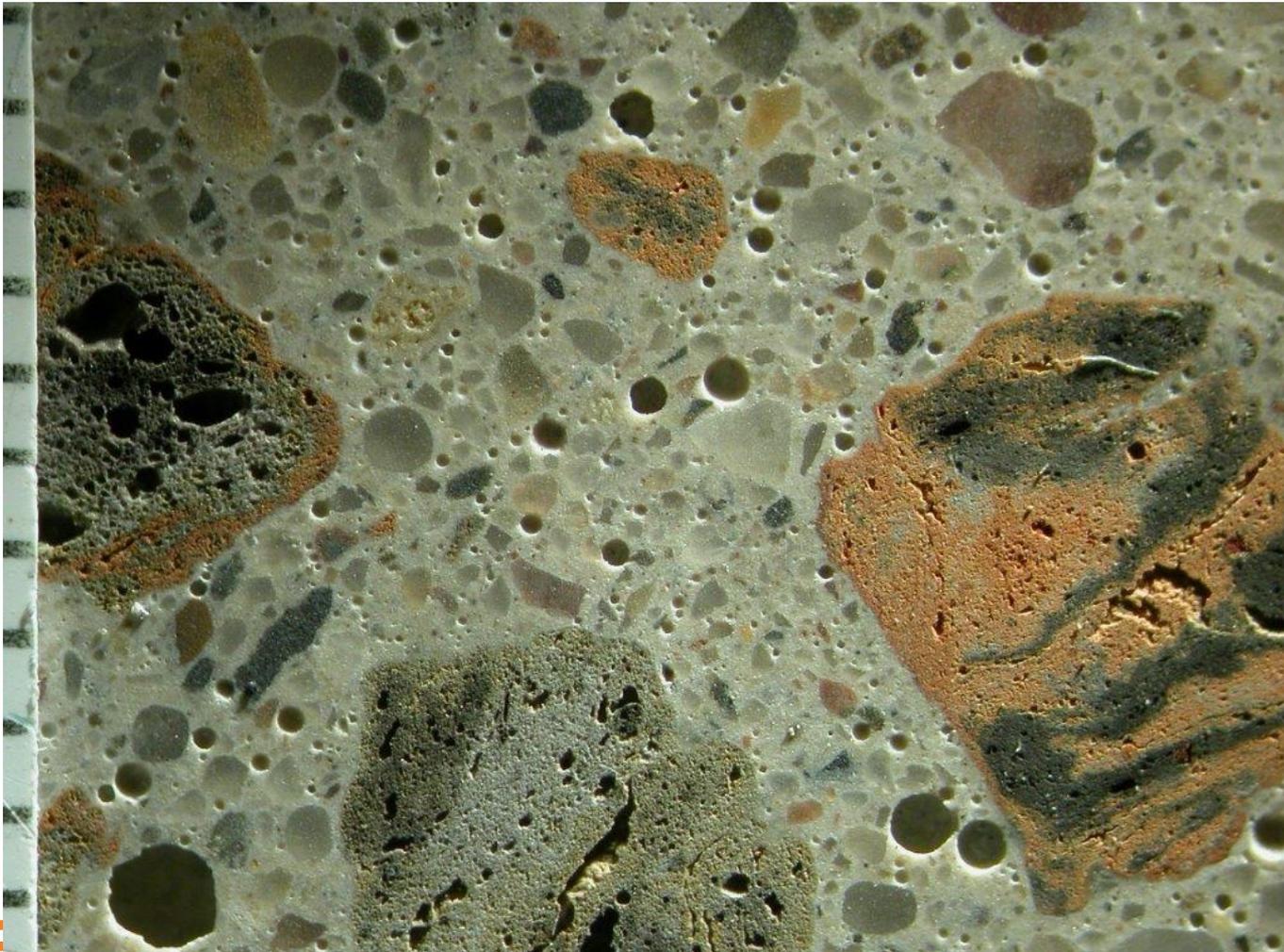
-
- CHAPTER 9 - SPECIALTY SUBCONTRACTORS/ENGINEERS
 - CHAPTER 10 - CONCRETE MATERIAL SUPPLIER
 - CHAPTER 11 - TESTING/INSPECTION AGENCY
 - CHAPTER 12 - CONSTRUCTION MANAGER
 - CHAPTER 13 - ~~FORENSIC~~ FAILURE ANALYSIS CONSULTANT
 - CHAPTER 14 - MULTIPLE-PRIME CONTRACTOR

8.5 - Prescriptive and performance specifications

- For prescriptive specifications, subcontractors shall provide concrete and construction in compliance with the Contract Documents and ensure that all requirements are assigned to the appropriate sub-subcontractor and/or Concrete Material Suppliers. Provide, for performance-based specifications, concrete and/or construction to achieve the specified performance criteria including all necessary design, if required.

-
- If a combination of prescriptive and performance criteria is specified, the Licensed Design Professional is ultimately responsible for the specification; however, the Subcontractor should communicate with the General Contractor immediately in writing if it becomes known to the Subcontractor that the combined prescriptive and performance criteria are inconsistent, incompatible, or impossible to perform.

Lightweight Slabs





The Current System for Concrete Specification

- 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 everthing is great.





Problem - two masters

- The mixture designer can have a conflict between prescription and performance

Failures

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

Bryant Mather

Spearin Doctrine

- 1918 Supreme Court Decision
- 5.9—Owner's requirements
- The licensed design professional should endeavor to fully understand the owner's requirements and incorporate them into the plans and specifications.

SUPERIOR



Cortesía de D. Salcedo

So what should the designer be responsible for?

Performance

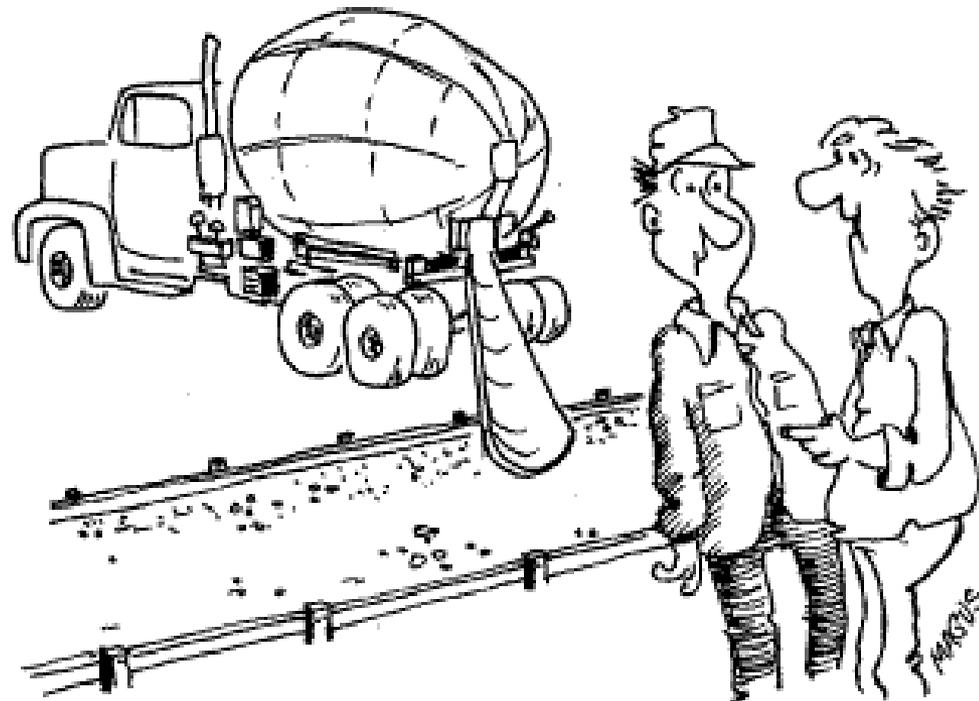
- the designer has control - if her design does not work, that is where the fault lies.
- Unless - the construction team failed to follow the instructions



ASTM C94

- Specification for Ready Mix Concrete
- 3 options
- Option A- Purchaser requires the manufacturer to select proportions based on strength determined on samples taken from discharge vehicles
- Option B-The purchaser specifies the proportions
- Option C- The purchaser specifies the proportions with a minimum cement content

Mixture Adjustment



HOW DO I KNOW IF IT'S FRESH... AND NOT BEEN SITTING AROUND IN YOUR TRUCK...?



Concrete Material Supplier

- The concrete material supplier has a responsibility to develop concrete mixtures to comply with project specifications and the following.
- **10.1.2**—Develop or establish concrete mixtures to comply with project specifications and placement requirements of the applicable general contractor, subcontractor, and specialty subcontractor by trial or production batch evaluation

Concrete Material Supplier

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- 10.1.2—Develop or establish concrete mixtures to comply with project specifications and **placement requirements** of the applicable general contractor, subcontractor, and specialty subcontractor by trial or production batch evaluation

-
- When the concrete material supplier's contract contains only prescriptive requirements for the concrete mixture composition, the concrete material supplier has a responsibility to develop mixtures in accordance with the standard of care for a concrete material supplier, but is not responsible for performance characteristics intended or resulting from the prescriptive requirements

-
- 10.1.4—When the concrete material supplier's contract assigns performance criteria to the concrete mixture, these criteria need to be clearly defined. It is the responsibility of the concrete material supplier to demonstrate compliance with the criteria set forth in the concrete material supplier's contract. In such cases, the concrete material supplier should have the right to retain confidentiality of the mixture composition

Proportion or Design ?

○ 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:

Unwritten Owner Requirements

- Shrinkage
- Curling
- Cracking
- Appearance
- Longevity

Constructor Requirements

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

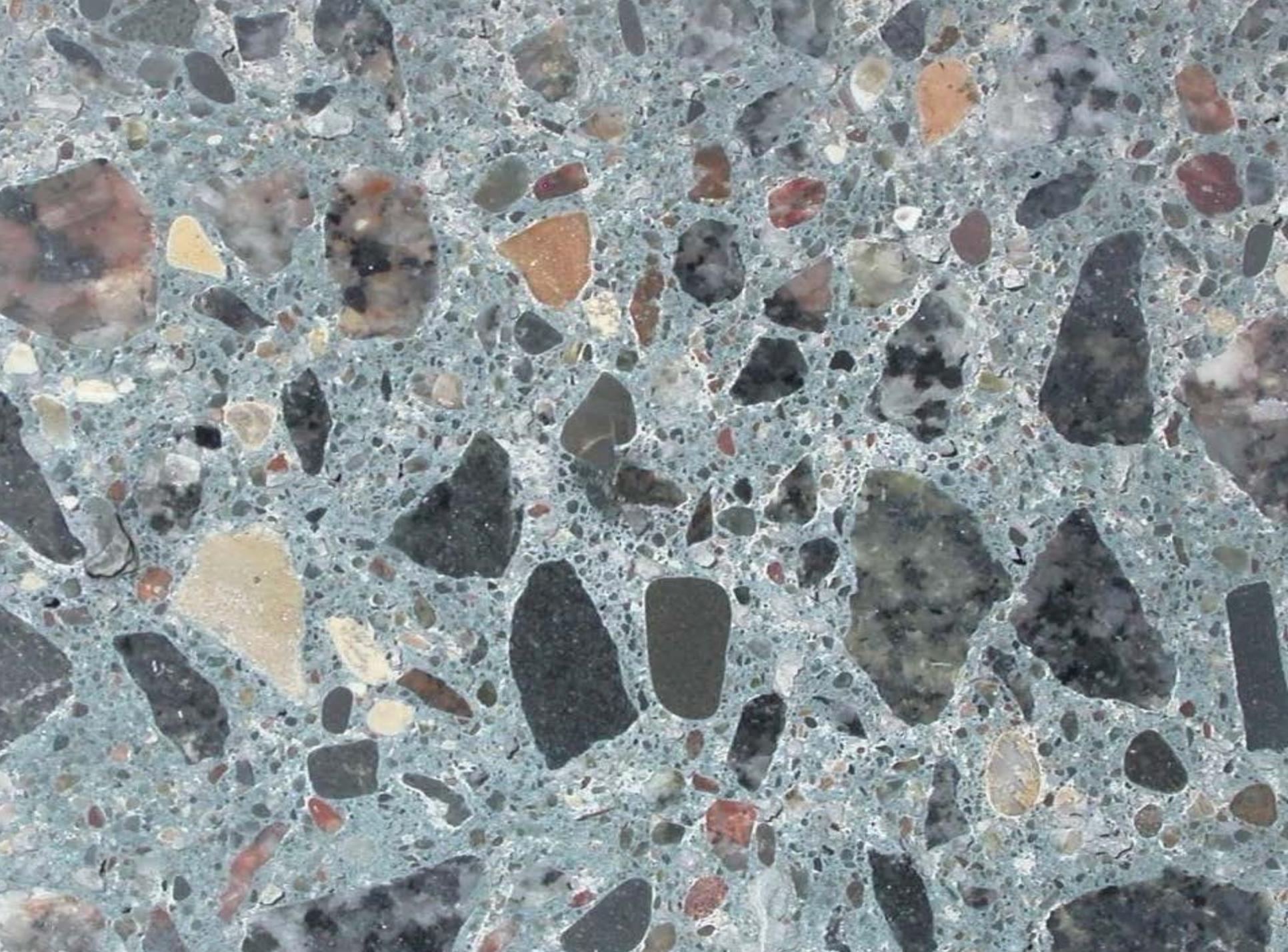


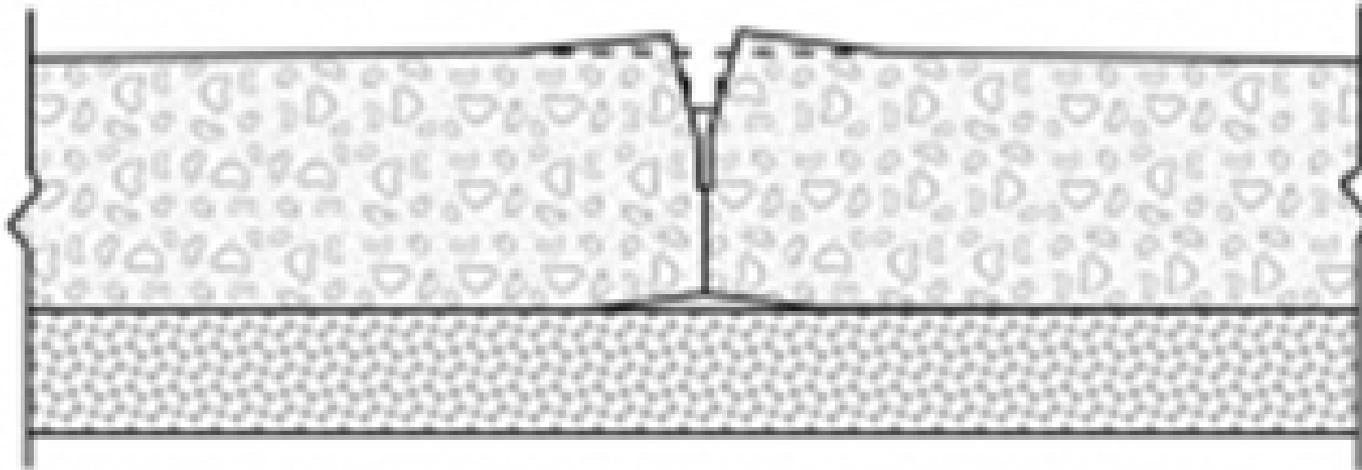
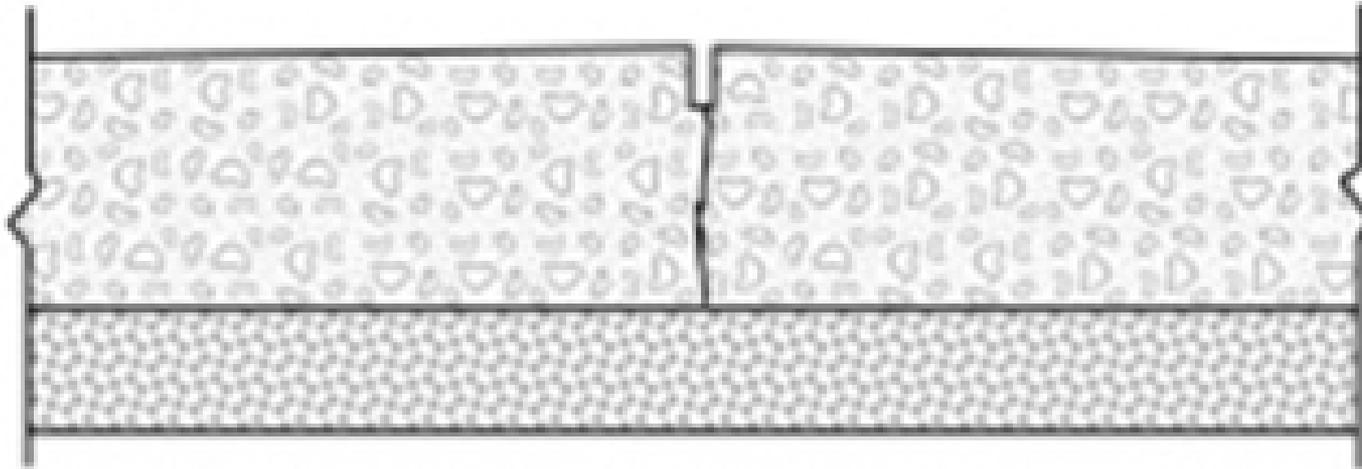


**"Here's what I want: Your concrete should pour like Niagara
and have the strength of Gibraltar."**

Polishing Concrete









The Common Alternative

The “common” alternative has become a much less viable option, due to the lack of clarity in defining the roles and responsibilities for specifying the various mix design parameters and for assuming responsibility for the concrete mix proportions.

What Type of Specification do we have?

- Prescriptive
- Performance
- Common - Both (or Neither)

Prescriptive

The concrete supplier is responsible for

- supplying concrete in accordance with the prescribed requirements
- conducting appropriate and sufficient quality control to demonstrate and document compliance.

Prescriptive

The use of the prescriptive approach transfers responsibility for the prescribed materials and processes from the contractor and supplier to the owner and design authority. The owner is therefore responsible for ensuring that the prescribed materials and processes will meet the performance requirements.

Performance Based Specifications

The designer is responsible for

- ◉ establishing the performance criteria, usually in consultation with the owner;
- ◉ preparing the technical specification that states the performance criteria in appropriate terms; and
- ◉ under the direction of the owner, conducting quality assurance and reviewing quality assurance reports, or both, to ascertain on the owner's behalf that the performance criteria have been met.

Performance

The concrete supplier is responsible for procuring materials and producing concrete that will, in its plastic and hardened states, meet the performance requirements. This includes responsibility for implementing a quality control program to demonstrate and document that the product as delivered is of appropriate quality and will meet the performance requirements..

Performance

Since in a typical construction project the custody of the concrete transfers from the supplier to the contractor while in its plastic state, a high degree of coordination is required between supplier and contractor to ensure that the final product meets the performance criteria and that the quality control processes are compatible and demonstrate compliance.



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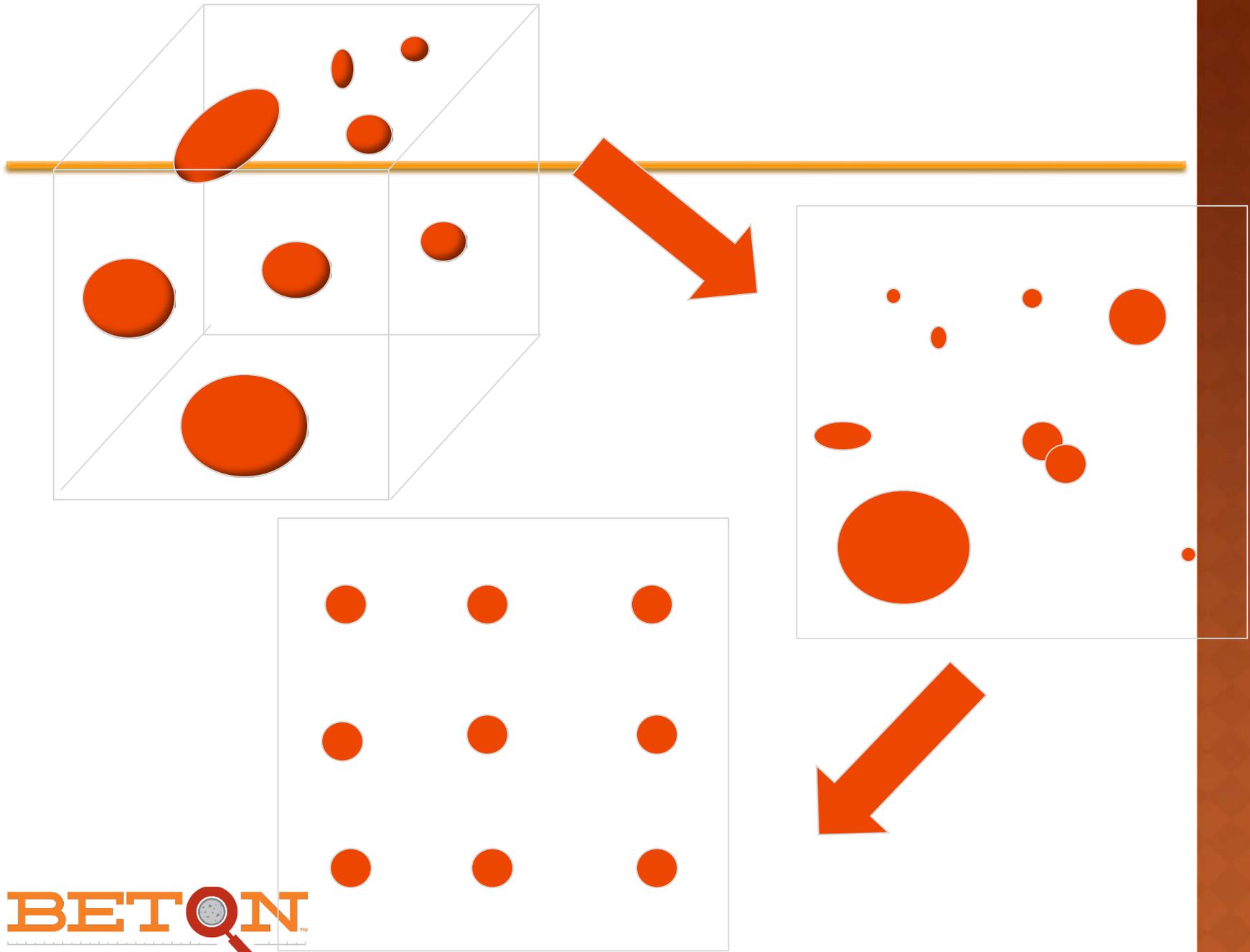
2

Testing / Inspection Agency

-
- 11.2—Qualifications
 - Comply with applicable qualification and licensing requirements. At a minimum, agencies performing acceptance tests on concrete should comply with ASTM C1077 and agencies performing acceptance inspections of concrete should comply with ASTM E329. Where applicable certifications exist the inspectors or technicians should be so certified.

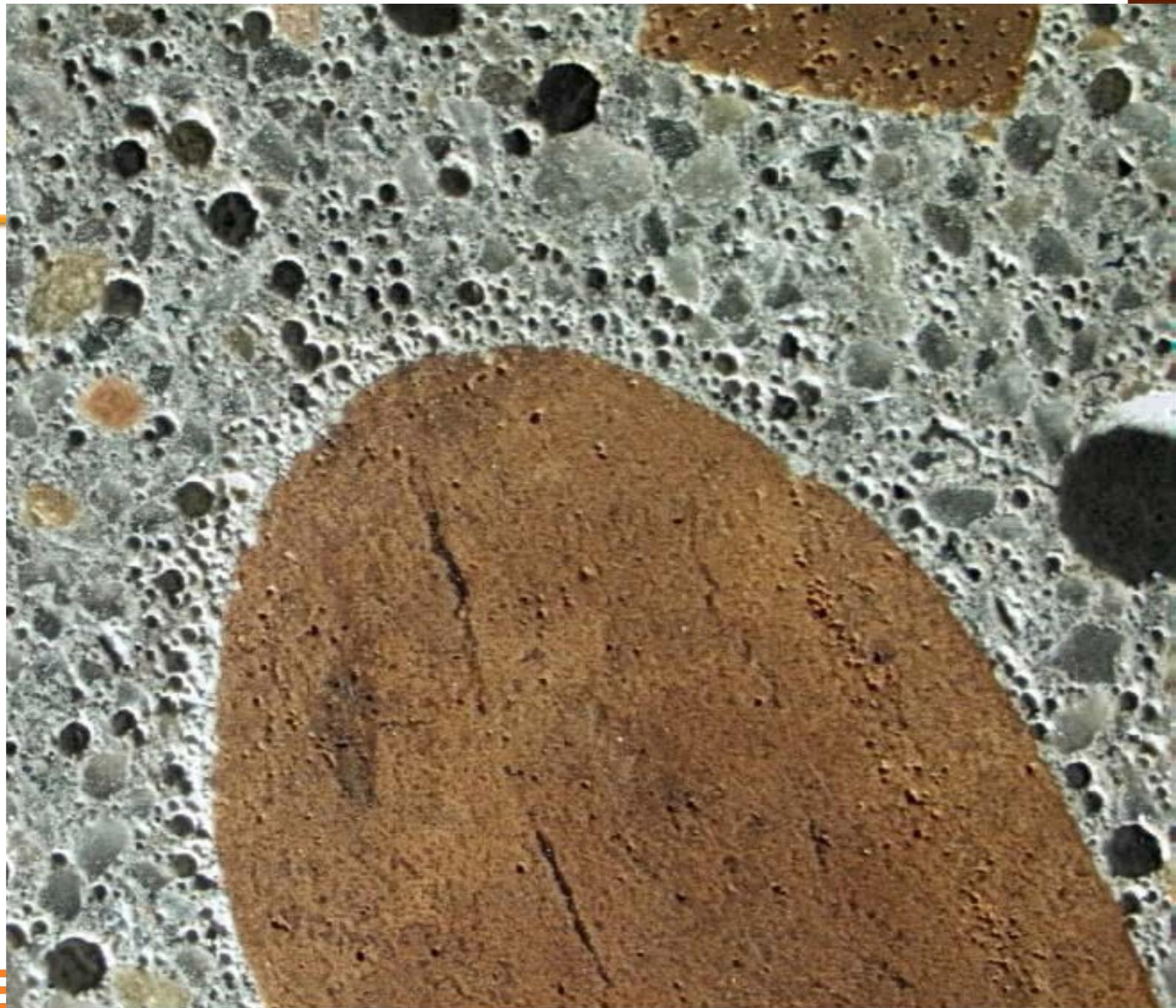
Recent ASTM Actions on C39



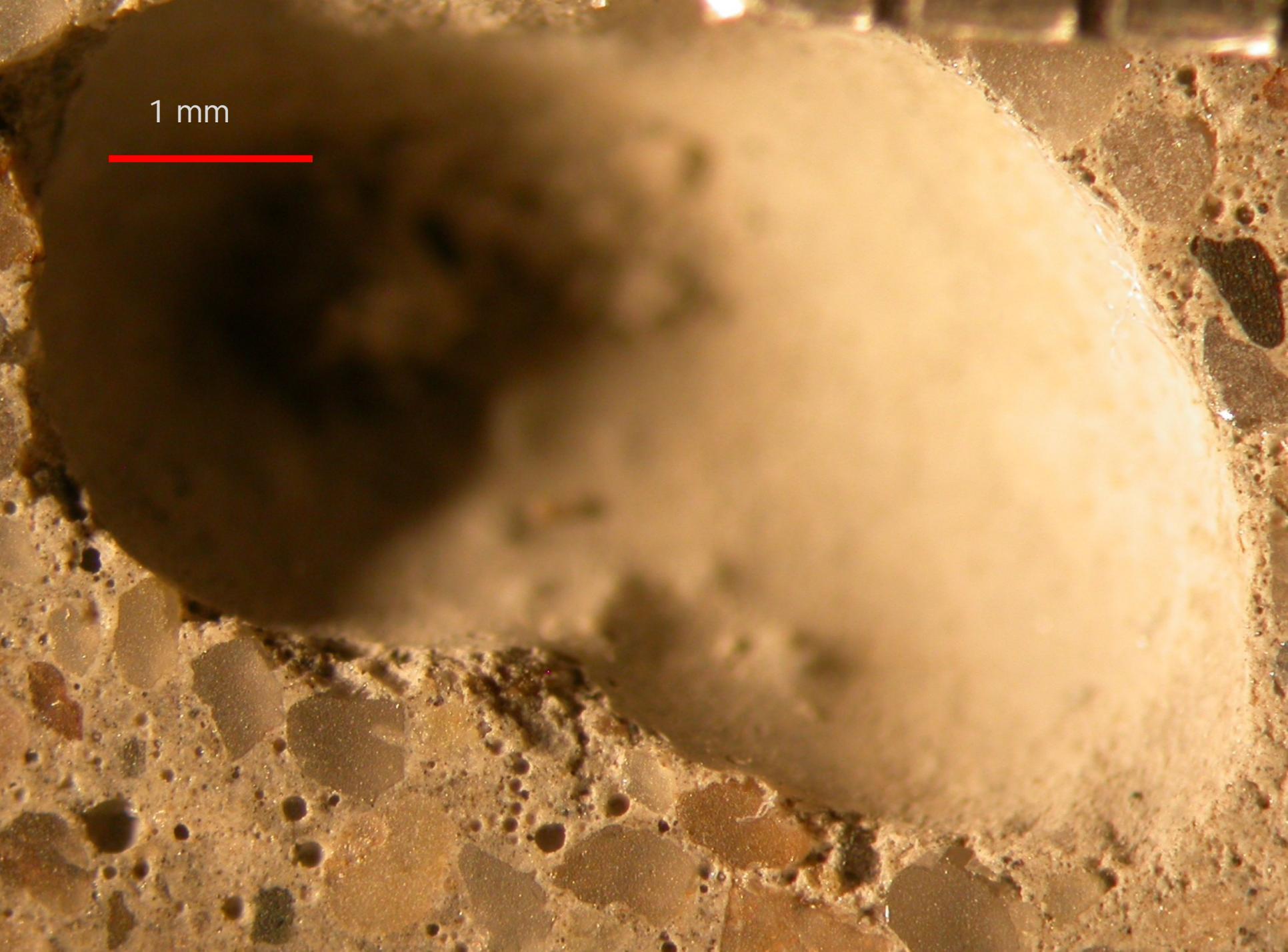


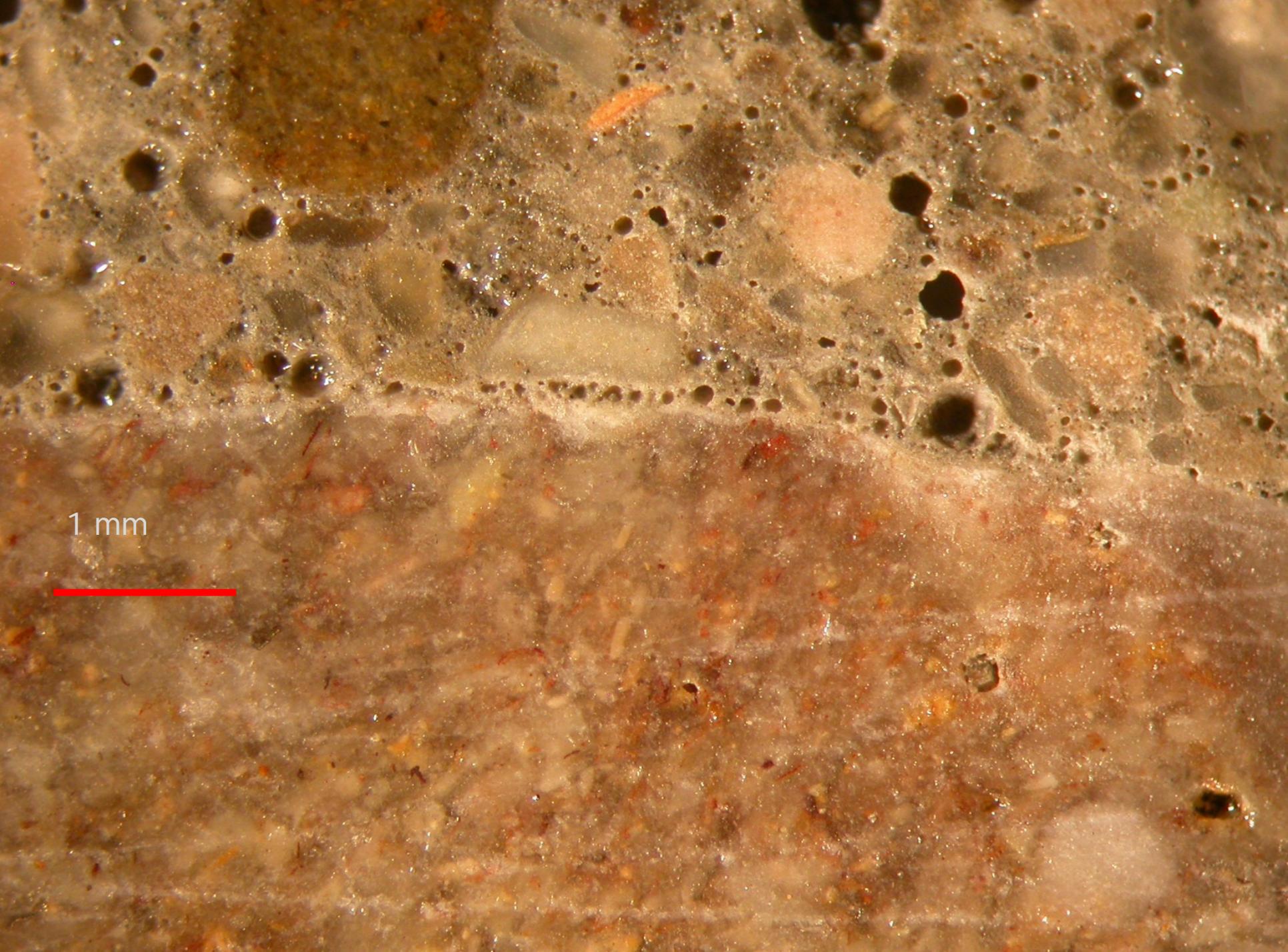
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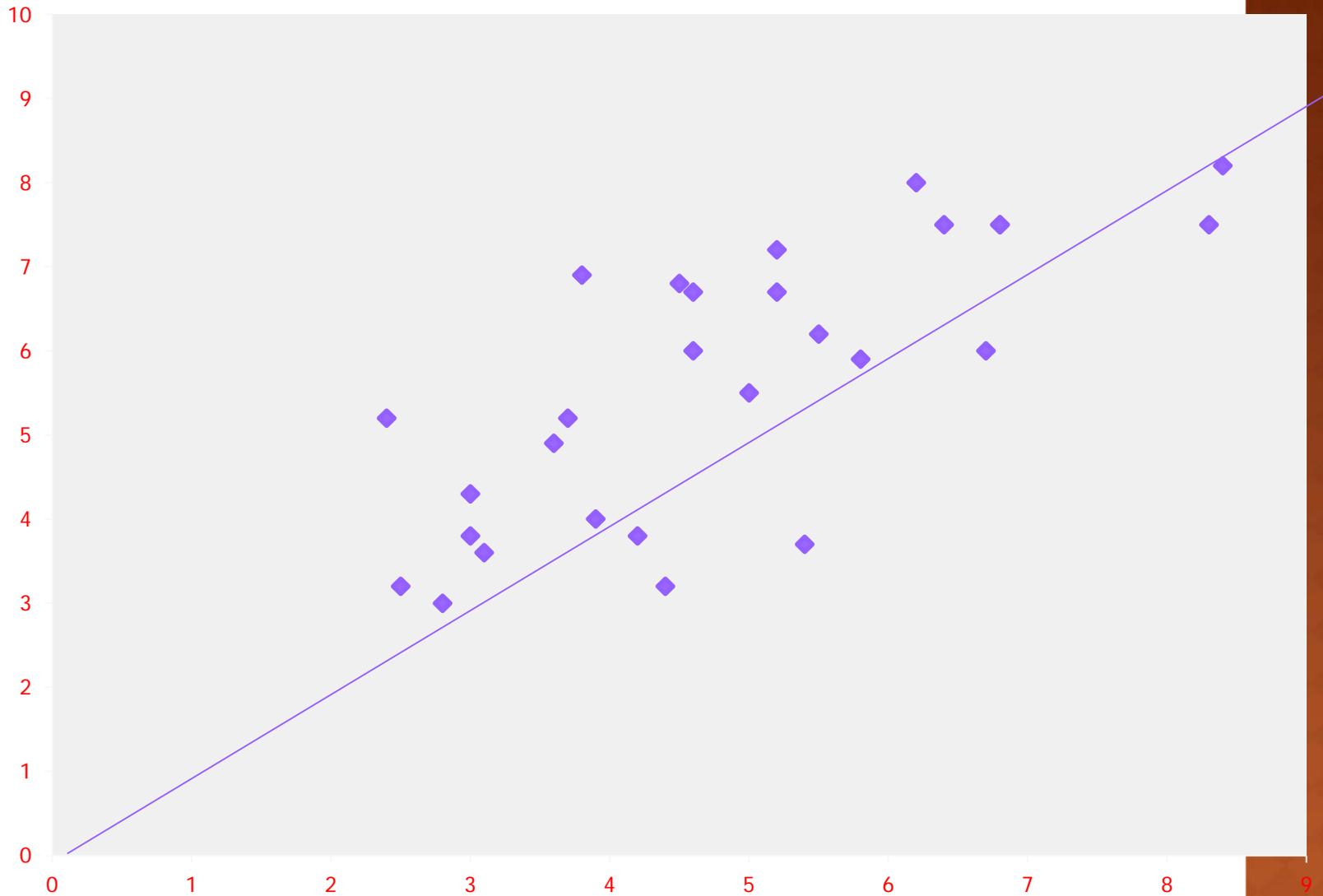
1 mm





1 mm

Air Content, percent, C457 Linear Traverse

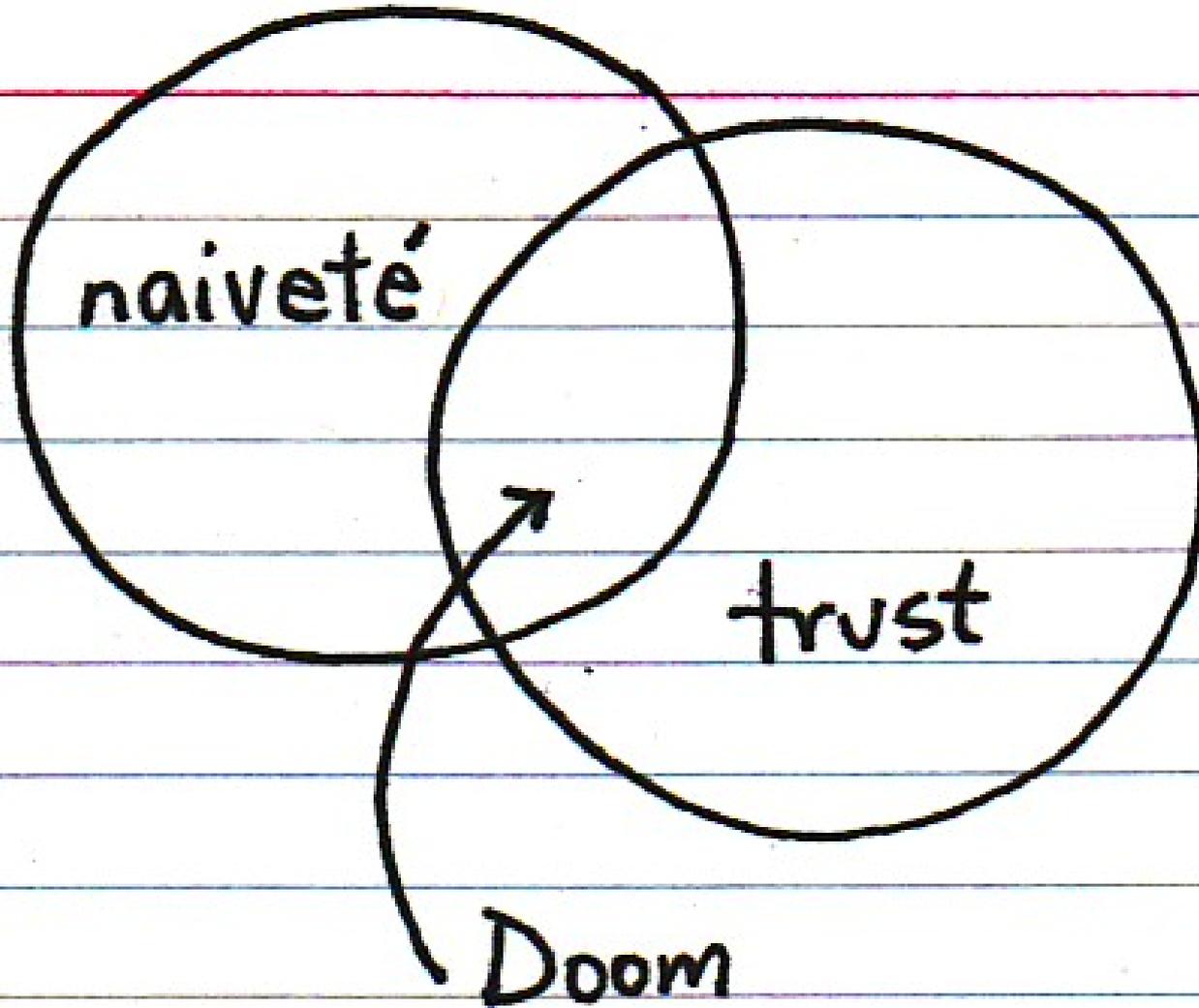


Air Content, percent Pressure Meter

Where to measure the air?

- Plant? Truck Discharge? Pump Discharge? In the Forms? In the Hardened concrete





Strength Issues

- IBC 1905.6.2.4 A test is the average of two cylinders

IBC 1905.6.3.3

- Strength is an average of three sets of two cylinders
- No individual set more than 500 psi low

Curing Conditions are important for samples as well



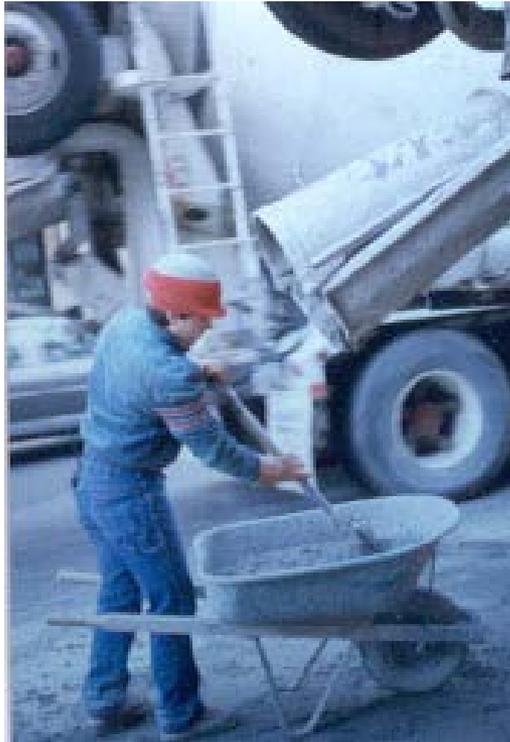
Strength Considerations

- ◉ Individual sets will fail 1 in 10
- ◉ Standards of control
- ◉ Average of three tests - 1 result in 100 fails
- ◉ If only one cylinder - not a test

IMPORTANT WARNING

- A statistical analysis assumes random sampling - I.e that any portion of the concrete has an equally likely probability of being tested - obviously wrong or different samples are invalid

Sampling



Sample should be representative – a composite sample is what is called for – if sampling the end of the truck the mixer should be turned for 5 minutes

Casting Problems



Insufficient
Consolidation

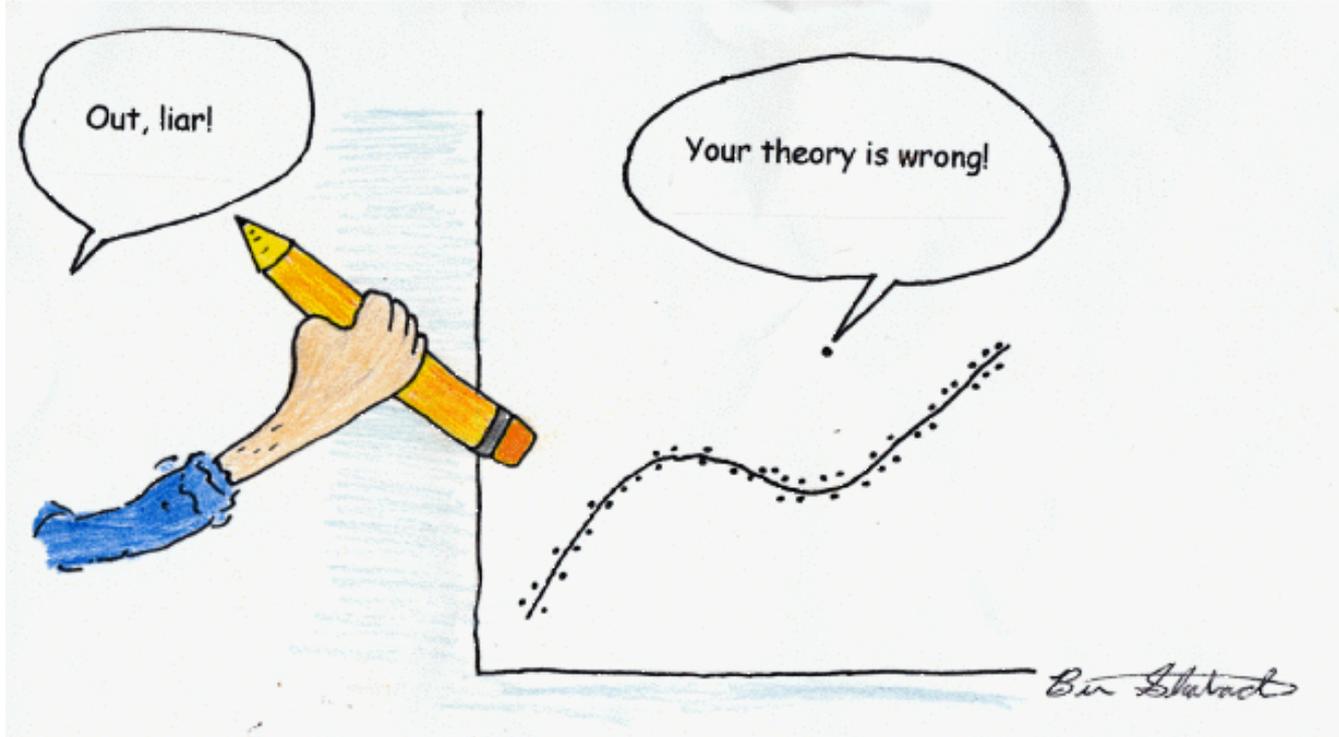
Up to 61 percent
strength loss

Rough ends before
capping

Up to 27 percent
loss

Reuse of cylinder
molds

Up to 22 percent



Curing Problems

Seven days in the field, warm temperature

Up to 18 percent

Immediate Freezing for 24 hours

Up to 56 percent



Capping Problems



Convex Ends	75 percent
Rubber Cap, no restraint	53 percent
Weak, soft capping compound	43 percent
Concave ends	30 percent
Rough ends, air gaps under cap	27 percent
Eccentric loading	12 percent



Form of Break is important
lab quality control tool



Common Sense
is still required





N.

Slump Limits: All concrete shall have a maximum slump of 4 inches, except concrete containing HRWR admixture (super plasticizer): Not more than 8" after addition of HRWR to site verified 2"-3" slump concrete.

- Can't the slumps be as required and proportioned?
- 4" maximum slump is too restrictive.
- Most HRWR are not site added.
- Why is there an 8" maximum if testing confirms the mix performs properly?
- Who know what workability is required best?

Consistency and Workability

- **consistency**-the relative mobility or ability of freshly mixed concrete or mortar to flow; the usual measurements are slump for concrete, flow for mortar or grout, and penetration resistance for neat cement paste.
- **workability**-that property of freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mixed, placed, consolidated, and finished.







Flow Test not Slump

No mortar
—
aggregate
separation

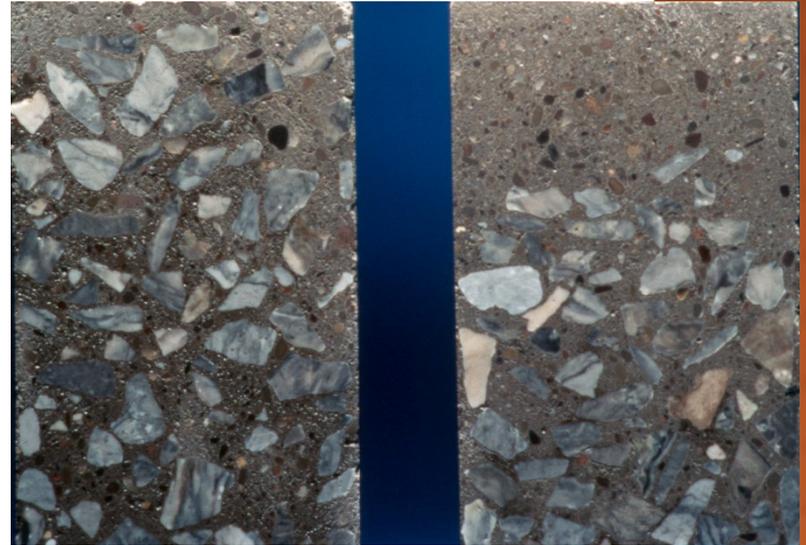


SEGREGATION

- ◉ cement chemistry
- ◉ insufficiently mixed
- ◉ admixture overdosing
- ◉ aggregate gradation gaps
- ◉ aggregate moisture content

**viscosity modifier can
overcome**

most segregation problems . .

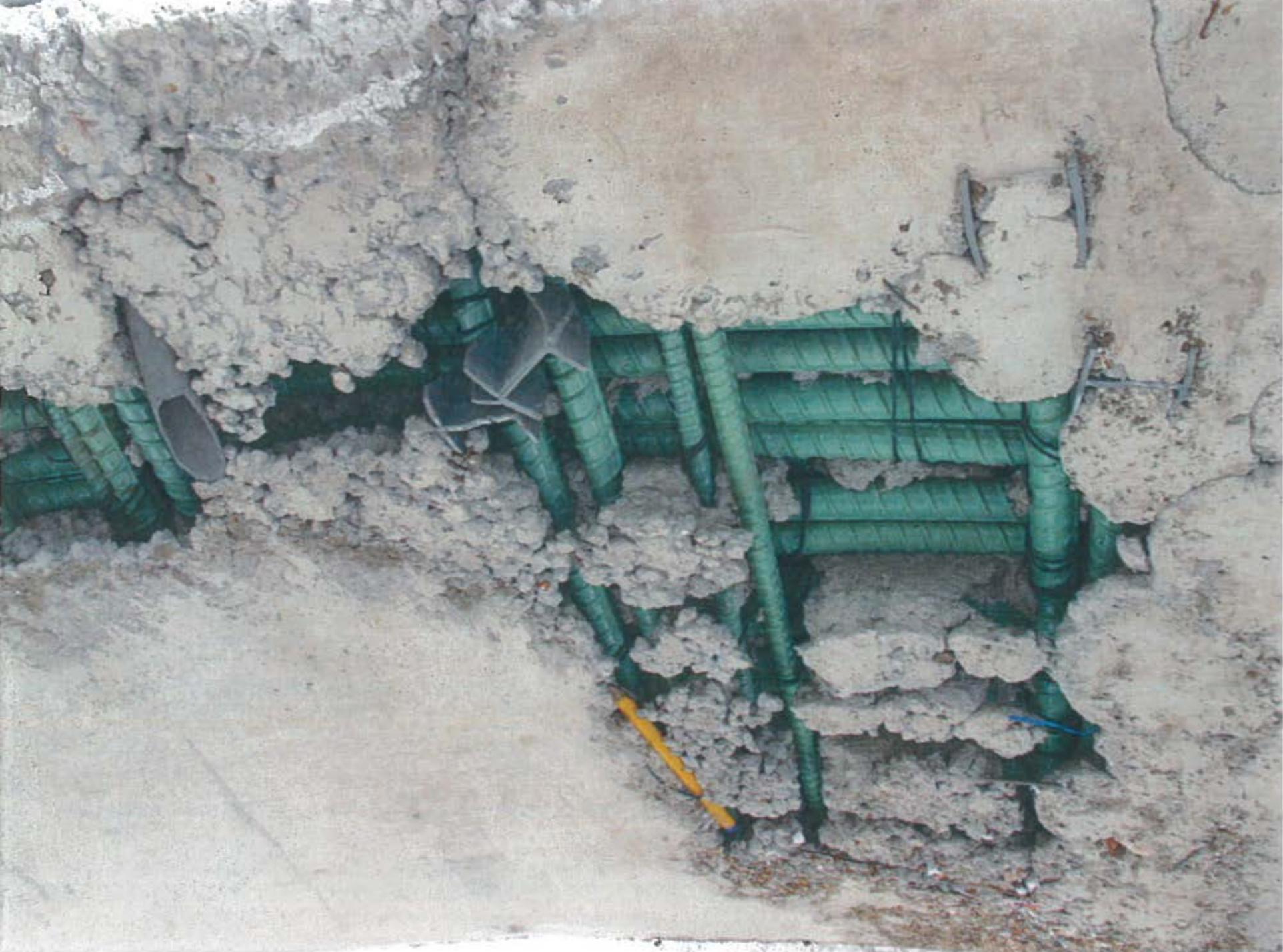




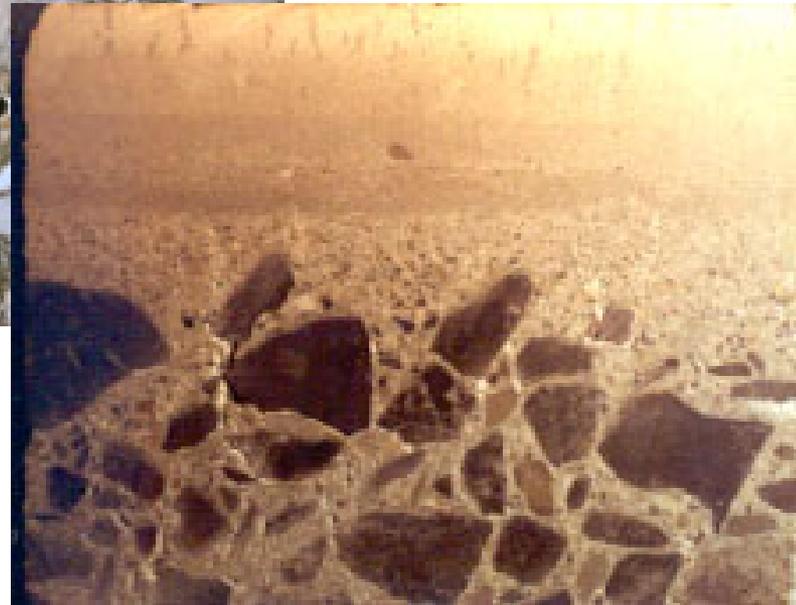
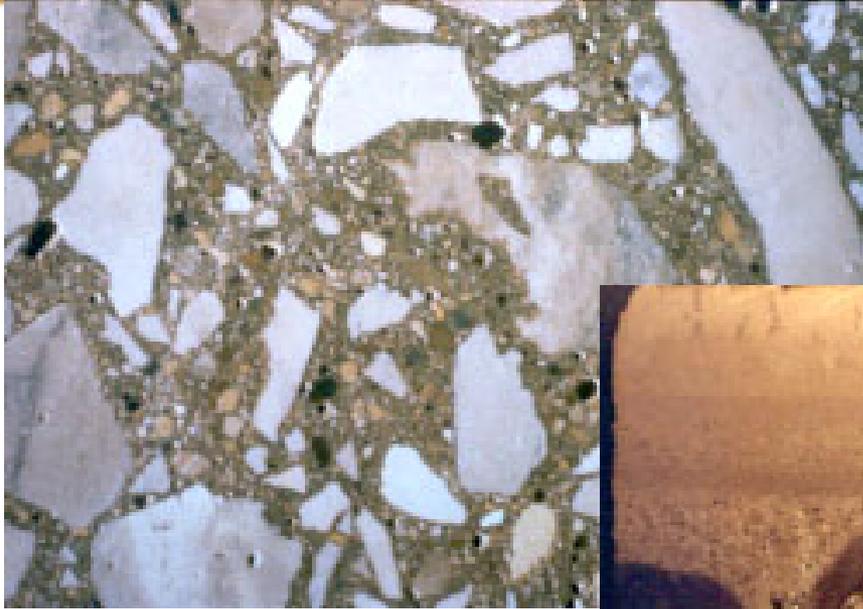








Concrete

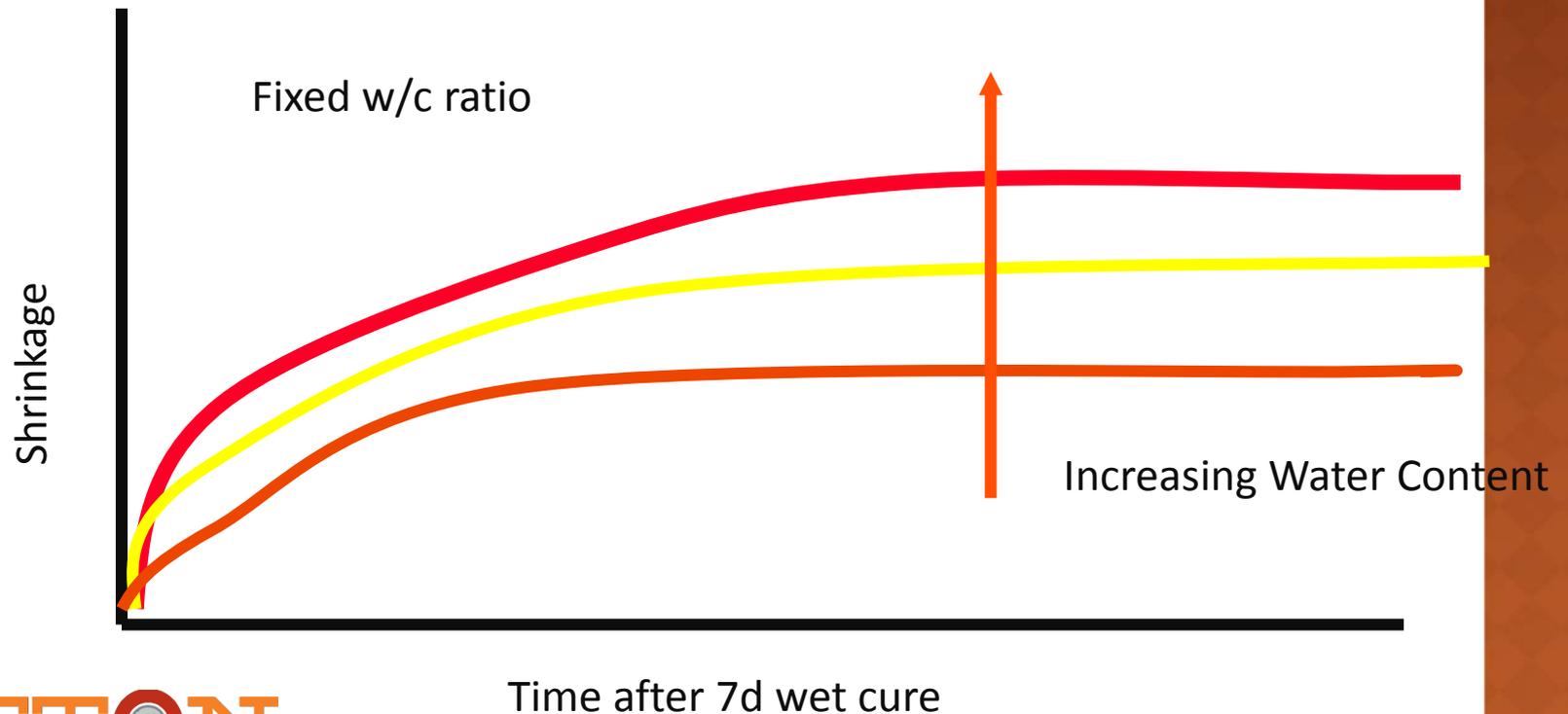


Problems and Pitfalls

- Lack of connection between strength and w/c ratio
- 3500 psi, 0.40 w/c ratio
- Which one do you want?

Problems and Pitfalls

- w/c ratio and shrinkage are not connected



Problems and Pitfalls

- ◉ 800 lb cement and 320 lb of water
- ◉ 600 lb cement and 240 lb of water

- ◉ Same w/c ratio

- ◉ Latter has much less shrinkage than the former
- ◉ Strength is the same or similar
- ◉ Permeability higher in the former



Friction

- Head loss

$$h_f = f_f \frac{L}{R_h} \frac{v^2}{2g}$$



Finishing Problems

- Use of “Sack” Mixes and Low water : Cement ratio leads to unclosable surfaces
- Relief may be needed to get the structure in place as required by the contract
- Addition of flyash or pozzolans can improve workability and reduce “rubberiness” of some low water - high flow concrete.



So what should the designer be responsible for?

Performance

- the designer has control - if her design does not work, that is where the fault lies.
- Unless - the construction team failed to follow the instructions

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Specialty Engineer / Contractor

- Concrete elements for which the design might be delegated to a specialty engineer include, but are not limited to:
- Precast/prestressed structural framing systems
- Post-tensioning systems for cast-in-place structural framing
- Precast architectural cladding
- Tilt-up concrete wall panels

Failure Analysis

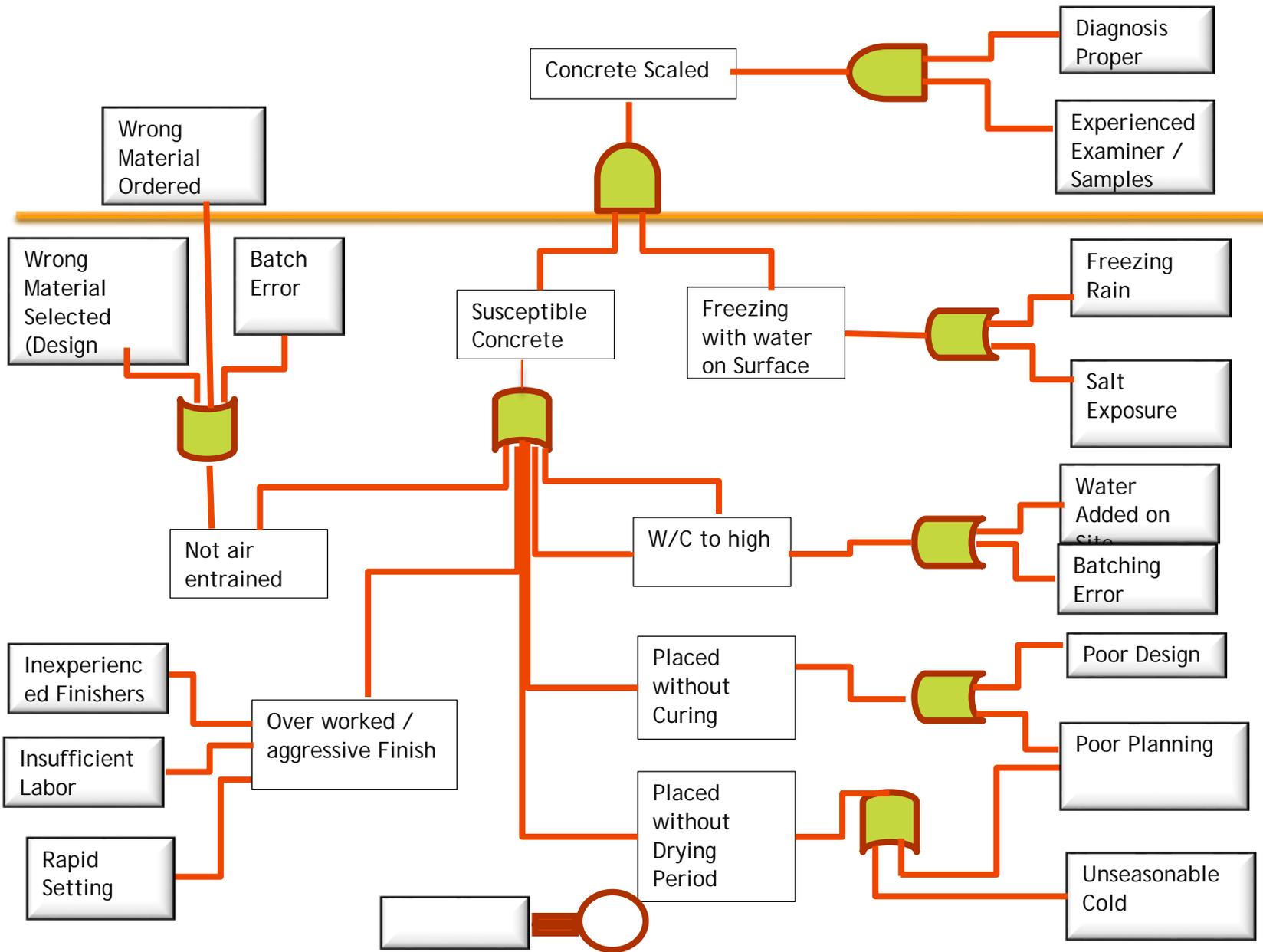
- 13.1 Independence
- The failure analysis consultant acts objectively and independently of the client to ensure that the data, report, or both, are not biased. Failure analysis consultants are not advocates and should endeavor to avoid conflict of interests as required by their profession.

Failure Analysis

- 13.4—Reliability
- The failure analysis consultant ensures that the techniques used during an investigation are reliable and generally accepted by the relevant scientific, engineering, or construction community.

Failure Analysis

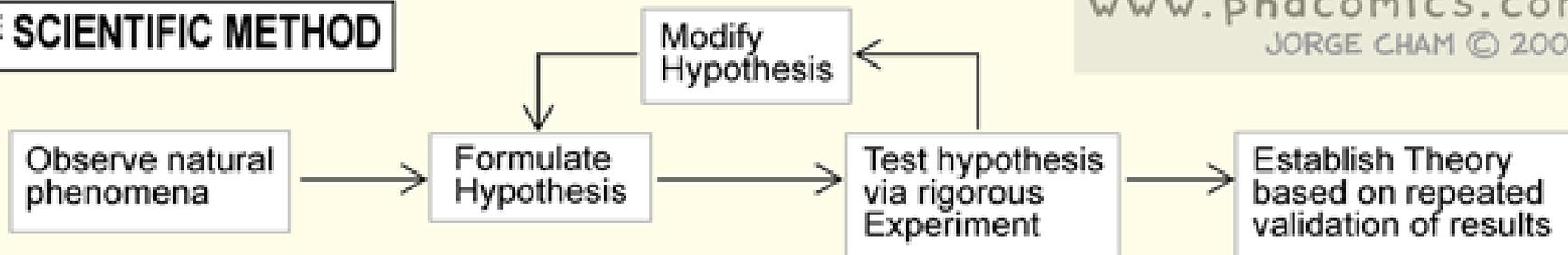
- 13.5—Standards
- The failure analysis consultant considers all relevant standards and codes during the investigation and collects all relevant information and data to minimize assumptions. They also evaluate all plausible explanations of causes and effects and develop objective and unbiased opinions based on the available evidence.



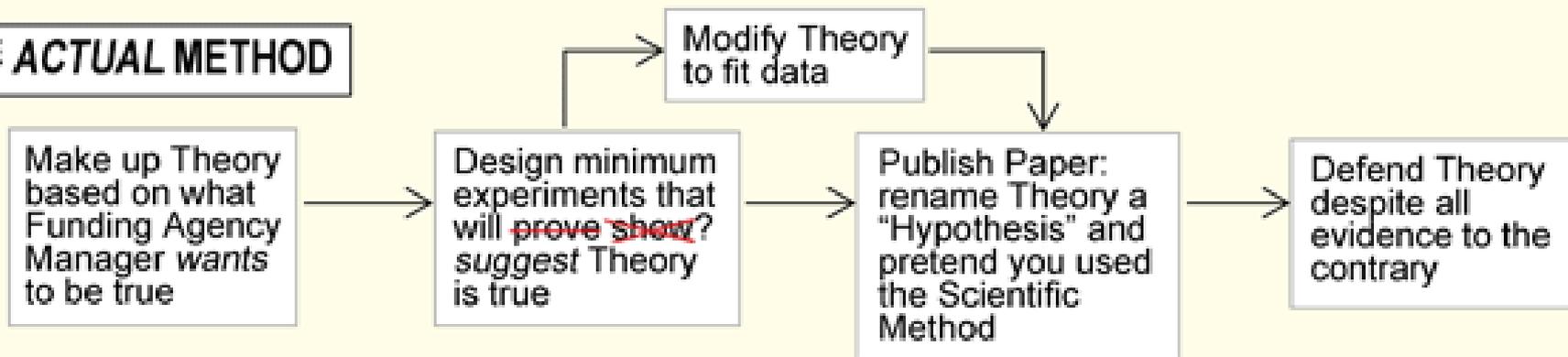
Which Analysis Method do you Prefer?

THE SCIENTIFIC METHOD

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JORGE CHAM © 2006



THE ACTUAL METHOD





Discoloration



Discoloration



Questions?

- ◉ Thanks for the time and attention