# Performance-based Specifications – Eliminating Prescriptive Requirements is an Easy First Step

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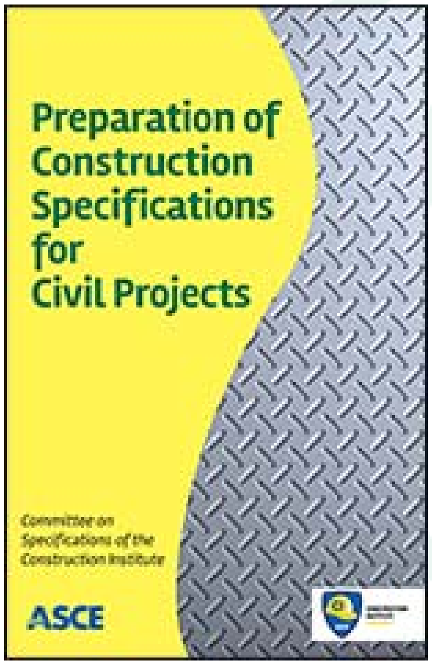
NRMCA

# Prescription vs. Performance



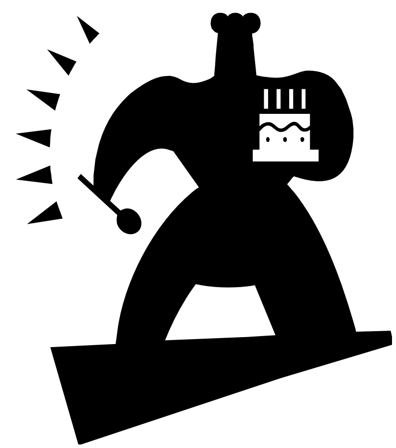

- Prescription Specification
  - Recipe for completing project
  - End result intended… not precisely defined
  - Contractor cannot be faulted if result is not achieved!
- Performance Specification
  - Describes end result desired … not how…
  - Must be clearly defined…
  - Contractor can develop methods to achieve result…
  - Needs straightforward testing and inspection…

# Definition

What do we mean by performance?

- Performance of a concrete mixture is measured by standard test methods with defined acceptance criteria stated in the contract documents and with no restrictions on the parameters of concrete mixture proportions

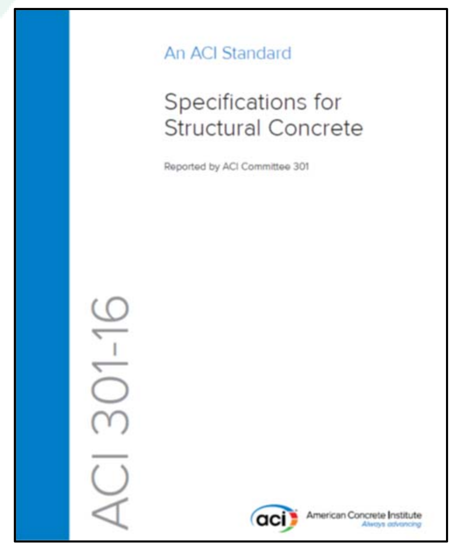
- Responsibility with assigned authority
  - Each party is responsible for own work



# How are Specifications Developed?

Structural Engineers

- Office Master
  - AIA MasterSpec
  - CSI Speclink
  - General reference to ACI 301
  - Add on provisions




State Agencies

- Each state has own spec / format

# Prescription – Why is it a problem?

Because it :

- Causes specification conflicts
- Restricts Innovation
- Prevents optimizing for performance
- Stifles competition
- Disincentivizes Quality Management
- Lack of ownership
- Inappropriate responsibility
- It may not achieve what is intended

# Industry Survey –
## Onerous Prescriptive Requirements?

- How often are these seen?
- Does it restrict optimizing mixtures?
- Does it impact cost?
- Does it improve performance?
  - For the type of application

# Rating of Prescriptive Requirements

| **Prescriptive Requirements** | **Avg. Rating** |
|---|---|
| Invoking maximum w/cm when not applicable | **1.6** |
| Invoking a minimum content for cementitious materials | **1.9** |
| Restriction on quantity of supplementary cementitious material (SCM) | **2.0** |
| Restrictions on characteristics of aggregates - grading etc. | **2.1** |
| Restriction on type and characteristics of SCM | **2.3** |
| Restriction on modifying approved mixtures | **2.6** |
| Restriction on type and source of aggregates | **2.8** |
| Requirement to use potable water | **2.8** |
| Restricting the use of a test record for submittals | **2.9** |
| Restriction on alkali content for cement | **3.3** |
| Prescriptive requirements for sustainability | **3.3** |
| Restrictions on type and source of cement | **3.4** |
| Restriction on use of recycled aggregates and mineral fillers | **3.5** |
| Restriction on type or brands of admixtures | **3.8** |
| Prohibiting cement conforming to ASTM C1157 and ASTM C595 | **4.3** |

# Review of Specifications

- Requested from concrete
- Reviewed 102 specifications
  - 39% commercial buildings
  - 23% educational / public buildings
  - 18% public works
  - 14% environmental structures
  - 13% floors

# Examples

2.1.2 Water-Cement Ratio

Maximum water-cement ratio (w/c) for concrete shall be 0.40 by weight, for all work.

segregation or bleeding. The cementitious materials content of concrete shall be at least 675 pounds per cubic yard. Except that concrete to be placed by tremie the cementitious materials content shall be at least 725 pounds per cubic yard.

Shrinkage Limits of Mixture Designs. Drying shrinkage of concrete for mixture design trial batches at 21 days of age shall not exceed 0.04 percent based on the averaged results from three or more specimens

# Examples

**2.08 CONCRETE MIX DESIGN**

A. Proportioning Normal Weight Concrete: Comply with ACI 211.1 recommendations.
   1. Replace as much Portland cement as possible with fly ash, ground granulated blast furnace slag, silica fume, or rice hull ash as is consistent with ACI recommendations.

E. Normal Weight Concrete:
   1. Compressive Strength, when tested in accordance with ASTM C39/C39M at 28 days: 3,000 pounds per square inch.
   2. Fly Ash Content: Maximum 15 percent of cementitious materials by weight.
   3. Calcined Pozzolan Content: Maximum 10 percent of cementitious materials by weight.
   4. Silica Fume Content: Maximum 5 percent of cementitious materials by weight.
   5. Water-Cement Ratio: Maximum 40 percent by weight.
   6. Total Air Content: 4 percent, determined in accordance with ASTM C173/C173M.
   7. Maximum Slump: 3 inches.
   8. Maximum Aggregate Size: 5/8 inch.

# Examples

B. Cementitious Materials: Use fly ash, pozzolan, ground granulated blast-furnace slag, and silica fume as needed to reduce the total amount of portland cement, which would otherwise be used, by not less than 40 percent. Limit percentage, by weight, of cementitious materials other than portland cement in concrete as follows:

1. Fly Ash: 25 percent.
2. Combined Fly Ash and Pozzolan: 25 percent.
3. Ground Granulated Blast-Furnace Slag: 50 percent.
4. Combined Fly Ash or Pozzolan and Ground Granulated Blast-Furnace Slag: 50 percent portland cement minimum, with fly ash or pozzolan not exceeding 25 percent.
5. Silica Fume: 10 percent.
6. Combined Fly Ash, Pozzolans, and Silica Fume: 35 percent with fly ash or pozzolans not exceeding 25 percent and silica fume not exceeding 10 percent.
7. Combined Fly Ash or Pozzolans, Ground Granulated Blast-Furnace Slag, and Silica Fume: 50 percent with fly ash or pozzolans not exceeding 25 percent and silica fume not exceeding 10 percent.

# Examples

5. Adjust proportions of combined coarse, intermediate, and fine aggregates to provide the following particle size distribution characteristics, unless otherwise approved:
   a. Coarseness Factor of 60 to 75%.
      1) The Coarseness Factor (CF) is the percent of combined aggregate retained on the #8 sieve that is also retained on the 3/8 inch sieve.
      2) The Coarseness Factor is calculated as follows:
         CF = Aggregate retained on 3/8 inch sieve / Aggregate retained on #8 sieve.
   b. Adjusted Workability Factor
      1) The Workability Factor (WF) is the percent of combined aggregate that passes the #8 sieve.
      2) The Adjusted Workability Factor (Adj-WF) is calculated as follows:
         Adj-WF = WF+[(Cementitous Material -564 lbs)/37.6]
      3) The range of accepted Adj-WF for a given CF is as follows:
         Adj-WF = [(11.25 - .15 CF) + 36] ± 2.5
      4) Combined percent retained on any given sieve size shall not exceed 24%.

# Examples

Slab On Grade - the concrete mix design shall obtain a minimum compressive strength of 5000 psi and shall be in accordance with ACI 350-R with the following properties:

| | |
|---|---|
| Water Cement Ratio | .43 To .47 |
| Slump | 3 Inches At Truck - 6 Inches After High Range |
| Water Reducing Admix | |
| Coarse Aggregate | Max 1 1/2 Inch with 50-50 Ratio of 1 1/2 Inch |
| and 3/8 Inch | |
| Cement Content | 6 Bags Per Yard ( 560 Lb/Yd) No Fly Ash |
| Air Content | 5 To 7 Percent |

# Examples

E. Cement content: Minimum cement content shall be as follows:

| CONCRETE CLASS | CEMENT CONTENT (# OF 94 LB SACKS) |
| --- | --- |
| A | 6.75 |
| B | 6.00 |
| C | 5.00 |

F. Water-cement ratio: Concrete mixtures shall be proportioned to give adequate workability for the use intended without exceeding the following prescribed quantities of mixing water:

| CONCRETE CLASS | TOTAL WATER – U.S. GALLONS PER 94 LB. SACK OF CEMENT |
| --- | --- |
| A | 5 |
| B | 5-1/2 |
| C | 7 |

1. For Class A concrete, the quantity of mixing water shall be determined on the basis of either laboratory trial batches or field experience in accordance with ACI 318.

# Examples

c. Fly Ash: Fly Ash shall have a high fineness and low carbon content and shall exceed the requirements of ASTM-C-618, "Specification for Fly Ash and Raw or Calcined Natural for Use in Portland Cement Concretes" for Class F, except that the loss of ignition shall be less than 3% and all fly ash shall be a classified processed material. Fly ash shall be obtained from one source for the concrete delivered to the project. Complete chemical and physical analysis of the fly ash shall be submitted to the Architect prior to use. Concrete mixes proportioned with fly ash shall contain not less than 10% nor more than 20% by weight of cement to fly ash.

# Examples

| Table 03300-C: Concrete Classes | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Concrete Class[1] | Minimum Specified Compressive Strength at 28 days, f'c [2] (pounds per square inch) | Ratio of water to cementitious materials[3] (minimum – maximum). | Cementitious Materials Content (pounds per cubic yard of concrete by weight ) | Cement Type (ASTM C150, low alkali) | Maximum Coarse Aggregate Size[4] | Air Entrainment (percent) (n/a : not applicable) | Admixtures required[5] | Slump Range (Inches) |
| A | 4,500 | 0.40 to 0.45 | 535 to 658 | II | 57 | 5+1.5 | AEA WRA | 2 to 4 |
| A-NA | 4,500 | 0.40 to 0.45 | 535 to 658 | II | 57 | n/a | WRA | 2 to 4 |
| A-SP | 4.500 | 0.40 to 0.45 | 535 to 658 | II | 57 | 5+1.5 | AEA WRA HRWR | 3 to 6 |
| B | 4,500 | 0.40 to 0.45 | 535 to 658 | III | 57 | 5+1.5 | AEA WRA | 2 to 4 |
| B-NA | 4,500 | 0.40 to 0.45 | 535 to 658 | III | 57 | n/a | WRA | 3 to 6 |
| B-SP | 4,500 | 0.40 to 0.45 | 535 to 658 | III | 57 | 5+1.5 | AEA WRA HRWR | 3 to 6 |
| C | 2,500 | 0.62 max. | 423 | II | 57 | 5+1.5 | AEA WRA | 3 to 6 |
| CE | 3,000 | 0.62 max. | 480 | II | 8 | 6+1.5 | AEA WRA, CA | 3 to 6 |
| PM | 4,500 | 0.40 - 0.45 | 535 | II | 57 | 5+1.5 | AEA, WRA | 3 to 6 |

# Examples

| Concrete Location | Max Aggregate | | Strength @ 56 Days (psi) | Min Slump[1] (inches) | Min Cement Content (Sacks) | GGBFS Content | Max Water Content (gals) | Max Water/ Cement Ratio | Max Flyash Content |
|---|---|---|---|---|---|---|---|---|---|
| Mat ................ | 1-1/2" | HR | 4000 | 3-1/2 | 6.0 | 35% | 36 | 0.60 | 35% |
| Lean Concrete ...... | 3/8" | HR | 500 | 6 | 2.0 | 0% | 36 | 0.60 | 0% |
| Columns............. | 1"x#4 | HR | 6000 | 3-1/2 | 7.0 | 30% | 35 | 0.55 | 25% |
| Basement Perimeter Walls/Pilasters... | 1"x#4 | HR | 4000 | 3-1/2 | 6.0 | 30% | 35 | 0.55 | 25% |
| Walls/Pilasters[2] (Level 3-Roof).... | 1"x#4 | HR | 5000 | 3-1/2 | 6.5 | 30% | 35 | 0.55 | 25% |
| Walls/Pilasters[2] (Fdn-Level 3)..... | 1"x#4 | HR | 6000 | 4 | 6.0 | 30% | 34 | 0.45 | 25% |
| Walls/Pilasters[2,4].. | 1"x#4 | HR | 7000 | 4 | 7.0 | 30% | 36 | 0.45 | 25% |
| Walls/Pilasters[2,4].. | Pea Gravel | | 7000 | 4 | 7.5 | 30% | 36 | 0.45 | 25% |
| Suspended slab ..... | 1"x#4 | HR-LS | 4000 | 3-1/2 | 6.0 | 0% | 33 | 0.45 | 25% |
| P/T Slab[3]........... | 1"x#4 | HR-LS | 5500 | 3-1/2 | 7.0 | 0% | 33 | 0.45 | 20% |
| Balcony/ Walkway Topping.. | 3/8" | HR | 2500 | 3-1/2 | 5.0 | 0% | 35 | 0.50 | 35% |

# Examples

1. Minimum Compressive Strength (f'c): 8000 psi at 56 days..
2. Maximum Water-Cementitious Materials Ratio: 0.45.
3. SCM Replacement ratio: [**25**][**40**][**50**][**70**] percent.
4. [Max cement content = 200 pcy]
5. Maximum Aggregate Size: 1-1/2 inch.
6. Slump Limit: 5 inches, plus or minus 1 inch.
7. Shrinkage Limit: .045 percent.

# State of Prescription

| Prescription | % of specs | Industry Standards |
|---|---|---|
| Restriction on SCM quantity | 85% | Exposure F3 |
| Max w/cm (when not applicable) | 73% | ACI 318 – Durability |
| Minimum cementitious content | 46% | ACI 301 – floors |
| Restriction on SCM type, characteristics | 27% | None |
| Restriction on aggregate grading | 25% | Suggested for floors |
| **Overall average** | **51%** | |

If ACI standards are followed – these would not be an issue!

# #1 – Limits on SCM Quantity

- Impacts durability
  - ASR
  - Sulfate resistance
  - Corrosion of reinforcing steel
- Temperature control in mass concrete
- Loose benefits of later-age strength and durability

# #2 – Max w/cm (when not applicable)

- Impacts workability
- Increases cementitious content / paste volume
- When w/cm not consistent with spec. strength
  - High avg. strength – acceptance criteria do not work
  - Concrete not optimized for member as designed

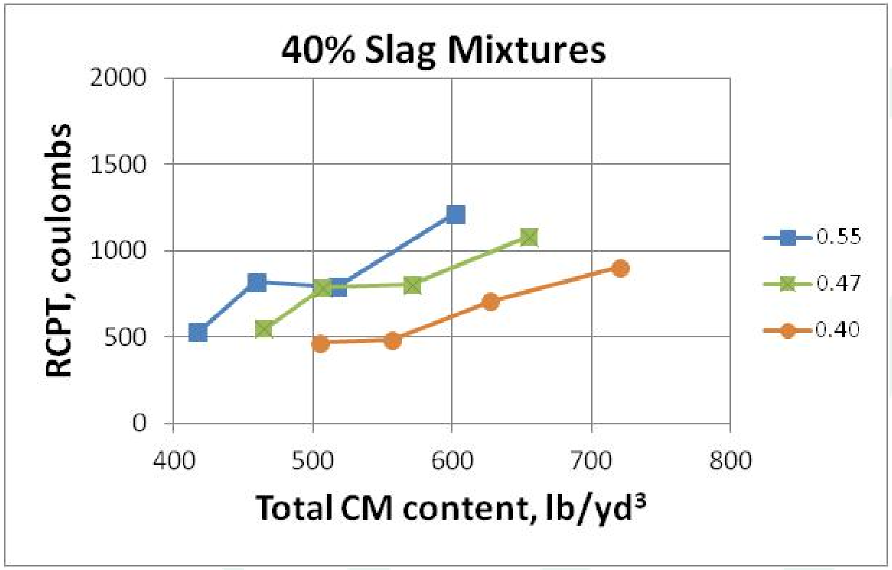
| w/cm | Non air | Air |
|---|---|---|
| 0.40 | 6900 | 6200 |
| 0.45 | 6000 | 5400 |
| 0.50 | 5200 | 4700 |
| 0.55 | 4500 | 4000 |

Source: NRMCA Survey (2014)

# #3 – Min cementitious content

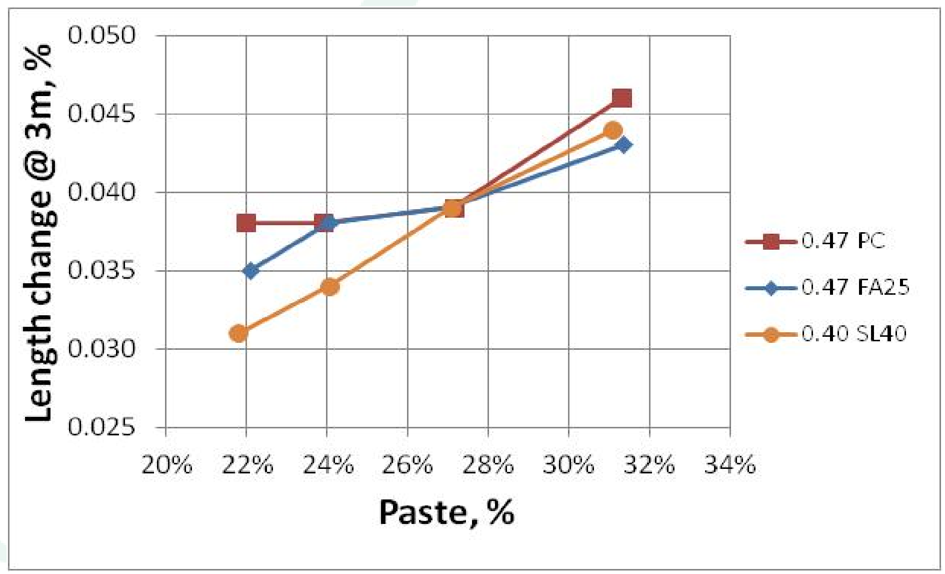
- Impacts workability
- Increases paste volume – potential for cracking
- Increase alkali content in mixture – ASR
- Expected durability may not be achieved
- May significantly exceed design strength
- No incentive to optimize / improve quality
  - Detrimental to all stakeholders
- Contrary to sustainability initiatives

# #3 – Min cementitious content




RCPT (accelerated curing)

Length Change (shrinkage) at 3 months



# #4 – SCM Type / Characteristics

- Available fly ash cannot be used
  - Currently there is a supply problem
  - performance history and service records
- Will need to import fly ash
- Intended performance may not be achieved

# #5 – Aggregate Grading Limits

- Intended performance may not be achieved
  - False sense of security
  - Improper assignment of responsibility
- Requirement cannot be verified during project
- Availability of sizes and storage at plants
- Some local sources cannot achieve grading requirements easily

Optimizing grading is a part of mixture proportioning – cannot be verified and enforced

# Prescriptive Specifications

## A reality check

*by Karthik H. Obla and Colin L. Lobo*

About a decade ago, the National Ready Mixed Concrete Association (NRMCA) embarked on an effort to evolve specifications for concrete to be more performance-based. The title *P2P Initiative* was coined to reflect the effort's thrust from prescription to performance. The primary goals were (are) to improve the quality of concrete construction, facilitate the use of concrete mixtures optimized for the functional requirements of different applications, and support innovation and sustainable development. The basic principle of the effort is that specifications should capitalize on the expertise of the concrete producer and the contractor—in the former case, for development of concrete mixtures, and in the latter case, for construction means and methods. Prescriptive specifications that describe the details of concrete mixture parameters are constraints against achieving these objectives. With prescriptive specifications for example, the concrete producer is often held responsible if there is any problem with concrete on a project. This violates a basic principle that responsibility and authority should be congruent.

A working definition of performance requirements for concrete materials is that the concrete meets acceptance criteria when evaluated using standard test methods. The test methods and criteria should be pertinent to the intended performance of the concrete member in the anticipated service condition and for the expected service life. Design and construction also have significant impact on achieving these goals.

The *P2P Initiative* generated many products and outcomes:

- Investigators made a global review of the state of codes and specifications;
- Research documented improved performance with minimized-prescription guide specifications—both by minimizing prescription and suggesting performance alternatives;
- Discussion items were generated for pre-construction meetings between producers and contractors;
- A quality certification program was developed for ready mixed concrete producers; and
- An overview of the impact of prescriptive specifications on sustainability was assessed.

Many of these products are available on the NRMCA website, **www.nrmca.org/p2p**.

The ACI Strategic Development Council (SDC) recognized the importance of performance-based specifications toward progressing innovation in the concrete industry. In connection with that recognition, ACI established Innovative Task Group (ITG) 8 to develop a document discussing the topic. Subsequently, ACI formed a new committee, ACI Committee 329, Performance Criteria for Ready Mixed Concrete. That committee has published "Report on Performance-Based Requirements for Concrete (ACI 329R-14),"[1] which is based on the ITG 8 report, and it is currently working on a guide to writing a performance-based specification. ACI Committee 318, Structural Concrete Building Code, also developed durability exposure categories that established requirements for concrete as applicable to anticipated exposure in service (ACI 318-08[2]).

### Prescriptive Requirements

#### Common restrictions

In 2014, NRMCA's Research Engineering and Standards (RES) committee decided to conduct a reality check on the impact of the *P2P Initiative*. The intent was to quantify the "state of prescription" in current specifications used for private work. Concrete producer members of NRMCA were provided a list of 15 prescriptive requirements commonly seen in specifications affecting concrete mixtures. They were asked to rate these prescriptive requirements in terms of the frequency that they were seen in specifications; the restrictive effects the requirements had on optimizing mixtures for performance and cost; and the effects the requirements had on performance for the type of placement and application. The list of prescriptive requirements is provided in Table 1, ranked relative to restrictive effect. It was decided to address the top five prescriptive provisions in the ranked list.

#### Frequency of use in specifications

In the next stage, the NRMCA's RES committee members provided copies of specifications from projects they had worked on in the previous 12 months. About 150 project

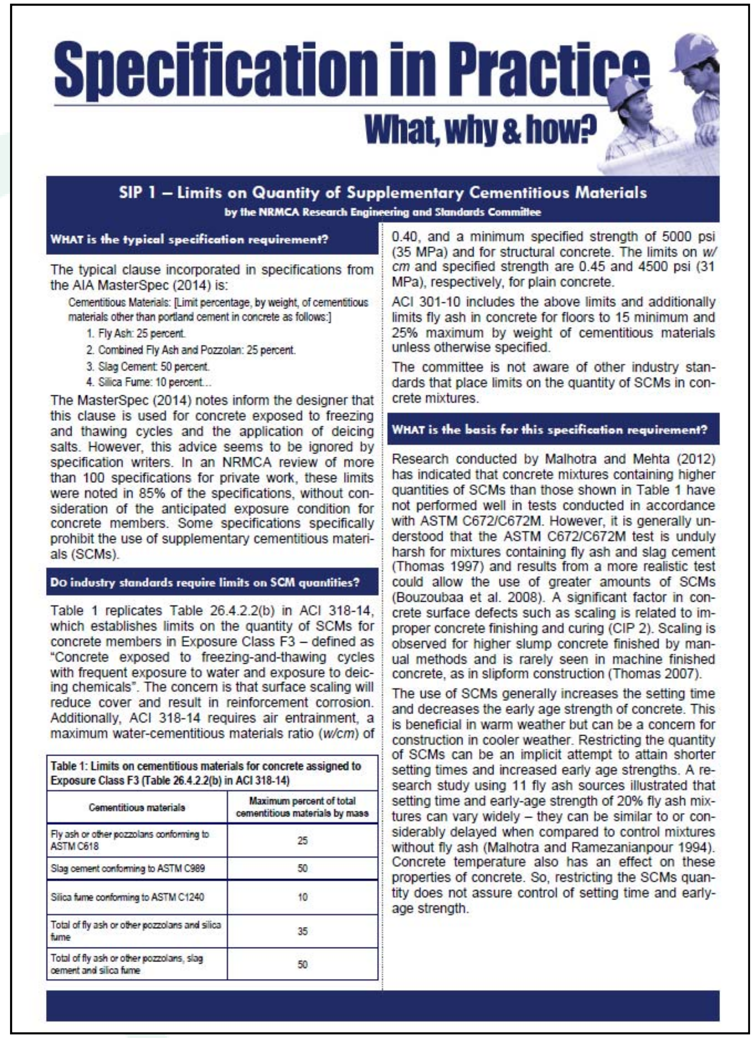
ACI Concrete International, August 2015

WWW. NRMCA.ORG

# Specification in Practice

- The prescriptive requirement
- Is this in industry standards?
- Basis
- Implications
- Suggested alternative
- Benefit of the alternative

http://www.nrmca.org/p2p



# Specification in Practice

## What, why & how?

### SIP 1 – Limits on Quantity of Supplementary Cementitious Materials

by the NRMCA Research Engineering and Standards Committee

#### WHAT is the typical specification requirement?

The typical clause incorporated in specifications from the AIA MasterSpec (2014) is:

> Cementitious Materials: [Limit percentage, by weight, of cementitious materials other than portland cement in concrete as follows:]
> 1. Fly Ash: 25 percent.
> 2. Combined Fly Ash and Pozzolan: 25 percent.
> 3. Slag Cement: 50 percent.
> 4. Silica Fume: 10 percent...

The MasterSpec (2014) notes inform the designer that this clause is used for concrete exposed to freezing and thawing cycles and the application of deicing salts. However, this advice seems to be ignored by specification writers. In an NRMCA review of more than 100 specifications for private work, these limits were noted in 85% of the specifications, without consideration of the anticipated exposure condition for concrete members. Some specifications specifically prohibit the use of supplementary cementitious materials (SCMs).

#### Do industry standards require limits on SCM quantities?

Table 1 replicates Table 26.4.2.2(b) in ACI 318-14, which establishes limits on the quantity of SCMs for concrete members in Exposure Class F3 – defined as "Concrete exposed to freezing-and-thawing cycles with frequent exposure to water and exposure to deicing chemicals". The concern is that surface scaling will reduce cover and result in reinforcement corrosion. Additionally, ACI 318-14 requires air entrainment, a maximum water-cementitious materials ratio (*w/cm*) of 0.40, and a minimum specified strength of 5000 psi (35 MPa) and for structural concrete. The limits on *w/cm* and specified strength are 0.45 and 4500 psi (31 MPa), respectively, for plain concrete.

ACI 301-10 includes the above limits and additionally limits fly ash in concrete for floors to 15 minimum and 25% maximum by weight of cementitious materials unless otherwise specified.

The committee is not aware of other industry standards that place limits on the quantity of SCMs in concrete mixtures.

Table 1: Limits on cementitious materials for concrete assigned to Exposure Class F3 (Table 26.4.2.2(b) in ACI 318-14)

| Cementitious materials | Maximum percent of total cementitious materials by mass |
|---|---|
| Fly ash or other pozzolans conforming to ASTM C618 | 25 |
| Slag cement conforming to ASTM C989 | 50 |
| Silica fume conforming to ASTM C1240 | 10 |
| Total of fly ash or other pozzolans and silica fume | 35 |
| Total of fly ash or other pozzolans, slag cement and silica fume | 50 |

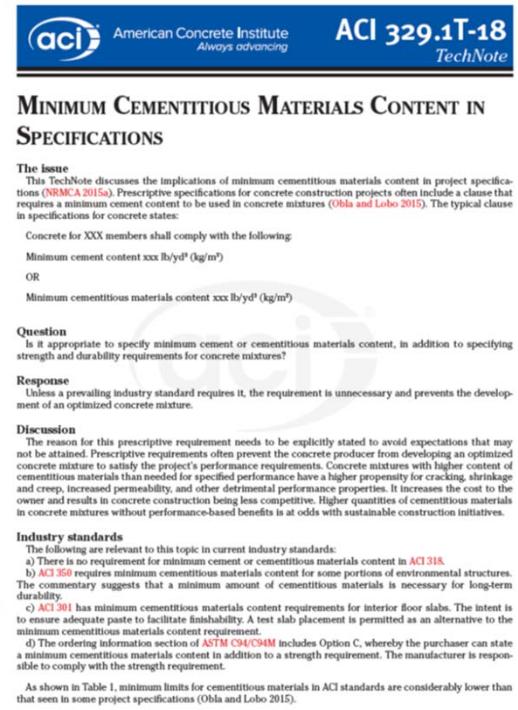
#### WHAT is the basis for this specification requirement?

Research conducted by Malhotra and Mehta (2012) has indicated that concrete mixtures containing higher quantities of SCMs than those shown in Table 1 have not performed well in tests conducted in accordance with ASTM C672/C672M. However, it is generally understood that the ASTM C672/C672M test is unduly harsh for mixtures containing fly ash and slag cement (Thomas 1997) and results from a more realistic test could allow the use of greater amounts of SCMs (Bouzoubaa et al. 2008). A significant factor in concrete surface defects such as scaling is related to improper concrete finishing and curing (CIP 2). Scaling is observed for higher slump concrete finished by manual methods and is rarely seen in machine finished concrete, as in slipform construction (Thomas 2007).

The use of SCMs generally increases the setting time and decreases the early age strength of concrete. This is beneficial in warm weather but can be a concern for construction in cooler weather. Restricting the quantity of SCMs can be an implicit attempt to attain shorter setting times and increased early age strengths. A research study using 11 fly ash sources illustrated that setting time and early-age strength of 20% fly ash mixtures can vary widely – they can be similar to or considerably delayed when compared to control mixtures without fly ash (Malhotra and Ramezanianpour 1994). Concrete temperature also has an effect on these properties of concrete. So, restricting the SCMs quantity does not assure control of setting time and early-age strength.

# Specification in Practice

1. Limits on Quantity of SCMs (ACI 232 TN)
2. Limits on w/cm
3. Min Cementitous Matls Content (ACI 329 TN)
4. Restrictions on Type and characteristics of fly ash
5. Restrictions on Aggregate Grading



American Concrete Institute
Always advancing

ACI 329.1T-18
TechNote

MINIMUM CEMENTITIOUS MATERIALS CONTENT IN SPECIFICATIONS

**The issue**

This TechNote discusses the implications of minimum cementitious materials content in project specifications (NRMCA 2015a). Prescriptive specifications for concrete construction projects often include a clause that requires a minimum cement content to be used in concrete mixtures (Obla and Lobo 2015). The typical clause in specifications for concrete states:

Concrete for XXX members shall comply with the following:

Minimum cement content xxx lb/yd³ (kg/m³)

OR

Minimum cementitious materials content xxx lb/yd³ (kg/m³)

**Question**

Is it appropriate to specify minimum cement or cementitious materials content, in addition to specifying strength and durability requirements for concrete mixtures?

**Response**

Unless a prevailing industry standard requires it, the requirement is unnecessary and prevents the development of an optimized concrete mixture.

**Discussion**

The reason for this prescriptive requirement needs to be explicitly stated to avoid expectations that may not be attained. Prescriptive requirements often prevent the concrete producer from developing an optimized concrete mixture to satisfy the project's performance requirements. Concrete mixtures with higher content of cementitious materials than needed for specified performance have a higher propensity for cracking, shrinkage and creep, increased permeability, and other detrimental performance properties. It increases the cost to the owner and results in concrete construction being less competitive. Higher quantities of cementitious materials in concrete mixtures without performance-based benefits is at odds with sustainable construction initiatives.

**Industry standards**

The following are relevant to this topic in current industry standards:

a) There is no requirement for minimum cement or cementitious materials content in ACI 318.

b) ACI 350 requires minimum cementitious materials content for some portions of environmental structures. The commentary suggests that a minimum amount of cementitious materials is necessary for long-term durability.

c) ACI 301 has minimum cementitious materials content requirements for interior floor slabs. The intent is to ensure adequate paste to facilitate finishability. A test slab placement is permitted as an alternative to the minimum cementitious materials content requirement.

d) The ordering information section of ASTM C94/C94M includes Option C, whereby the purchaser can state a minimum cementitious materials content in addition to a strength requirement. The manufacturer is responsible to comply with the strength requirement.

As shown in Table 1, minimum limits for cementitious materials in ACI standards are considerably lower than that seen in some project specifications (Obla and Lobo 2015).

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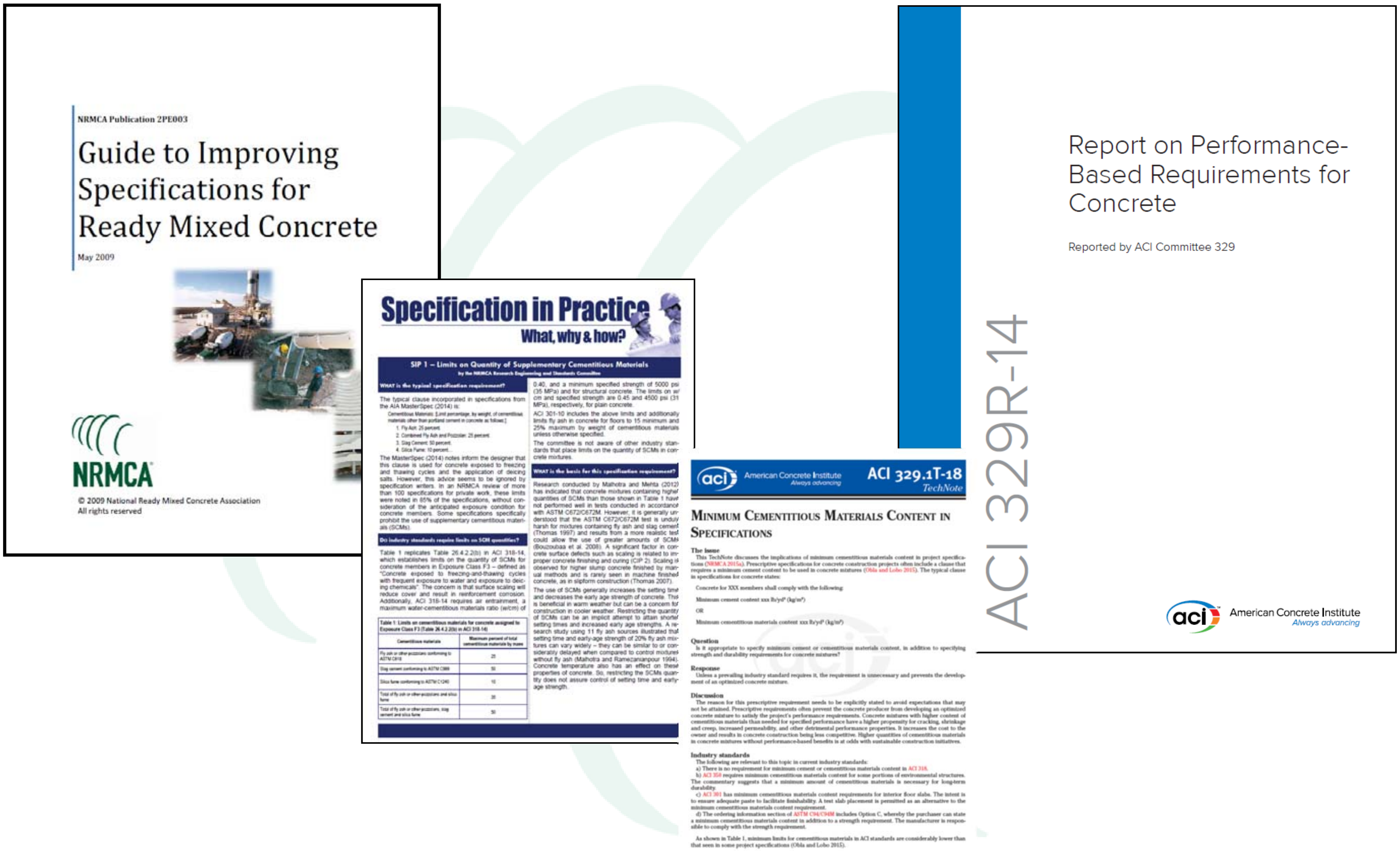
# Resources for Specifications



# Evolution to Performance

- The Engineer specifies
  - Basic requirements (Code)

NRMCA
Guide Performance-Based Specification for Concrete Materials
Section 03300 for Cast-in-place Concrete

| *Member* | *Mix ID* | *Durability Exposure* | | | | *Specified Strength, f′c, psi* | *Max w/cm or Performance Alternative* | *Nom. max Aggregate, in.* | *Air Content* | *Slump/ Slump Flow* | *Chloride Limit* | *Temp. Limits* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *F* | *S* | *W* | *C* | | | | | | | |
| Footings | | | | | | | | | | | | |
| Foundation Walls | | | | | | | | | | | | |
| Slabs-on-grade | | | | | | | | | | | | |
| Exterior slabs | | | | | | | | | | | | |
| Suspended slabs (interior) | | | | | | | | | | | | |
| Suspended slabs (exterior) | | | | | | | | | | | | |
| Frame members | | | | | | | | | | | | |
| Columns (interior) | | | | | | | | | | | | |
| Columns (exterior) | | | | | | | | | | | | |
| Walls (interior) | | | | | | | | | | | | |
| Concrete toppings | | | | | | | | | | | | |

# Evolution to Performance

- If the Engineer desires, specify
  - Performance requirements as applicable


NRMCA
Guide Performance-Based Specification for Concrete Materials
Section 03300 for Cast-in-place Concrete

| *Durability Exposure Class/Property/MeNNumber* | *Prescriptive Requirement* | *Performance Alternative* |
|---|---|---|
| F3 | SCM limits (ACI 318) | ASTM C672 Visual rating less than or equal to 2. Note that this test is not very repeatable or necessarily representative of field performance. |
| S1, S2, S3 | Cementitious types | ASTM C1012 expansion criteria (ACI 318-14 Table 26.4.2.2(c) |
| W1, C2 | w/cm (ACI 318) | ASTM C1202 less than:<br>2500 coulombs (for W1)<br>1000 coulombs (for C2) |
| Alkali Silica Reaction | Low alkali cement, SCM types and dosages, alkali content of concrete | ASTM C1567 using combination of cementitious materials used in the project – length change less than 0.10% at 16 days |
| Shrinkage (W1, C2, Concrete Floors) | w/cm | ASTM C157 (7 days lime water curing and dried for 28 days – length change less than 0.05% |
| Concrete Floors | w/cm, SCM limits, cement content, paste volume, aggregate grading/shape | Shrinkage – see above<br>ASTM C403 initial setting time (contractor requirement)<br>Test slab placement to ensure desired workability, finishability |

# Performance Engineered Mixtures Program

Standard Practice for

**Developing Performance Engineered Concrete Pavement Mixtures**

AASHTO Designation: PP 84-17[1]

National Concrete Pavement Technology Center

CP Tech Center

IOWA STATE UNIVERSITY

Institute for Transportation

# Performance-based Specifications – Its where the future is (or should be)

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