

## **Performance-Based Specifications for Concrete**

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### ***Abstract***

Demands on concrete structures are more severe than ever. Engineers, contractors, and material suppliers are being asked to design and construct buildings that are taller, larger, and last longer than in the past. Traditional prescriptive specifications for concrete are no longer effective and the concrete construction industry is moving towards performance-based specifications. This paper will explore how performance-based specifications are being used to implement innovative products such as high-performance concrete, self-consolidating concrete and high-strength concrete.

### ***Introduction***

Modern ready mixed concrete producers have technical experts that participate in the standards development process and laboratories that incorporate rigorous quality control and product development programs to design concrete mixtures optimized for performance for any application. Concrete contractors employ the latest forming and placement methods to build faster and more economically than ever before. Concrete construction is now much more complicated, and the expertise that exists with the various parties involved needs to be leveraged to ensure that the owner gets a high quality structure with a long projected service life.

Unfortunately, many project specifications are prescriptive in nature and stifle innovation by limiting the types and quantities of ingredients, mixture proportions and construction means and methods. Prescriptive clauses in specifications for concrete are often based on outdated knowledge or empirical relationships. In many cases, prescriptive clauses are invoked that cause significant inherent conflicts of intent, performance attributes and assignment of responsibility. Prescriptive specifications are often overly conservative, which can lead to higher costs and unexpected negative results...ultimately leading to unsatisfied customers.

A shift from prescriptive specifications to performance-based specifications is the next logical step in the evolution of the concrete industry. Performance-based specifications address requirements for mechanical and functional properties of the concrete. The requirements should be based on the design professional assessment of loads and exposure conditions of the concrete structural elements. Compliance is verifiable through measurement or testing to assure the product meets the desired requirements. The assigned responsibilities for achieving certain objectives are clear. Finally, performance-based specifications are free of process limitations such as mixture proportions and construction methods. Performance-based specifications encourage partnering within the construction team which can lead to innovative products and construction methods resulting in superior projects and satisfied customers.

### ***What is a Prescriptive Specification?***

A prescriptive specification is one that includes clauses for means and methods of construction and composition of the concrete mix rather than defining performance requirements. Many times intended performance requirements are not clearly indicated in project specifications, and the prescriptive requirements may conflict with the intended performance.

Many project specifications include controls on the composition of the concrete mixture such as a minimum cement content, type of cement, limits on the quantity of supplementary cementitious materials, maximum water-cementitious materials (w/cm) ratio, limits on the grading of aggregates or type used, brand of admixture and required dosage, etc. In addition there may be requirements on compressive strength or other properties that are implied but not clearly stated in the specification. Very often these requirements cannot be achieved based on the restrictions placed on the mixture composition. For each set of materials there is a unique relationship between the mixture proportions such as cement content and w/cm ratio and resulting strength and durability properties. Placing unjustified limitations on one or more of these parameters of the concrete mixture in a specification often contradicts the intended or implied performance.

Consider an example of a prescriptive specification for concrete used for interior building columns. The specification requires a 0.40 w/cm ratio, a minimum cement content of 640 lb/yd<sup>3</sup>, a maximum fly ash content of 15% by mass of cementitious material, a compressive strength of 4,000 psi, and a maximum slump of 4 in.

For this structural element the critical performance characteristic is the compressive strength. Since the column is protected from exposure the w/cm ratio limit is not necessary for durability and the requirement for a minimum cementitious content is not needed to meet the strength requirements. Presumably the limit on fly ash is to ensure rapid strength gain for form stripping but this is an issue of means and methods of construction and should therefore be avoided in the specification. The

restriction on the w/cm ratio and slump will likely cause placement problems with congested reinforcement and likely result in surface defects due to difficulties with consolidation.

There are a few options that a producer might use to comply with this specification:

- One option is to start with water, estimated at 295 lb/yd<sup>3</sup> for the target slump with the local materials and use a cementitious content of 740 lb/yd<sup>3</sup> to meet the maximum w/cm requirement. The strength of this mixture is more likely to be in the range of 7,000 psi or higher. This mixture also has a high paste content which will cause associated problems such as high heat of hydration, shrinkage, and creep. The mix will not be the most economical one because of the high cementitious materials content.
- Another option is to start with the minimum cementitious content and establish the maximum water content of the mix at 250 lb/yd<sup>3</sup> again to meet the maximum w/cm requirement. Based on the water demand of the local materials, this mixture will require relatively high dosages of water reducing and/or high range water reducing admixtures. This mixture has a lower paste content but may not have the appropriate consistency for proper placement. The strength is likely to be in the range of 6,500 psi.
- If the only requirement was strength, say at 3 days for form stripping and at 28 days for design requirements, the producer might choose to optimize the mixture by controlling aggregate quantity and grading, minimizing the paste content and provide the necessary mixture consistency, possibly using self consolidating concrete, and achieve the necessary form stripping and design strength. A concrete mixture targeting an average strength of about 4,600 psi can be designed with a cementitious content of about 460 lb/yd<sup>3</sup>, with possibly up to 25% fly ash. This mixture will have the lowest paste content and minimize heat of hydration, shrinkage and creep. If designed for proper consistency without the restrictions on the w/cm, cement content, or slump, it will also result in a better surface finish.

This example illustrates how prescriptive provisions in a specification might result in widely different concrete mixtures. The same example can be extended to durability properties of concrete. The typical surrogate for durability is to set a low w/cm ratio limit. This is a key parameter of a concrete mixture that controls several properties including permeability. Lower permeability typically leads to more durable concrete. However as stated earlier for strength, the relationship between w/cm and permeability is unique to the set of materials used. One can get a wide range of permeability of concrete at a 0.40 w/cm ratio with different mixtures, especially with the use of modern day chemical admixtures and supplementary cementitious materials.

Prescriptive specifications also potentially lead to higher costs to the owner for several reasons: mixtures not optimized cost more, and prescribing mixture ingredients may not afford the characteristics needed for constructability, causing

defects that must be repaired or replaced and results in delayed schedules. Further, they potentially restrict necessary changes in mixture proportions to accommodate variability in materials, construction methods and seasonal temperature variations. The bidder with the lowest overhead—which usually means lowest investment in quality control, research and development—is often the one that can bid the lowest and profit the most at the lowest bid. An engineer might think he/she has established a level playing field with a prescriptive mix, but in fact could be facilitating low quality. For this reason, engineers based on past experience often revert to more prescriptive limitations that are extremely conservative (over-designed) to compensate for low quality.

If the engineer specifies the desired performance and relies on the expertise of the concrete contractor and concrete producer to deliver an optimized mix, it can often be delivered at a lower in-place cost with higher quality to the project.

### ***What is a Performance Specification?***

A performance specification is a set of instructions that outlines the functional requirements for hardened concrete depending on the application. The instructions should be clear, achievable, measurable and enforceable.

For example, the performance criteria for interior columns in a building might be compressive strength only, since durability is not a concern. Aspects such as heat for prevention of thermal cracking (heat of hydration), modulus of elasticity and creep might also be important. Conversely, performance criteria for a bridge deck or parking garage slab, besides design strength, might include limits on permeability and cracking since the concrete will be subjected to a harsh environment.

Performance specifications should also clearly specify the test methods and the acceptance criteria that will be used to verify and enforce the requirements. Some testing might be required for pre-qualification and some might be for jobsite acceptance. The specifications should provide the necessary flexibility to the contractor and producer to provide a mix that meets the performance criteria in the way they choose. The contractor and producer will also work together to develop a mix design for the plastic concrete that meets additional requirement for placing and finishing, such as flow and set time, while ensuring the performance requirements for the hardened concrete are not compromised. Flexibility on mixture composition is also necessary to accommodate source variability of ingredient materials and seasonal aspects that impact ambient conditions during construction.

Performance specifications should avoid requirements for means and methods, and should avoid limitations on the ingredients or proportions of the concrete mixture. The general concept of how a performance-based specification for concrete would work is as follows:

- There would be a qualification and certification system that establishes the standards for concrete production facilities and the people who design concrete mixes. This establishes the credentials necessary to deliver performance-based concrete.
- The project specification would clearly define the functional requirements of the hardened concrete.
- Producers and contractors would partner to ensure that the right mix is designed, delivered and installed.
- The submittal would not be a detailed list of mixture ingredients, but rather a certification that the mix will meet the specification requirements including pre-qualification test results.
- After the concrete is placed, a series of field acceptance tests would be conducted to determine if the concrete meets the performance criteria.
- A clear set of instructions outlining what happens when concrete does not conform to the performance criteria.

It is the design professional's responsibility to establish the appropriate measurable and enforceable performance criteria for concrete to assure the owner that he gets what he wants. It is a design function to select appropriate performance measures and criteria for expected service life of the structure. There will be a transfer of responsibility associated with performance specifications. The concrete producer and the contractor, will be responsible for meeting the performance criteria established by the design professional. With that responsibility comes the authority to do the right things to comply with the specification.

### ***Defining Roles and Responsibilities***

As the U.S. construction industry moves towards performance-based specifications it is imperative that we address the issue of roles and responsibilities in construction both within building codes and standards and within construction contract documents (construction drawings and specifications). Building codes and standards in the U.S. have not done a particularly good job of delineating roles and responsibilities. One model that the U.S. construction industry might consider following is the new Canadian Standards Association (CSA) document CSA A23.1-04/A23.2-04 titled *Concrete materials and methods and concrete construction/Methods of test and standard practices for concrete*.

### ***Canadian Standard***

The new Canadian standard provides two alternatives for specifying concrete with well defined levels of responsibilities for each member of the construction team:

1. Performance: When the owner requires the concrete supplier to assume responsibility for performance of the concrete as delivered and the contractor to assume responsibility for the concrete in place, and
2. Prescription: When the owner assumes responsibility for the concrete.

Table 5 (see figure 1) of the Standard clearly states the roles and responsibilities for the owner, contractor and supplier for each alternative.

### ***Prescription Alternative***

Under the Prescription alternative the owner is responsible for specifying the mix proportions down to the details of quantities of all materials including cementing materials, aggregates, admixtures, and water by mass per cubic meter of concrete. They are also responsible for specifying ranges for air content and slump. They are also responsible for specifying a quality assurance plan to verify compliance.

Under the Prescription option the contractor is responsible for planning construction methods based on the owner's mix proportions. He is also responsible for informing the owner of any anticipated problems or deficiencies with the mix proportions related to construction and obtain approval from the owner for any deviation from the specified mix design.

The concrete producer must provide verification that the plant, equipment and all materials comply with the Standard and demonstrate that the concrete complies with the prescriptive criteria. The producer is also responsible for informing the contractor of any anticipated problems or deficiencies with the mix design related to construction.

Under the Prescription alternative the contractor and producer are not responsible for the strength or durability of the concrete so long as they follow the strict prescriptive requirements for mix design and approved installation procedures. This may seem attractive to contractors and producers but it certainly doesn't reward innovation or quality construction. For example, an innovative contractor that has the ability to complete a project more quickly and with less labor using self-consolidating concrete versus conventional concrete is at a disadvantage if self-consolidating concrete is not identified as an acceptable option, since a prescriptive specification just will not work for this type of concrete. Likewise a producer who has the ability to optimize mix designs based on superior quality control (lower standard deviation of strength test results for example) would be at a disadvantage since he is not permitted to optimize the mixture or to change proportions to accommodate changing materials or environmental conditions.

### ***Performance Alternative***

In the Performance alternative of the Canadian Standard the responsibility for mix design, construction methods and quality control shifts away from the owner and towards the contractor and producer. Along with increased responsibilities comes increased authority. In other words the contractor and producer have significantly more latitude to innovate and optimize on mix designs and construction methods.

**Table 5**  
**Alternative methods for specifying concrete**  
(See Clauses 4.1.2.1, 4.1.2.3, 4.1.1, 5.2.4.3.2, and 8.1.5, and Annex J.)

Alternative	The owner shall specify	The contractor shall	The supplier shall
<b>(1) Performance:</b> When the owner requires the concrete supplier to assume responsibility for performance of the concrete as delivered and the contractor to assume responsibility for the concrete in place.	(a) required structural criteria including strength at age; (b) required durability criteria including class of exposure; (c) additional criteria for durability, volume stability, architectural requirements, sustainability, and any additional owner performance, pre-qualification or verification criteria; (d) quality management requirements (see Annex I*); (e) whether the concrete supplier shall meet certification requirements of concrete industry certification programs;* and (f) any other properties they may be required to meet the owner's performance requirements.	(a) work with the supplier to establish the concrete mix properties to meet performance criteria for plastic and hardened concrete, considering the contractor's criteria for construction and placement and the owner's performance criteria; (b) submit documentation demonstrating the owner's pre-qualification performance requirements have been met; and (c) prepare and implement a quality control plan to ensure that the owner's performance criteria will be met and submit documentation demonstrating the owner's performance requirements have been met.	(a) certify that the plant, equipment, and all materials to be used in the concrete comply with the requirements of this Standard; (b) certify that the mix design satisfies the requirements of this Standard; (c) certify that production and delivery of concrete will meet the requirements of this Standard; (d) certify that the concrete complies with the performance criteria specified; (e) prepare and implement a quality control plan to ensure that the owner's and contractor's performance requirements will be met if required; (f) provide documentation verifying that the concrete supplier meets industry certification requirements, if specified;* and (g) at the request of the owner, submit documentation to the satisfaction of the owner demonstrating that the proposed mix design will achieve the required strength, durability, and performance requirements.
<b>(2) Prescription:</b> When the owner assumes responsibility for the concrete.	(a) mix proportions, including the quantities of any or all materials (admixtures, aggregates, cementing materials, and water) by mass per cubic metre of concrete; (b) the range of air content; (c) the slump range; (d) use of a concrete quality plan, if required; and (e) other requirements.	(a) plan the construction methods based on the owner's mix proportions and parameters; (b) obtain approval from the owner for any deviation from the specified mix design or parameters; and (c) identify to the owner any anticipated problems or deficiencies with the mix parameters related to construction.	(a) provide verification that the plant, equipment, and all materials to be used in the concrete comply with the requirements of this Standard; (b) demonstrate that the concrete complies with the prescriptive criteria as supplied by the owner; and (c) identify to the contractor any anticipated problems or deficiencies with the mix parameters related to construction.

\* The owner may accept ready mixed concrete association certification programs such as provincial or regional ready mixed concrete association facility certification programs (e.g., Atlantic Provinces Ready Mixed Concrete Association — APRMCA Concrete Production Facilities Certification Program, Association Béton Québec — BNQ 2621-905, Ready Mixed Concrete Association of Ontario — RMC/O Approved Quality Plan, Manitoba Ready Mixed Concrete Association — Certificate of Conformance for Concrete Facilities, Saskatchewan Ready Mixed Concrete Association — SRMCA Concrete Production Facilities Certification Program, Alberta Ready Mixed Concrete Association — Alberta Certification of Concrete Production Facilities). These certification programs deal with materials, material handling, batching, mixing equipment, etc., ensuring the capability of the supplier to produce concrete as prescribed by each program.  
**Note:** Refer to Annex J for background information and guidance on the use of this Table.

**Figure 1. Canadian Standard – Table 5: Alternative methods for specifying concrete from CSA A23.1-04/CSA A23.2-04.\***

The owner's responsibility is to specify the required strength at a certain age; the durability criteria including the class of exposure; and any additional requirements such as limits on shrinkage or creep, color, finish, and texture. He is also responsible for defining the quality assurance criteria (acceptance testing, pass/fail criteria, and problem resolution) and required qualifications (certifications) of the concrete producer and contractor.

What makes this standard different than standards in the U.S. is that there are tables that identify exposure classes (see figure 2) and performance criteria (see figures 3) that must be met for each exposure class. The owner, or more appropriately the owner's engineer and architect, simply has to identify the strength and exposure class for the different concretes used on a project and it becomes the contractor's and producer's responsibility to design mixes and construction methods to meet the criteria.

The contractor is responsible for working with the producer to establish mix properties to meet performance criteria for both the plastic and hardened concrete considering the contractor's needs and the owner's performance criteria (usually strength and exposure class). He must also submit documentation to demonstrate that pre-qualification performance requirements have been met and prepare a quality control plan to ensure that the owner's performance criteria will be met.

The supplier must certify that the plant, equipment, materials, mix design, production, and delivery comply with the Standard. He must prepare a quality control plan to ensure the contractor's and owner's performance requirements will be met and provide documentation that he meets industry certification requirements as specified by the owner. In addition, he must submit documentation to the owner that the proposed mix design will achieve the required performance criteria. Once a contractor and producer meet the performance criteria through pre-qualification and acceptance testing they have fulfilled their responsibility.

### ***Choosing between prescription and performance***

In the Canadian standard, the owner is assigned the task of selecting the appropriate alternative: Performance or Prescription. The owner must determine the relative benefits of each alternative. The owner may select the Prescription alternative if he believes he has a better knowledge of local concrete materials and construction techniques than producers and contractors in an area. In this case the owner takes full responsibility for performance and economy. The Prescription alternative requires a less vigorous quality assurance program since he only needs to verify the prescribed concrete proportions and installation procedures were followed.

The Prescription alternative is probably best suited for locations where concrete producers and contractors lack the facilities and qualifications to design concrete mixes and construction techniques such as in rural areas. Another example is when an owner has developed a relationship with a contractor and producer and feels he is

already receiving good quality concrete work at reasonable cost and can forgo the expense of a rigorous quality assurance program.

The Performance alternative is probably best suited for owners (architects and engineers) who build (design) in a wide variety of locations and don't have good knowledge of materials and construction practices in every location. The contractor and producer presumably have better knowledge of cost-effective construction practices and material properties. In this case the owner stipulates the performance criteria (strength and exposure class) and relies on his contractor and producer to develop mixes and installation methods to meet the criteria.

Presumably the producer already has concrete mix designs that are pre-qualified for the particular strength and exposure class since the performance criteria are predefined in the Standard (see figure 2 and 3) and he would have completed pre-qualification testing and trial designs for different classes typically specified in his area.

There's no doubt the contractor and his concrete supplier take on more responsibility in the Performance alternative. However, for a quality contractor and producer the rewards outweigh the risk. A quality producer and contractor will presumably be awarded more contracts since they will be able to meet the owner's performance needs more competitively. However, as the U.S. construction industry modifies codes and standards to allow for performance specification it must be diligent in defining roles and responsibilities such that the benefits can be realized.

### *Moving Towards Performance*

In one of several efforts to move towards performance-based specifications, the National Ready Mixed Concrete Association (NRMCA), who represents the ready mixed concrete industry in the U.S., has established the P2P Initiative to promote a shift from traditional prescriptive specifications to performance specifications for concrete. P2P is an acronym for Prescription to Performance specifications. The primary goal of the P2P Initiative is to improve quality by moving away from prescriptive requirements to those based on performance criteria. Strategies for the P2P Initiative include:

- Allow performance specifications as an alternative to current prescriptive specifications through education and communication
- Leverage the expertise of all stakeholders in the construction industry to improve quality and reliability of concrete construction
- Assist architects and engineers to address concrete specifications in terms of performance requirements, allowing concrete suppliers and contractors flexibility on the details of concrete mixtures and construction means and methods
- Elevate the performance level and credibility of the ready mixed concrete industry through training and certification

**Table 1**  
**Definitions of C, F, N, A, and S classes of exposure**  
(See Clauses 4.1.1.1.1, 4.1.1.5, 4.4.4.1.1.1, 4.4.4.1.1.2, 6.6.7.5.1, and 8.4.1.2, and Table 2.)

C-XL	Structurally reinforced concrete exposed to chlorides or other severe environments with or without freezing and thawing conditions, with higher durability performance expectations than the C-1, A-1, or S-1 classes.
C-1	Structurally reinforced concrete exposed to chlorides with or without freezing and thawing conditions. Examples: bridge decks, parking decks and ramps, portions of marine structures located within the tidal and splash zones, concrete exposed to seawater spray, and salt water pools.
C-2	Non-structurally reinforced (i.e., plain) concrete exposed to chlorides and freezing and thawing. Examples: garage floors, porches, steps, pavements, sidewalks, curbs, and gutters.
C-3	Continuously submerged concrete exposed to chlorides but not to freezing and thawing. Examples: underwater portions of marine structures.
C-4	Non-structurally reinforced concrete exposed to chlorides but not to freezing and thawing. Examples: underground parking slabs on grade.
F-1	Concrete exposed to freezing and thawing in a saturated condition but not to chlorides. Examples: pool decks, patios, tennis courts, freshwater pools, and freshwater control structures.
F-2	Concrete in an unsaturated condition exposed to freezing and thawing but not to chlorides. Examples: exterior walls and columns.
N	Concrete not exposed to chlorides nor to freezing and thawing. Examples: footings and interior slabs, walls, and columns.
A-1	Structurally reinforced concrete exposed to severe manure and/or silage gases, with or without freeze-thaw exposure. Concrete exposed to the vapour above municipal sewage or industrial effluent, where hydrogen sulphide gas may be generated. Examples: reinforced beams, slabs, and columns over manure pits and silos, canals, and pig slats; and access holes, enclosed chambers, and pipes that are partially filled with effluents.
A-2	Structurally reinforced concrete exposed to moderate to severe manure and/or silage gases and liquids, with or without freeze-thaw exposure. Examples: reinforced walls in exterior manure tanks, silos, and feed bunkers, and exterior slabs.
A-3	Structurally reinforced concrete exposed to moderate to severe manure and/or silage gases and liquids, with or without freeze-thaw exposure in a continuously submerged condition. Concrete continuously submerged in municipal or industrial effluents. Examples: interior gutter walls, beams, slabs, and columns; sewage pipes that are continuously full (e.g., forcemains); and submerged portions of sewage treatment structures.
A-4	Non-structurally reinforced concrete exposed to moderate manure and/or silage gases and liquids, without freeze-thaw exposure. Examples: interior slabs on grade.
S-1	Concrete subjected to very severe sulphate exposures (Tables 2 and 3).
S-2	Concrete subjected to severe sulphate exposure (Tables 2 and 3).
S-3	Concrete subjected to moderate sulphate exposure (Tables 2 and 3).

**Notes:**

- (1) "C" classes pertain to chloride exposure.
- (2) "F" classes pertain to freezing and thawing exposure without chlorides.
- (3) "N" class is exposed to neither chlorides nor freezing and thawing.
- (4) All classes of concrete shall comply with the minimum requirements of "S" class noted in Tables 2 and 3.

**Figure 2. Canadian Standard – Table 1: Definitions of exposure classes from CSA A23.1-04/CSA A23.2-04.\***

**Table 2**  
**Requirements for C, F, N, A, and S classes of exposure**  
(See Clauses 4.1.1.1.1, 4.1.1.3, 4.1.1.4, 4.1.1.5, 4.1.1.6.2, 4.1.2.1, 4.3.1, 7.4.1.1, 8.8.3, and 8.8.6.1, and Table 1.)

Requirements for specifying concrete							
Class of exposure*	Maximum water-to-cementing materials ratio†	Minimum specified compressive strength (MPa) and age (d) at test†	Air content category as per Table 4	Curing type (see Table 20)			Chloride ion penetrability test requirements and age at test‡
				Normal concrete	HVSCM 1	HVSCM 2	
C-XL	0.37	50 within 56 d	1 or 2§	3	3	3	< 1000 coulombs within 56 d
C-1 or A-1	0.40	35 at 28 d	1 or 2§	2	3	2	< 1500 coulombs within 56 d
C-2 or A-2	0.45	32 at 28 d	1	2	2	2	
C-3 or A-3	0.50	30 at 28 d	2	1	2	2	
C-4** or A-4	0.55	25 at 28 d	2	1	2	2	
F-1	0.50	30 at 28 d	1	2	3	2	
F-2	0.55	25 at 28 d	2††	1	2	2	
N‡‡	For structural design	For structural design	None	1	2	2	
S-1	0.40	35 at 56 d	2	2	3	2	
S-2	0.45	32 at 56 d	2	2	3	2	
S-3	0.50	30 at 56 d	2	1	2	2	

\*See Table 1 for a description of classes of exposure.

†The minimum specified compressive strength may be adjusted to reflect proven relationships between strength and the water-to-cementing materials ratio. The water-to-cementing materials ratio shall not be exceeded for a given class of exposure.

‡In accordance with ASTM C 1202. An age different from that indicated may be specified by the owner. Where calcium nitrite corrosion inhibitor is to be used, the same concrete mixture, but without calcium nitrite, shall be prequalified to meet the requirements for the permeability index in this Table.

§Use air content category 1 for concrete exposed to freezing and thawing. Use air content category 2 for concrete not exposed to freezing and thawing.

\*\*For class of exposure C-4, the requirement for air-entrainment should be waived when a steel trowelled finish is required. The addition of supplementary cementing materials may be used to provide reduced permeability in the long term, if that is required.

††Interior ice rink slabs and freezer slabs with a steel trowelled finish have been found to perform satisfactorily without entrained air.

‡‡To allow proper finishing and wear resistance, Type N concrete intended for use in an industrial concrete floor with a trowelled surface exposed to wear shall have a minimum cementing materials content of 265 kg/m<sup>3</sup>.

**Figure 3. Canadian Standard – Table 2: Requirements for classes of exposure from CSA A23.1-04/CSA A23.2-04.\***

- Foster innovation and acceptance of new technology at a faster pace through research and development

One of the critical goals of the P2P Initiative is to initiate changes to ACI 318, *Building Code Requirements for Structural Concrete*, to allow for performance-based specifications for concrete. Recent proposals include the concept of exposure classes within chapter 4 on durability similar to the exposure class concept defined in the Canadian standard. In addition, the rapid chloride permeability test (RPCT), ASTM C 1202, has been proposed as an alternative to the maximum w/cm criterion in ACI 318. NRMCA has also commissioned research to quantify the benefits of performance-based specifications and identify and improve test methods that could be used for pre-qualification and acceptance of concrete. Details of the P2P Initiative can be found at [www.nrmca.org/P2P](http://www.nrmca.org/P2P).

### ***Conclusions***

A specification for concrete construction is a set of instructions from the owner, typically written by a design professional as his representative, to the concrete contractor. A specification eventually forms the basis of a contract, a legal agreement, between the owner and the contractor and establishes the joint and separate responsibilities of the various stakeholders in the construction team towards achieving the objectives of the owner. For that reason the specification should be written in terse mandatory language with clear, measurable and achievable requirements.

The authors have reviewed numerous project specifications written by national and regional design firms and observe several problems that could cause unintended negative consequences and restrict the expertise of the contractor and concrete producer. Listed below are some general suggestions for improving specifications for concrete:

- Specification clauses that require compliance with industry reference documents, especially guidance documents written in non-mandatory language should be avoided. These documents discuss various options and if a specific option is needed for the project it should be written in the specification in mandatory language.
- The specification should not include a general statement requiring compliance with the Building Code. It is the design professional's responsibility to establish provisions of the Code that apply to the project and write them in the specification. Do not apply code provisions to portions of structures for which they are not applicable. For example, non-structural elements such as slabs-on-grade or exterior flatwork are not governed by ACI 318.
- The specification should avoid outlining details of construction means and methods as the expertise of the contractor is stifled.
- The specification should avoid dictating details of the mixture proportions as the concrete producer's expertise is stifled. Often the contractor and concrete supplier can work out the requirements of plastic concrete for construction.

For example, allow the contractor and producer to select slump and method of placement.

- State the required performance in measurable terms that are enforceable. For example, “Concrete as discharged from the transportation vehicle shall have entrained air of 5.5% +/- 1.5% when tested in accordance with ASTM C 231.”
- Requiring the use of specific brands of products or equipment should be avoided, especially when reference standards or alternative equivalents are available.
- Avoid adding on requirements to a set of conditions that currently work as this can cause a different problem. Avoid making acceptance criteria more restrictive than accepted industry practice as that may not be achievable or could cost more for no associated benefit.
- Submittals prior to the start of work should be limited to documenting conformance to the specification requirements. This process can be significantly simplified from the current practice.

The evolution to performance-based specifications is critical to the success of the concrete construction industry in competing with alternative building materials and in the sustainable construction initiatives. Performance specifications will only be successful if the stakeholders in the concrete construction process are knowledgeable and cognizant of the needs and capabilities of the others. All stakeholders including architects, engineers, contractors and producers must partner to ensure a successful project. Although the challenges are many and the effort involved will be extensive, the change is necessary to ensure continued growth and improvement of the concrete industry.

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