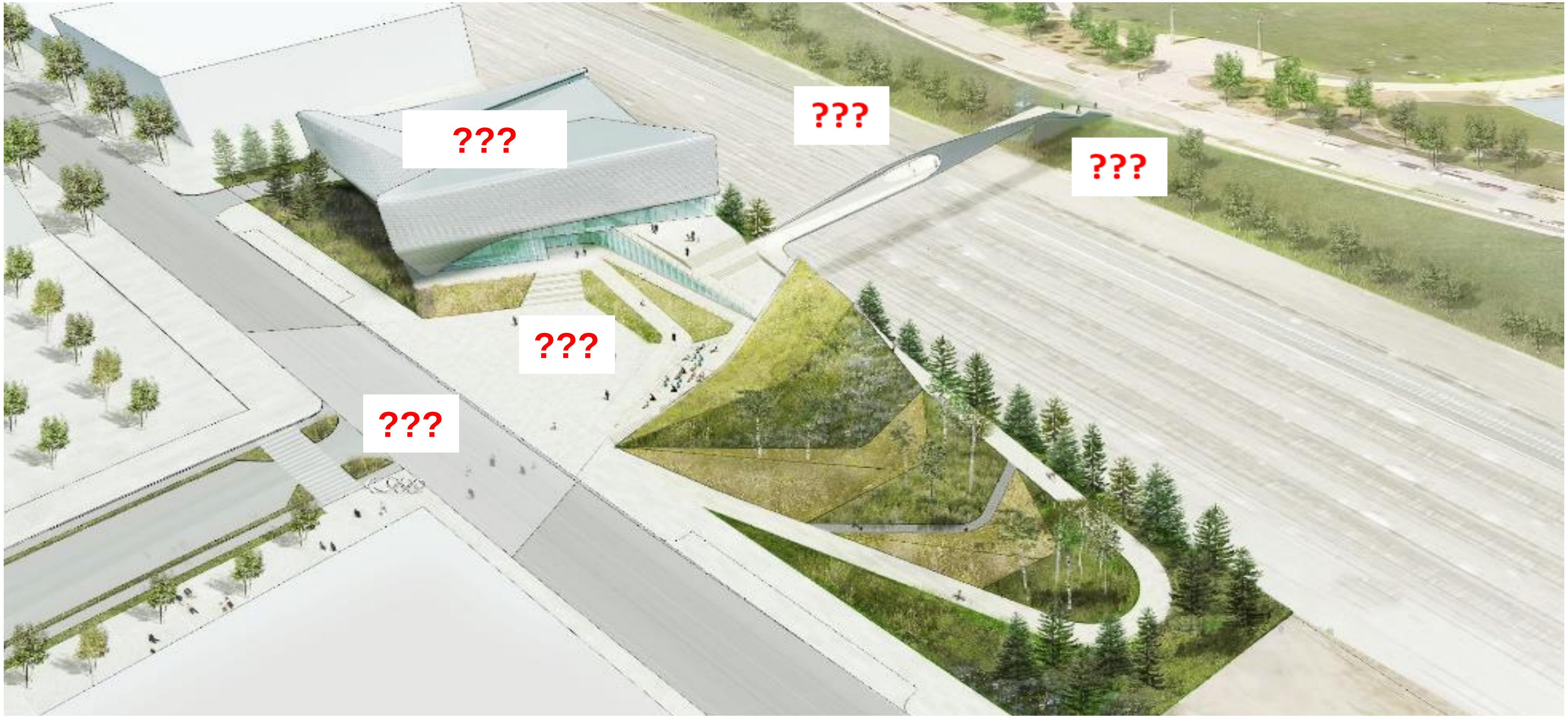
A Perspective on the North American Approach to Performance Requirements and Standards for Concrete

Oscar R. Antommattei, MS, PE, FACI
Concrete, Chief Concrete & Engineering Manager
Kiewit Engineering Group, Inc.

CONCRETE PERSPECTIVE



What would be the conditions of work and demands for design and construction of the concrete at each area identified above? Same, or not? Why?

SPECIFICATIONS’ CHALLENGES

Clear Goals, Undefined Requirements

> “*The contractor shall submit the combination of materials that will produce concrete to meet the requirements of the structure with respect to workability, dimensional stability and freedom from cracking, low temperature rise, adequate strength, durability and low permeability to the...*”

Hidden Goals, Defined Requirements

> **Minimum Volume of Coarse Aggregate**: The minimum requirements detailed herein apply to all methods of placement, including pump mixes. All mixes shall contain a minimum of 39% coarse aggregate by volume…
>
> 1) …,
>
> 2) …,
>
> 3) Bridge decks; bridge deck concrete mixes shall contain a minimum of 41% coarse aggregate and total minimum aggregate volume of 67%,

WHAT ABOUT CONCRETE S.M.A.R.T REQUIREMENTS?

S	M	A	R	T
Specific	Measurable	Achievable	Relevant	Time-Bound

- Clear expectations
- Defined requirements
- Consistent with design goals
- Aligned with construction
- Qualify performance
- Ensure quality is met
- Be Safe

Can Requirements be S.M.A.R.T?

FUNDAMENTALS OF CONCRETE

STRENGTH

- w/cm ratio
- Materials
- Quality

DURABILITY

- Freeze/Thaw
- Sulfate Resistance
- Permeability
- Service Life

WORKABILITY

- Slump Retention
- Placing
- Consolidation
- Finishing

ECONOMICS

- Mix Costs
- Consistency
- Rework

Meet design criteria and construction demands!

ACI 301-20 MIX DESIGN PROPORTIONS

4.1—General

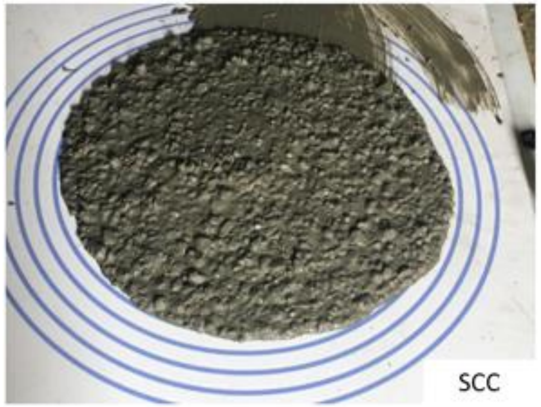
4.1.1 *Scope*—This Section covers requirements for materials, proportioning, production, and delivery of concrete.

4.1.2 *Submittals*

4.1.2.1 *Mixture proportions*—Concrete mixture proportions and characteristics.

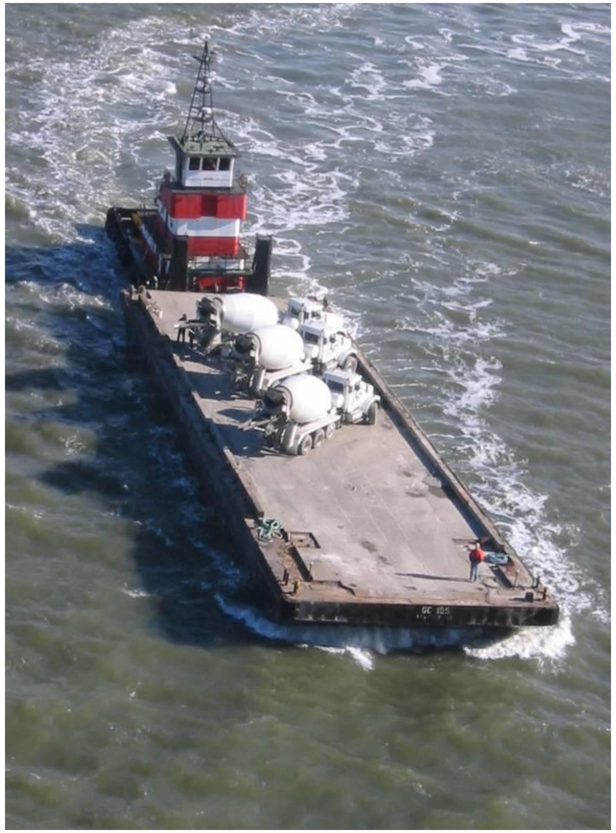
4.1.2.1(a) Indicate proposed ranges of mixture proportions and changes in concrete materials to adjust concrete mixtures to accommodate changes in project conditions and comply with Contract Documents.

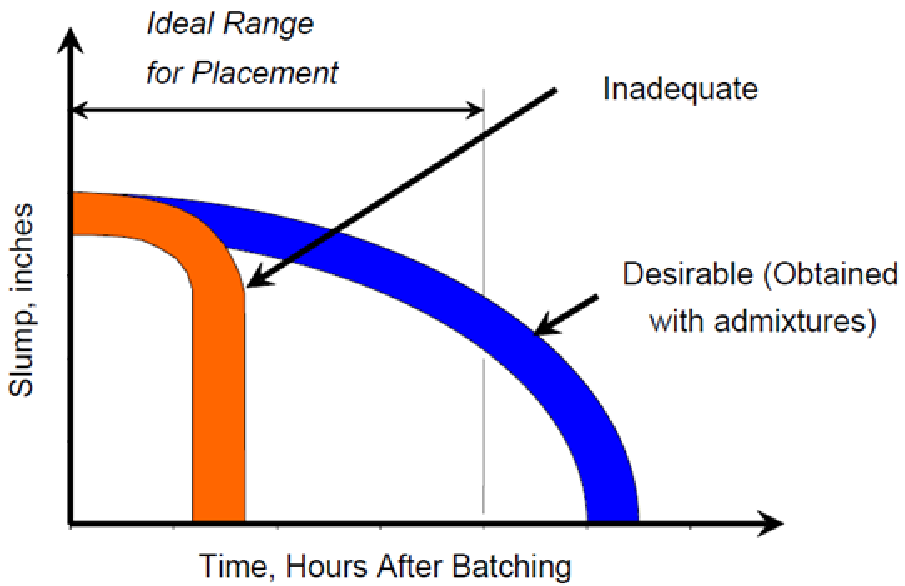
SLUMP



Ref. FHWA NHI Course No. 132014

SLUMP RETENTION





ACI 301-20 SLUMP

4.2.2.1 *Slump*—Unless otherwise specified, select a target slump at the point of delivery for concrete mixtures used for Work. Selected target slump shall not exceed 9 in. Concrete shall not show visible signs of segregation. The target slump indicated on the submittal shall be used as the basis for acceptance during the project. Determine the slump by ASTM C143/C143M. Slump tolerances shall be in accordance with ACI 117.

CSA A23.1-19, CLAUSE 4.3.2.3 – SLUMP OR SLUMP FLOW

4.3.2.3 Slump or slump flow

4.3.2.3.1 General

Slump or slump flow shall be consistent with the placement and consolidation methods, equipment, and site conditions. Slump requirements shall be identified and reviewed by the contractor and concrete supplier prior to construction. When the slump is specified, the acceptance of the concrete in the field shall be subject to the tolerances specified in Clause 4.3.2.3.2.

Notes:

1) *Flowing concretes, such as self-consolidating concrete mixtures, require slump flow methods of measurement for testing consistency. For more information, see Clause 8.6.3.1.*
2) *Alternative devices and methods to measure workability are available. For more information on this subject, see ASTM C1362.*
3) *For general guidance in mix proportioning, see ACI 211.1 and ACI 302.1R.*
4) *For guidance on selecting appropriate slumps, see ACI 211.1 and ACI 302.1R; ASTM STP 169D; Neville (1995); and CAC EB101.*

NMX C155-14 – SLUMP

5.2.2. Slump

The maximum water content should be limited in a way that the maximum nominal slump does not exceed 10 cm. If it is required to increase the slump, this increase should be obtained through the use of the additives mentioned in section 5.1.4. of this standard.

In case the slump is lower than the specified limit, the concrete can be accepted if there are no difficulties for its placement, under the responsibility of the user.

MASS CONCRETE

- ***Traditional mass concrete:*** Use for structures such as dams, typically lightly reinforced, where the majority of the structure is mostly mass concrete and is constructed of sequential placements.

- ***Thermally-controlled concrete:*** Use for structures such as high-rise building foundations or bridges, typically heavily reinforced, where the majority of the structures are individual placements

ACI 301-20 DEFINING MASS CONCRETE

Mass concrete	
8.1.1	Designate portions of Work to be constructed as mass concrete. Concrete placements where maximum temperatures and temperature differences must be controlled due to factors including the content and type of cementitious materials, environment surrounding placement, and minimum dimension of placement should be designated as mass concrete. Evaluate the requirements for each portion of project. In general, a placement of concrete with a minimum dimension equal to or greater than 4 ft should be considered mass concrete. Similar considerations should be given to other concrete placements that do not meet this minimum dimension but generate high heat at early ages such as concretes that contain Type III cement, accelerating admixtures, or have high cementitious materials contents. Consideration should also be given to placements that trap heat such as where heat in soil does not allow placement to cool or in stacked placements with too little time provided for adequate heat dissipation. Refer to ACI 207.1R for further guidance on mass concrete construction, and Gajda et al. (2018) for information regarding mass concrete behavior based on member thickness and concrete mixture proportions.

CSA A23.1-19, CLAUSE 7.6.3 – MASS CONCRETE

7.6.3.1 General

Concrete placements having dimensions large enough (typically having a minimum dimension equal or greater than 1 m) to require measures be taken to minimize cracking resulting from the generation of heat from hydration of cement and attendant volume change shall be considered mass concrete unless otherwise specified or approved by the owner.

Notes:

1) *See Annex T on mass concrete for further guidance and considerations to define mass placements.*
2) *Some non-structural concrete applications that meet the typical dimensions of mass concrete might not require thermal control measures to be taken to minimize risk of thermal cracking.*
3) *Some structural concrete applications that do not meet the typical dimensions of mass concrete might require thermal control measures to be taken to minimize the risk of thermal cracking.*

ACI 207.1R-21 DEFINING RISK OF MASS CONCRETE

Typical

Equivalent Cement Content, lb/yd³	Equivalent Cement Content, kg/m³	Minimum Dimension, ft																			
		0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10
		Minimum Dimension, m																			
		0.2	0.3	0.5	0.6	0.8	0.9	1.1	1.2	1.4	1.5	1.7	1.8	2.0	2.1	2.3	2.4	2.6	2.7	2.9	3.0
250	148																				
300	178																				
350	208																				
400	237																				
450	267																				
500	297																				
550	326																				
600	356																				
650	386																				
700	415																				
750	445																				
800	475																				
850	504																				
900	534																				
950	564																				
1000	593																				

Ref. ACI 207.1-21

ACI 301-20 MAXIMUM CONCRETE TEMPERATURE (TMAX)

SECTION 8—MASS CONCRETE

8.1—General

8.1.1 *Scope*—This Section covers construction requirements for concrete designated as mass concrete in Contract Documents.

8.1.2 *General requirements*—Unless otherwise specified in this Section or in Contract Documents, requirements of Sections 1 through 5 are applicable for mass concrete.

8.1.3 *Temperature limits*—Unless otherwise specified, the following temperature limits shall apply for mass concrete placements:

(a) Maximum temperature in concrete after placement shall not exceed 160°F.

(b) Maximum temperature difference between center and surface of placement shall not exceed 35°F.

OPTIONAL REQUIREMENTS CHECKLIST

Section/Part/Article	Notes to Specifier
Mass concrete	
8.1.2	Review Sections 1 through 5 and specify requirements to be omitted or made mandatory for mass concrete in Work.
8.1.3	Specify alternative maximum temperature limit. Maximum temperature is limited to minimize future durability concerns due to delayed ettringite formation (DEF), restraint cracking, and potential reductions in ultimate strength. ACI 201.2R suggests that the potential for DEF in concrete at temperatures between 160 and 185°F may be reduced by using cementitious materials that consist of at least one of the following: (a) 25 percent Class F fly ash (b) 35 percent slag cement (c) 35 percent Class C fly ash (d) 5 percent silica fume with either 20 percent Class F fly ash or 30 percent slag cement (e) 10 percent metakaolin Specify if maximum temperature difference limit in concrete after placement can be other than 35°F. The purpose of limiting the temperature difference is to minimize thermal cracking. A higher temperature difference limit may be acceptable depending on concrete properties, placement dimensions, and reinforcement configuration. The temperature difference limit for a specific concrete mixture and placement conditions can be determined through numerical simulations and comparing calculated thermally induced tensile stresses with the developing tensile strength at the surface of the concrete placement. Refer to ACI 207.2R for additional guidance.

CSA A23.1-19, CLAUSE 7.6.3 – MASS CONCRETE (TMAX)

7.6.3.2.4 Maximum concrete temperature

The maximum concrete temperature in mass placements shall not be greater than

a) 70 °C for non-HVSCM concrete;

b) 75 °C for HVSCM-2 concrete; and

c) 85 °C for HVSCM-1 concrete.

Note: *The maximum concrete temperature is mainly influenced by the temperature rise of concrete and fresh concrete placing temperature at time of placement. Information and references in Annex T are provided for guidance into the considerations to the applicable maximum concrete temperature for different conditions and concrete properties.*

ACI 301-20 MAXIMUM CONCRETE TEMPERATURE DIFFERENCE (TDIFF)

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(b) Maximum temperature difference between center and surface of placement shall not exceed 35°F.

OPTIONAL REQUIREMENTS CHECKLIST

Section/Part/Article	Notes to Specifier
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CSA A23.1-19, CLAUSE 7.6.3 – MASS CONCRETE (TDIFF)

7.6.3.2.5 Maximum concrete temperature difference

7.6.3.2.5.1

The maximum concrete temperature difference in mass placement shall not be greater than 20 °C, specified as a fixed limit, except where higher temperature difference limits are permitted as provided for in Clauses 7.6.3.2.5.2 to 7.6.3.2.5.4.

Note: *The maximum temperature difference in mass concrete can be specified in different ways based on the concrete properties and placement attributes. Refer to Annex T for further information and guidance.*

7.6.3.2.5.2

A maximum concrete temperature difference fixed limit shall be specified not to exceed 25 °C when the coefficient of thermal expansion of the concrete is less than 10 millionths/°C, except as provided for in Clause 7.6.3.2.5.4.

7.6.3.2.5.3

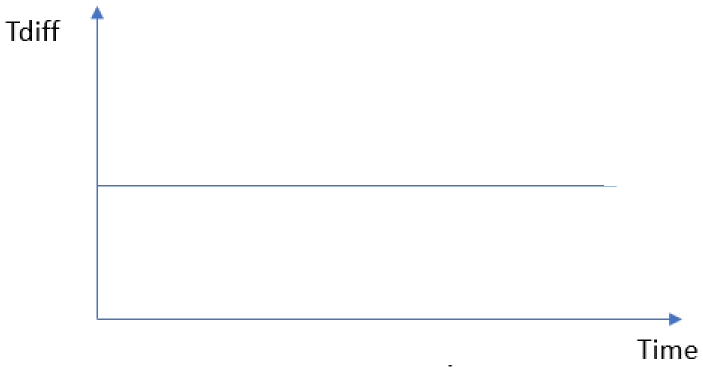
An incremental maximum temperature difference limit shall be specified not to exceed 25 °C, except as provided for in Clause 7.6.3.2.5.4.

Note: *Refer to Clause T.4.3.3 for information on incremental temperature difference limits.*

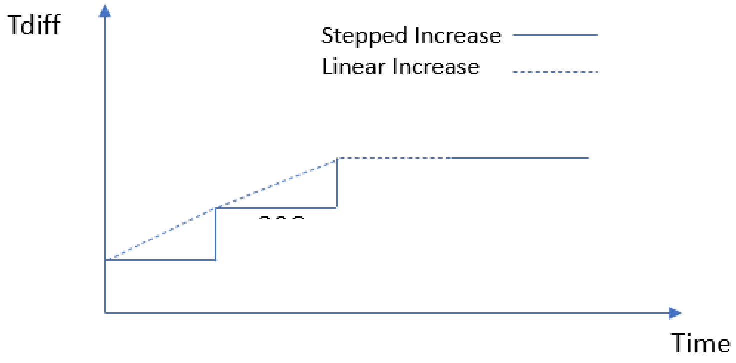
7.6.3.2.5.4

A performance based approach based on numerical analysis and modeling with a project specific testing program shall be specified when a maximum concrete temperature difference limit higher than 25 °C is permitted.

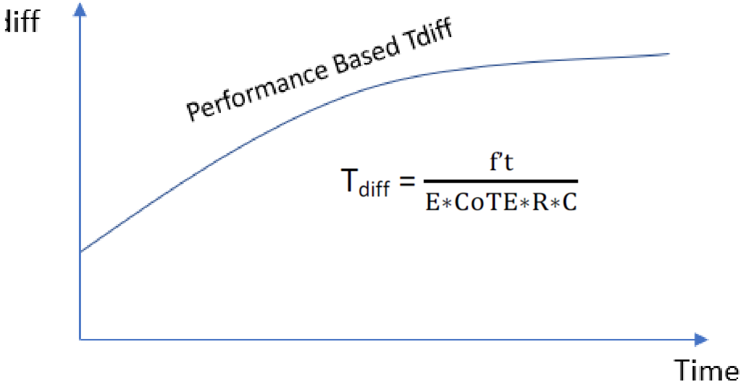
MAXIMUM CONCRETE TEMPERATURE DIFFERENCE LIMIT (OPTIONS)



Fixed Limit

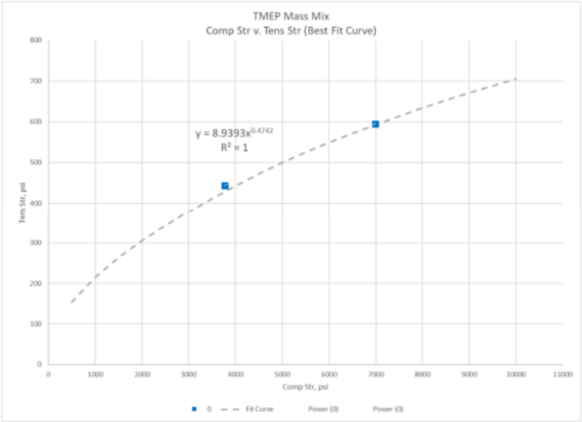


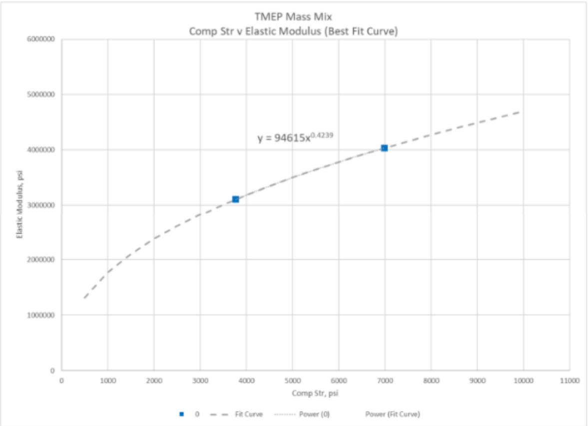
Incremental Limit

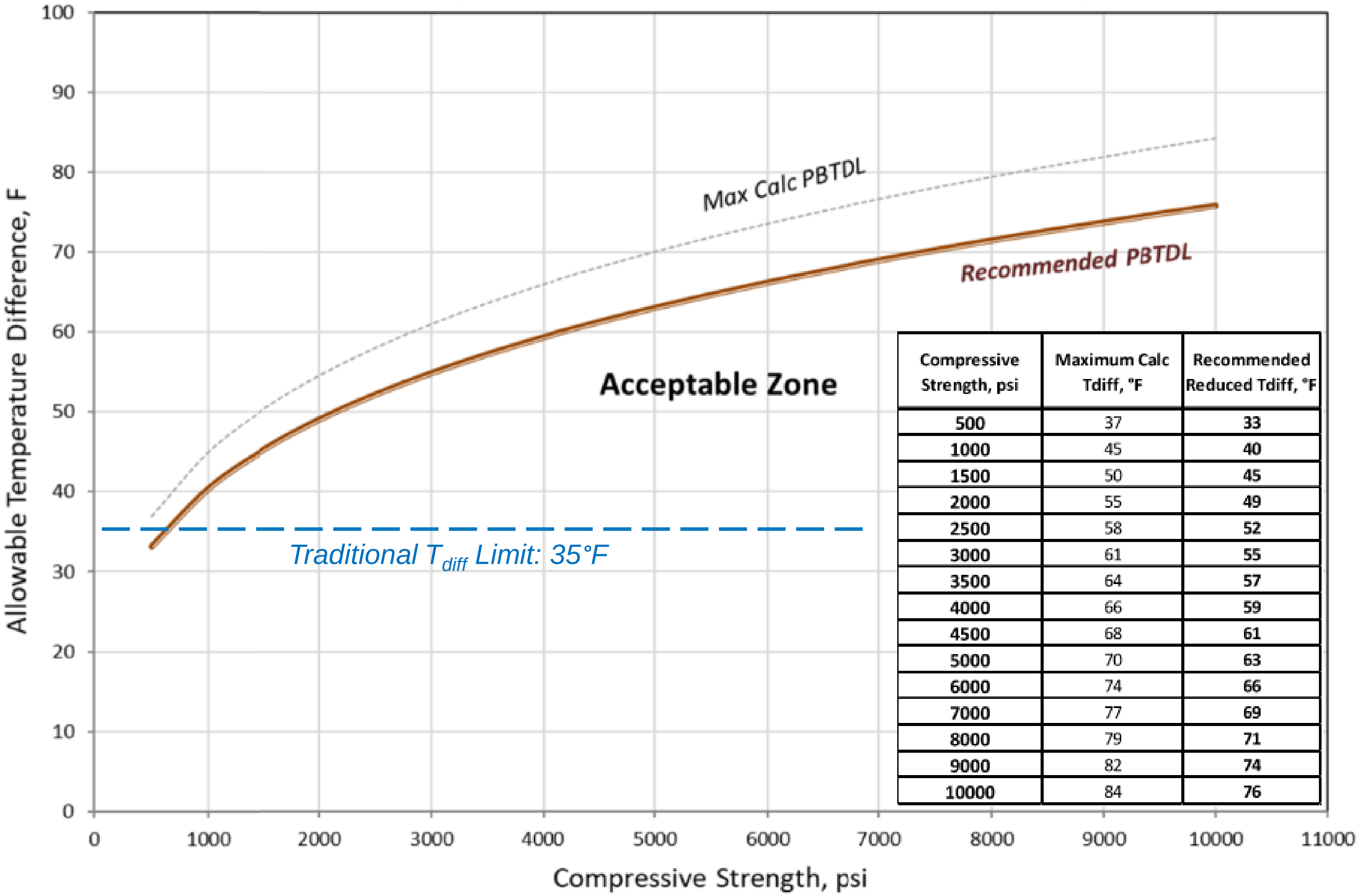


Performance Limit

QUALIFY PERFORMANCE BASED TEMPERATURE DIFFERENCE LIMIT





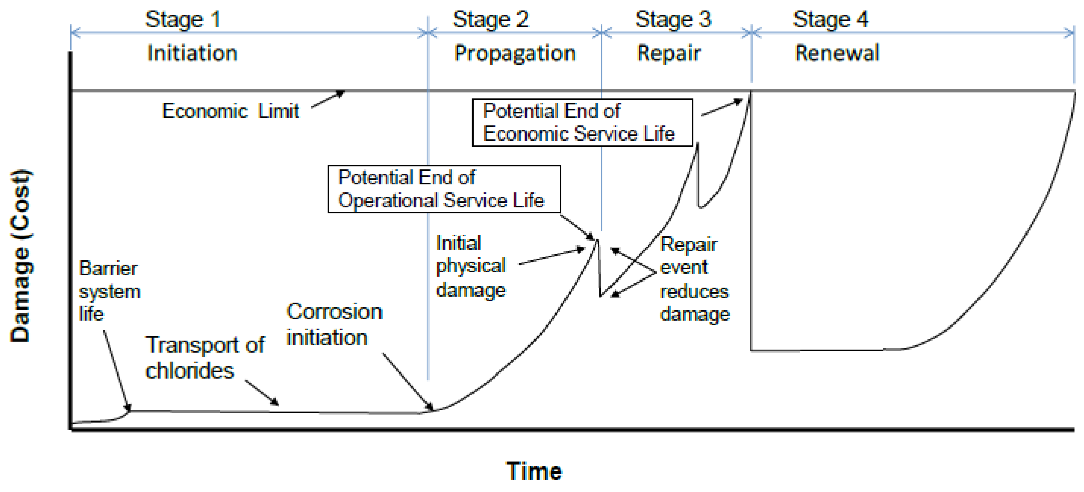


Compressive Strength, psi	Maximum Calc Tdiff, °F	Recommended Reduced Tdiff, °F
500	37	33
1000	45	40
1500	50	45
2000	55	49
2500	58	52
3000	61	55
3500	64	57
4000	66	59
4500	68	61
5000	70	63
6000	74	66
7000	77	69
8000	79	71
9000	82	74
10000	84	76

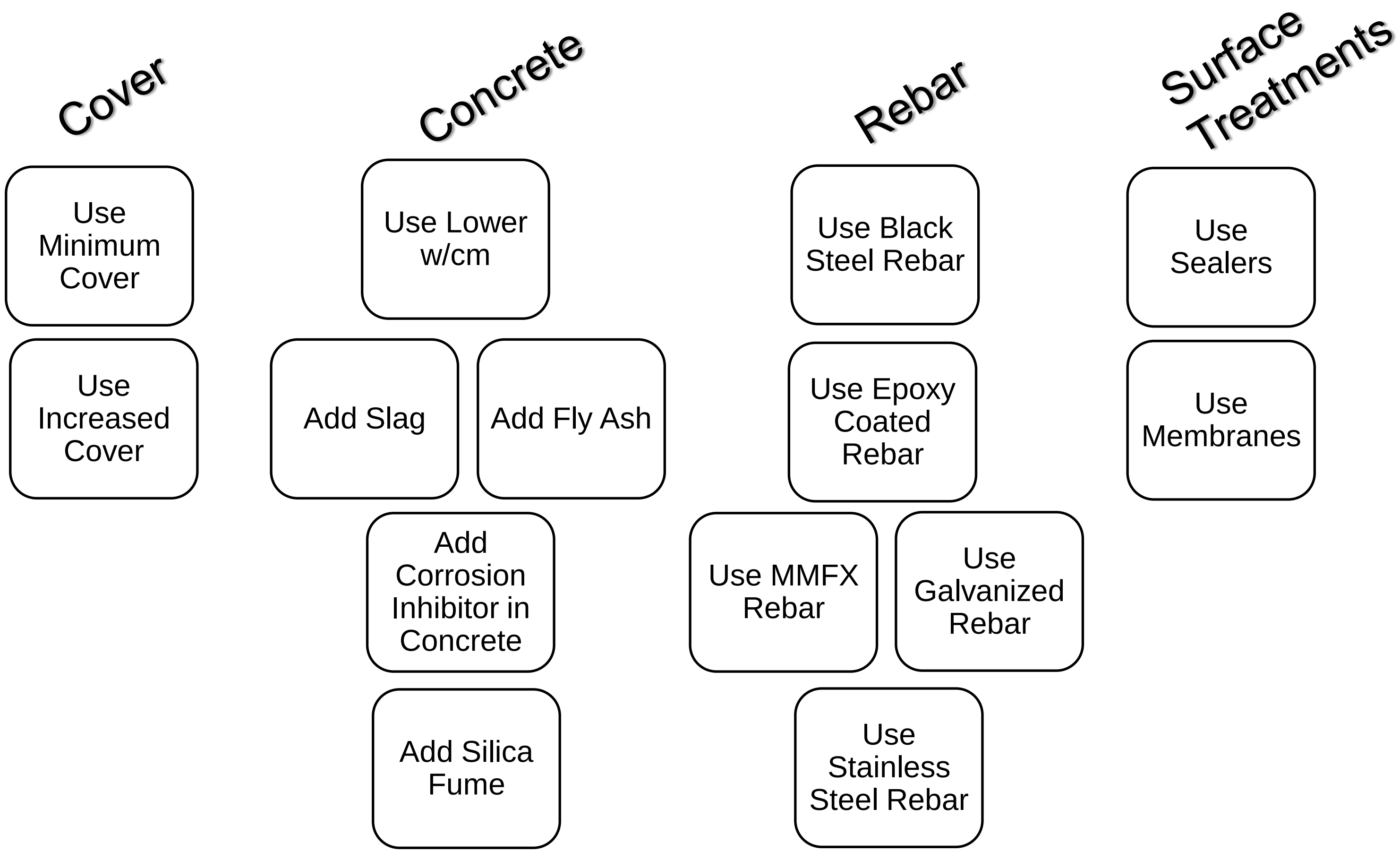
IMPROVING CONCRETE DURABILITY PERFORMANCE

Key Aspects to Achieve Concrete Service Life

- ✓ Ensuring concrete properties are met
- ✓ Avoiding degradation mechanisms
- ✓ Improving resistance to chloride induced corrosion



TYPICAL ALTERNATIVES TO IMPROVE SERVICE LIFE & DURABILITY



ACI 318 EXPOSURE CLASSES / REQS

Table 19.3.2.1—Requirements for concrete by exposure class

Exposure class		Maximum w/cm[1,2]	Minimum f_c', psi	Additional requirements			Limits on cementitious materials
				Air content			
F0		N/A	2500	N/A			N/A
F1		0.55	3500	Table 19.3.3.1 for concrete or Table 19.3.3.3 for shotcrete			N/A
F2		0.45	4500	Table 19.3.3.1 for concrete or Table 19.3.3.3 for shotcrete			N/A
F3		0.40[3]	5000[3]	Table 19.3.3.1 for concrete or Table 19.3.3.3 for shotcrete			26.4.2.2(b)
				Cementitious materials[4] — Types			Calcium chloride admixture
				ASTM C150	ASTM C595	ASTM C1157	
S0		N/A	2500	No type restriction	No type restriction	No type restriction	No restriction
S1		0.50	4000	II[5][6]	Types with (MS) designation	MS	No restriction
S2		0.45	4500	V[6]	Types with (HS) designation	HS	Not permitted
S3	Option 1	0.45	4500	V plus pozzolan or slag cement[7]	Types with (HS) designation plus pozzolan or slag cement[7]	HS plus pozzolan or slag cement[7]	Not permitted
	Option 2	0.40	5000	V[8]	Types with (HS) designation	HS	Not permitted
W0		N/A	2500	None			
W1		N/A	2500	26.4.2.2(d)			
W2		0.50	4000	26.4.2.2(d)			
				Maximum water-soluble chloride ion (Cl^-) content in concrete, percent by mass of cementitious materials[9,10]		Additional provisions	
				Nonprestressed concrete	Prestressed concrete		
C0		N/A	2500	1.00	0.06	None	
C1		N/A	2500	0.30	0.06		
C2		0.40	5000	0.15	0.06	Concrete cover[11]	

Table 19.3.1.1—Exposure categories and classes

Category	Class	Condition	
Freezing and thawing (F)	F0	Concrete not exposed to freezing-and-thawing cycles	
	F1	Concrete exposed to freezing-and-thawing cycles with limited exposure to water	
	F2	Concrete exposed to freezing-and-thawing cycles with frequent exposure to water	
	F3	Concrete exposed to freezing-and-thawing cycles with frequent exposure to water and exposure to deicing chemicals	
Sulfate (S)		Water-soluble sulfate (SO_4^{2-}) in soil, percent by mass[1]	Dissolved sulfate (SO_4^{2-}) in water, ppm[2]
	S0	$SO_4^{2-} < 0.10$	$SO_4^{2-} < 150$
	S1	$0.10 \leq SO_4^{2-} < 0.20$	$150 \leq SO_4^{2-} < 1500$ or seawater
	S2	$0.20 \leq SO_4^{2-} \leq 2.00$	$1500 \leq SO_4^{2-} \leq 10{,}000$
	S3	$SO_4^{2-} > 2.00$	$SO_4^{2-} > 10{,}000$
In contact with water (W)	W0	Concrete dry in service	
	W1	Concrete in contact with water where low permeability is not required	
	W2	Concrete in contact with water where low permeability is required	
Corrosion protection of reinforcement (C)	C0	Concrete dry or protected from moisture	
	C1	Concrete exposed to moisture but not to an external source of chlorides	
	C2	Concrete exposed to moisture and an external source of chlorides from deicing chemicals, salt, brackish water, seawater, or spray from these sources	

[1]Percent sulfate by mass in soil shall be determined by ASTM C1580.

[2]Concentration of dissolved sulfates in water, in ppm, shall be determined by ASTM D516 or ASTM D4130.

CSA A23.1-19 EXPOSURE CLASSES

Table 1
Definitions of C, F, N, A, S and R classes of exposure
(See Clauses 3, 4.1.1.1.1, 4.1.1.1.3, 4.1.1.5, 4.1.1.8.1, 4.1.2.3, 6.1.4, 6.6.7.6.1, 7.1.2.1, 9.1, L.3, and R.1, Tables 2, 3, and 17, and Annex L.)

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 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 structures exposed to seawater located within the tidal and splash zones, concrete exposed to seawater spray, and salt water pools. For seawater or seawater-spray exposures the requirements for S-3 exposure also have to be met.
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 structures exposed to seawater. For seawater or seawater-spray exposures the requirements for S-3 exposure also have to be met.
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 that when in service is neither exposed to chlorides nor to freezing and thawing nor to sulphates, either in a wet or dry environment. Examples: footings, walls, and columns.
N-CF	Interior concrete floors with a steel-trowel finish that are not exposed to chlorides, nor to sulphates either in a wet or dry environment. Examples: interior floors, surface covered applications (carpet, vinyl tile) and surface exposed applications (with or without floor hardener), ice-hockey rinks, freezer warehouse floors.
A-XL	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 might be generated, with higher durability performance expectations than A-1 class.
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 might 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 and to seawater or seawater spray (Tables 2 and 3).
R-1	Residential concrete for footings for walls, columns, fireplaces and chimneys.
R-2	Residential concrete for foundation walls, grade beams, piers, etc.
R-3	Residential concrete for interior slabs on ground not exposed to freezing and thawing or deicing salts.

Table 1 (Concluded)

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 exposed to sulphates shall comply with the minimum requirements of S class noted in Tables 2 and 3. In particular, Classes A-1 to A-4 and A-XL in municipal sewage elements could be subjected to sulphate exposure.*
5) *No hydraulic cement concrete will be entirely resistant in severe acid exposures. The resistance of hydraulic cement concrete in such exposures is largely dependent on its resistance to penetration of fluids.*
6) *Decision of exposure class should be based upon the service conditions of the structure or structural element, and not upon the conditions during construction.*

CSA A23.1-19 EXPOSURE REQS

Table 2
Requirements for C, F, N, A, and S classes of exposure
(See Clauses 4.1.1.1.1, 4.1.1.1.3, 4.1.1.3, 4.1.1.4, 4.1.1.5, 4.1.1.6.2, 4.1.1.8.1, 4.1.1.11, 4.1.2.1, 4.3.1, 4.3.7.1, 4.3.7.2, , 7.1.2.1, 7.5.1.1, 8.7.4.1, 9.4, 9.5, L.1, L.3, and R.3 and Table 1.)

			Air content category as per Table 4[d]		Curing type (see Table 19)			
Class of exposure[a]	**Maximum water-to-cementitious materials ratio[b]**	**Minimum specified compressive strength (MPa) and age (d) at test[b, i]**	**Exposed to cycles of freeze/thaw**	**Not exposed to cycles of freeze/thaw**	**Normal concrete**	**HVSCM-1**	**HVSCM-2**	**Chloride ion penetrability requirements and age at test[c]**
C-XL or A-XL	0.40	50 within 56 d	1	[e]	3	3	3	< 1000 coulombs within 91 d
C-1 or A-1	0.40	35 within 56 d	1	[e]	2	3	2	< 1500 coulombs within 91 d
C-2	0.45[h]	32 at 28 d	1	n/a	2	2	2	—
C-3	0.50	30 at 28 d	n/a	[e]	1	2	2	—
C-4[e]	0.55	25 at 28 d	n/a	[e]	1	2	2	—
A-2	0.45	32 at 28 d	1	[e]	2	2	2	—
A-3	0.50	30 at 28 d	2	[e]	1	2	2	—
A-4	0.55	25 at 28 d	2	[e]	1	2	2	—
F-1	0.50[i]	30 at 28 d	1	n/a	2	3	2	—
F-2 or R-1 or R-2	0.55[i]	25 at 28 d	2[f]	n/a	1	2	2	—
N	As per the mix design for the strength required	For structural design	n/a	[e]	1	2	2	—
N-CF[g] or R-3	0.55	25 at 28 d	n/a	[e]	1	2	2	—
S-1	0.40	35 within 56 d	1	[e]	2	3	2	—
S-2	0.45[j]	32 within 56 d	1	[e]	2	3	2	—
S-3	0.50[j]	30 within 56 d	1	[e]	1	2	2	—

NMX C155-14 EXPOSURE CLASSIFICATIONS

TABLE 9.-Exposure classification to concrete deterioration actions

Classification	Exposure conditions		
1	Dry environment:		
	□ Interior of habitable buildings		
	□ Interior components not being directly exposed to wind nor soils or water		
	□ Regions with relative humidity greater than 60 % for a period not longer than three months per year		
2ª	Humid environment without freezing:		
	□ Interior of buildings with relative humidity greater than 60% for more than three months per year		
	□ Exterior elements exposed to wind but not to freezing		
	□ Elements in non-reactive or non-aggressive soils, and/or in water without freezing possibility		
2b	Humid environment with freezing		
	□ Exterior elements exposed to wind and freezing		
	□ Elements in non-reactive or non-aggressive soils, and /or water with possibility of freezing		
3	Humid environment with freezing and de-icing agents		
	□ Exterior elements exposed to wind, with possibility of freezing and/or exposure to de-icing agents		
	□ Elements in non-reactive non-aggressive soils and/or in water with possibility of freezing and de-icing chemical agents		
4ª	Marine Environment Totally Submerged		
	Totally submerged structures without partial or total air exposure.		
4b	Marine Environment Moderate Grade		
	Salts rich or coastal area, without water contact. Structures with marine air influence in moderate grade, located between 3 km and 300m of the coastal line.		
4c	Marine Environment Severe Grade		
	Salts rich or coastal area, without water contact. Structures with marine air influence in severe grade, located between the coastal line and 300 meters.		
4d	Marine Environment Splashing Zone		
	Salts rich area with water contact, and sea water, water contact cycles. Structures in contact with moistening and drying air.		
5ª	Environment of light chemical aggressiveness (by gases, liquids or solids):		
	□ In contact with water		
	pH	6,5-5,5	
	Aggressive CO_2 (in mg/l as CO_2)	15-30	
	Ammonium (in mg/l as $NH4^+$)	15-30	
	Magnesium (in mg/l as Mg^{2+})	100-300	
	Sulfate (in mg/l as SO_4^{2-})	200-600	
	□□ In contact with soil		
	Degree of acidity according to Baumann – Gully	higher than 20	
	Sulfates (in mg of SO_4^{2-}/kg air dried soil)	2 000 – 6 000	
5b	Environment of moderate chemical aggressiveness (by gases, liquids or solids):		
	□ In contact with water		
	pH	5,5 - 4,5	
	Aggressive CO_2 (in mg CO_2/l)	31 – 60	
	Ammonium (in mg NH_4^+/l)	31 – 60	
	Magnesium (in mg Mg^{2+}/l)	301 - 1 500	
	Sulfate (in mg SO_4^{2-}/l)	601 - 3 000	
	□□ In contact with soil		
	Sulfates (in mg SO_4^{2-}/kg of air dried soil)	6 000-12 000	

NMX C155-14 EXPOSURE CLASSIFICATIONS

5c	Environment with high chemical aggressiveness (by gases, liquids or solids):	
	□□ In contact with water	
	pH	4,5 - 4,0
	Aggressive CO_2 (in mg CO_2/l)	61 – 100
	Ammonium (in mg NH_4^+/l)	61 – 100
	Magnesium (in mg Mg^{2+}/l)	1 501 - 3 000
	Sulfate (in mg SO_4^{2-}/l)	3 001 - 6 000
	□□ In contact with soil	
	Sulfates (in mg SO_4^{2-}/kg of air dried soil)	› 12 000
5d	Environment with high chemical aggressiveness (by gases, liquids or solids):	
	pH	< 4,0
	Aggressive CO_2 (in mg CO_2/l)	> 100
	Ammonium (in mg NH_4^+/l)	> 100
	Magnesium (in mg Mg^{2+}/l)	> 3 000
	Sulfate (in mg SO_4^{2-}/l)	> 6 000
6	Erosion or cavitation actions	
6ª	Light Grade. Road with scarce circulation. Light vehicles and pedestrian traffic. Without freezing risk (SRC).	
6b	Medium Grade. Highways and secondary network roads. Industrial floors with circulation of forklifts with rubber tires with less than 12 t of load. Surfaces with light freight maneuvers in interiors.	
6c	High Degree. Highways with intense load. Forklifts fitted with rubber or metallic wheels with loads greater than 12 t. Hydraulic flow below 12 m/s.	
6d	Severe Degree. Highways with very intense load. Forklifts fitted with rubber, metallic and caterpillar tracked wheels. Switchyards with high traffic and dragging of heavy objects. Hydraulic flow greater than 12 m/s with a risk of cavitation.	

NMX C155-14 DURABILITY REQS

TABLE 10.- Durability requirements according to the exposure class to concrete deterioration actions

DURABILITY REQUIREMENTS		Exposure class according to Table 7																			
		1	2a	2b	3	4a	4b	4c	4d	5a		5b		5c		5d		6a	6b	6c	6d
										With Sulfates	Without Sulfates	With Sulfates	Without Sulfates	With Sulfates	Without Sulfates	With Sulfates	Without Sulfates				
CONCRETE	Minimum Compressive Strength, kgf/cm²	250	250	250	250	300	300	350	350	250	250	300	300	350	350	400	400	250	300	350	400
	Ratio Water/Cement	0,60	0,60	0,55	0,55	0,45	0,45	0,40	0,40	0,50	0,50	0,50	0,50	0,45	0,45	0,40	0,40	0,50	0,50	0,45	0,45
	Air content in accordance with the maximum size of the aggregate in percent				≥ 4% for 40 mm ≥ 5 % for 20 mm ≥ 6% for 10 mm															(**)	(**)
	Maximum permeability to chloride ion, Coulombs	3 500	3 500	3 500	3 500	3 000	2 300	1 800	1 000	3 500	3 500	2 300	2 300	1 800	1 800	1 000	1 000				
	Content of soluble chlorine ions in water (% of the cement weight) Pre-stressed concrete Reinforced concrete																				
		0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06
		0,30	0,30	0,30	0,30	0,08	0,15	0,15	0,08	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30
	*Density, absorption and voids in hardened concrete																				
	*Capillary Absorption																				
	Additional protection of the concrete											yes	yes	yes	yes	yes	YES			yes	yes

NMX C155-14 DURABILITY REQS

TABLE 10.- Durability requirements according to the type of exposure to concrete deterioration actions (Continued)

SPECIAL REQUIREMENTS OF THE CONSTITUENT MATERIALS

Type of cement according to NMX-C-414-ONNCCE (see 3: References) (*)																				
If there is chemical attack of aggressive agents						RS	RS	RS	RS		RS		RS		RS			RS	RS	RS
If the aggregates are reactive or potentially reactive		BRA	BRA	BRA	BRA	BRA	BRA	BRA	BRA	BRA	BRA	BRA	BRA	BRA	BRA	BRA	BRA	BRA	BRA	BRA
Aggregates according to NMX-C-111-ONNCCE																				
Health, NA2, SO4 Maximum loss (%)				< 12 Gravel ≤ 10 Sand													-	≤12 gravel ≤10 sand		
Fines content in sand (% that goes through #200 mesh)																		<5, natural <7 crushed do	<3, natural <5 crushed do	<3, natural <5 crushed do
Fines content in gravel (% that goes through #200 mesh)																	-	≤1	≤1	≤1
Reactivity with cement alkalis		Non-reactive				Non-reactive					Non-reactive					Non-reactive				
Gravel abrasion resistance and impact (%)																	-	≤50	≤50	≤50
Light particles in gravel (%)																	-	≤0.5	≤0.5	≤0.5
Friable particles in sand (%)																	-	≤3.0	≤3.0	≤3.0
Friable particles in gravel (%)																	-	≤5	≤3	≤3

A PERSPECTIVE ABOUT IMPROVING CONCRETE REQUIREMENTS

Accelerated Schedule / Fast-Track

Emergencies

IMPROVING CONCRETE SPECIFICATIONS

S	M	A	R	T
Specific	Measurable	Achievable	Relevant	Time-Bound

A simple way to improve specifications for construction is using the S.M.A.R.T goals fundamentals as part of the review process to ensure the specifications are constructable.

IMPROVING CONCRETE REQUIREMENTS FOR PERFORMANCE

- Technically sound
- Relevant to work
- Clear, concise and specific
- Alignment with demands
- Achievable and executable
- Performance driven
- Flexible to fit for purpose
- No "one size fits all"

Oscar Antommattei, MS, PE, FACI
Chief Concrete Engineer
concrete@kiewit.com

Thank you!

QUESTIONS

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For more information, contact me at concrete@kiewit.com

THANKS!!!