EARLY STRENGTH PROPERTIES

HVFA CONCRETE MIXES FOR HIGH-RISE CONSTRUCTION

PRELIMINARY REPORT

Prepared for:

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1.0 INTRODUCTION

Greater Vancouver Regional District (GVRD) and Industry Canada, in consultation with the concrete industry, has been active in developing the concept of replacing some cement in concrete with fly ash. This activity relates to an overall strategy for sustainability.

Replacement of large volumes of cement, say over 40%, with fly ash results in a concrete known to the industry as high volume fly ash (HVFA). It is recognized that this concrete has excellent long-term properties but can have the disadvantage of slower setting times and lower early age strength. However, the use of HVFA has been successfully implemented on a number of industrial, commercial and institutional structures. To date, it has not been used for high-rise construction because of the more demanding early strength requirements.

GVRD, through their Consultant, Fast & Epp, entered into discussion with a prominent high-rise constructor, Ledcor, about the feasibility of using HVFA in the pending Great West Life Building in downtown Vancouver. Ledcor's concerns were the potential disadvantages noted above, particularly those in cold weather when much of the Great West Life concrete construction will occur. The main concern was the possible need for delayed stripping time and/or additional shoring.

It was agreed that a laboratory trial mix program would be conducted to evaluate the magnitude of the disadvantages and assist Ledcor in assessing these. This report presents the results of that program. It is designated as preliminary because some later age concrete mix strength data is outstanding.

The intent was to improve HVFA mix performance by one of two systems:

- addition of accelerating admixtures;
- reduction of the water:cement by the use of superplasticizers.

The program used common industry concrete mix design for two critical high-rise schedule elements – columns and slabs. Mixes were tested for early age properties at both Summer and Winter temperature conditions. Work was generally in accordance with Levelton's proposal of July 11, 2000. The work was modified after discussion with the concrete supply industry, Ledcor, and Fast & Epp as outlined by Levelton, July 14, 2000.

2.0 OBJECTIVES

The basic objective was to produce HVFA concrete with early age properties equivalent to those of conventional concrete. Specifically, the objectives were:

1) Produce HVFA concrete with early age strength equivalent to normal proportioned concrete, i.e. at 20% fly ash replacement.

2) Achieve 15 MPa in approximately 16 to 40 hours, even at lower curing temperatures.[Note]

[Note] Early strength requirements have been defined by Fast & Epp. They vary for each type of element – see Table in the Appendix.

3) Achieve 1) and 2) in a mode "non-intrusive" to site works, i.e. by the use of accelerating and/or superplasticizing admixtures. In this way, the adjustments are in the mixture proportions, not the construction procedures.

3.0 MATERIALS

Ledcor suggested a choice of two likely concrete suppliers. One of those, Ocean Construction Suppliers Ltd., was selected here due to their strategic location in proximity to the Project site. All materials for the trials were obtained from OCSL.

Levelton undertook to identify an appropriate accelerator by industry and supplier inquiries. It was determined that the most promising admixture was Polarset from Grace – see information in the Appendix.

The superplasticizer used was one in common local use, WRDA 64 by Grace.

Admixture selection was dictated by availability through OCSL. There was no attempt to optimize this selection.

4.0 MIX DESIGNS

The Appendix contains relevant information developed by Fast & Epp in consultation with Ledcor. Included are proposed fly ash replacement amounts. Critical components were:

- 25 or 30 MPa Tower Slabs; 30 MPa was used here as a more representative mix for efficient use of HVFA.
- 40 MPa Shear Walls and Columns.

Levelton has on file standard mix designs from Ocean for the above two classes of concrete. Both are designated as pumpable. These were used as a base for the trial mix proportions here.

The mix designs are shown in Table 1. It will be noted that:

- the aggregate proportioning is relatively sandy and appears to be intended to accommodate pumping; more coarse aggregate would improve strength performance;
- the accelerator dosages designated as "high" in Table 1 represent the upper limit of Grace's recommendations. Such high dosages would not normally be used;
- the HVFA mixes required much less water for a designated slump (compare Mixes 1 and 2) testifying to the improved workability appreciated with HVFA;
- the S/P dosages are higher than what normally would be required – note 230 mm slump for Mix #8 and #9 in Table 2. This was done to assess the limit of the lower water:cement concept; lower dosages would normally be used;

TABLE 1

CONCRETE MIXTURE PROPORTIONS FOR TRIAL MIXES

	Accelerator Series					Low W/C Series		
	Slabs @ 30 MPa						Columns @ 40 MPa	
Temperature	S	S	S	W	W	W	W	S
Mix No.	1	2	3	4	6	7	8	9
Accelerator	None (Control)	Low	High	None (Control)	High	None	None	None
Material								
Cement, kg	240	165	165	240	165	165	210	210
Fly ash, kg	60 = 20%	135 = 45%	135 = 45%	60 = 20%	135 = 45%	135	175 = 45%	175 = 45%
Water. P	150	130	135	150	135	100	112	112
Coarse Aggregate 10 x 5 mm 20 x 10 mm	 350 785	 350 805	 350 805	 350 785	 350 805	 360 800	 345 805	 345 805
Fine Aggregate, kg, SSC	855	855	855	855	855	845	765	765
AEA, ml	90	90	90	90	90	90	116	116
WRA, ml	750	750	750	750	750	750	965	965
Accelerator, P	0	2.5	5.0	0	5.0	0	0	0
Superplasticizer, (S/P), P	-	-	-	-	-	1.5	2.0	2.0

Note: S = Summer - ~ 23°C
W = Winter - 5°C

- fly ash replacement was done as a direct weight-for-weight of cement. Common mixture proportioning would increase the total cementing materials content of these HVFA mixes by 5 to 10%.

Overall, the mix designs were intended to provide conservative results.

The 20% fly ash for Control mixes is the amount commonly used by the ready-mix industry. The 45% used for HVFA is considered a maximum practical limit for high-rise construction and is consistent with Fast & Epp's recommendations in the Appendix.

5.0 METHODOLOGY

Following is a description of the test program.

- Trial mixes were prepared in a 0.07 m^3 revolving drum mixer to CSA A23.2-2C procedures.
- Normal plastic property tests were conducted to the appropriate requirements of CSA A23.2.[Note]
- Maturity was measured using a meter commonly used in the field. See Photographs 1 and 2.
- Time of set was measured by penetration needles (ASTM C403) – see Photograph 3 .
- All compressive strength cylinders were 100 x 200 mm.
- All "Summer" samples were stored in the moist room at 23ºC.
- "Winter" samples were stored in Levelton's cold room at 5ºC until an age of 3 days, and at 23ºC in a moist room thereafter. The 5ºC curing was selected as the minimum that would be used without supplementary heating in high-rise construction. This temperature would violate Table 14 of CSA A23.1 for thinner sections such as walls, but it is still commonly used – see Appendix.

[Note] The Maturity theory was developed in the 1950s by Plowman and subsequently refined by a number of researchers (Saul, Malhotra, Carino). It basically says:

$$f_c = fn\,(A + B \log_{10} \bullet M)$$

where

f_c is the concrete compressive strength at a particular age

A and B are constants
M is the maturity which is {time X (temperature over a base normally taken as –11ºC)}

The theory results in a linear relation between strength and time when plotted on a semi-log scale.

6.0 REFERENCE INFORMATION

Prior to undertaking this program, Levelton attempted to determine if parallel research had been done elsewhere. A literature search was conducted and an enquiry made of CANMET who are recognized authorities in HVFA. Test results for time of set vs fly ash dosage were located but there was limited information on early age strength applicable here other than general statements, well known, that "…fly ash mixes will have lower early strength…".

6.1 Setting Time

Rivera[(1)] compared setting time and determined:

- For a control mix with no fly ash or S/P, final setting increased from 6 hour to 9-1/2 hours with a temperature decrease from 23 to 15°C;
- The addition of a naphthalene S/P increased final setting times by ½ hour at 23°C and by ¾ hour at 15°C;
- The replacement of 30% fly ash increase the same setting time ½ hour at 23°C and 1 hour at 15°C;
- When both S/P and fly ash were used, there was a cumulative effect which increased final setting times:
    - at 23°C, 2 hours.
    - at 15°C, 3 hours.

Eren[(3)] also investigated the effect on time of set of mixes with increasing fly ash contents. That work can be summarized for purposes here as:

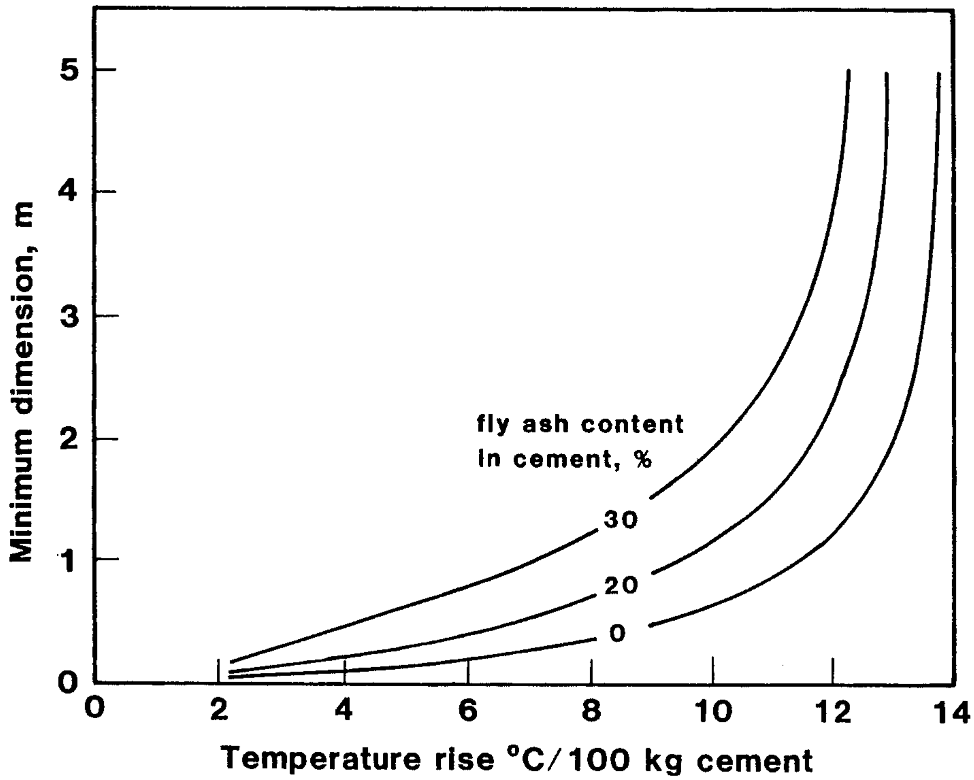
Fly Ash Replacement, %	Final Set, Hours, for Curing Temperature	
	20°C	6°C
0	7	16
30	8-1/4	19-1/2
50	10-1/2	21-1/2

(1) "Effect of Temperature on the Properties of Mortars and Superplasticized Concrete Containing Low-Calcium Fly Ash", R. Rivera, ACI SP 91-9, p219, 1986.

(3) "Setting Times of Fly Ash and Slag-Cement Concretes as Affected by Curing"; O. Eren, J. Brooks, T. Celik, ASTM Cement, Concrete, and Aggregates, Vol. 17, #1, June/95.

6.2 Temperature Rise by Heat of Hydration.

Berry and Malhotra[(2)] showed the following relationship.



This emphasizes the reduced heat (and corresponding reduced strength gain) in forms when fly ash is used.

6.3 Strength vs Temperature

Berry and Malhotra[(2)] also showed that 20% fly ash replacement in a 300 kg cement mix resulted in 1 day strength drops from 12 MPa to 9 MPa when cured at 23°C.

With a high calcium fly ash, 7 day strengths of a 50% fly ash replacement 35 MPa mix dropped to 21 MPa compared with a 20% fly ash mix at 27 MPa.

What is missing from the literature is a family of curves showing temperature vs strength at various early ages and at various fly ash replacements.

[(2)] "Fly Ash in Concrete", Berry and Malhotra, CANMET Publication, Feb/86.

7.0 RESULTS

Concrete properties are presented in Table 2. Following are some observations:

- Mixes with S/P have higher slumps than are normally used.
- Air contents are generally high which will provide conservative strength results. The addition of accelerator and S/P generally increased the air content.
- The combination of HVFA + S/P (Mixes 7,8,9) resulted in very low water:cementing materials.
- Initial results showed poor performance with the accelerator so the planned low temperature mix with lower accelerator dosage was abandoned.

Graphs 1 and 2 show the strength as Maturity for Slab concrete, both Summer and Winter curing temperatures. Graph 3 shows the results for Column mixes.

Graphs 4 and 5 are simplified versions of Graphs 1 and 2. They show approximate age:strength relationships for Summer and Winter exposure.

8.0 ANALYSIS

8.1 Properties of Trial Mixes

In considering this data, it is emphasized, as explained in 4.0, that the results are intentionally conservative in that:

- Air contents – see Table 2 – are relatively high. At more common lower values, additional strength (often approximated as 5% strength for each 1 % air) would be appreciated.
- Slumps, and therefore S/P dosages for lower water:cementitious are higher than is normally required.
- The 5°C winter temperature is lower than limits permitted in CSA A23.1.
- Fly ash was batched as a direct replacement for cement.

One area where results are not conservative is in the initial mix temperature which was 20 +/-°C here but would be lower, typically 15°C, in Winter concrete supply.

The following is observed:

1) For setting times, Control mixes produced expected values (5 +/- hours for initial set in Summer). The delay for HVFA mixes at Summer temperatures is about 1 hour. Dramatic delays occur at 5ºC exposure for control and HVFA mixes, much more so for the latter, again as expected and as reported in the literature – see 6.0.
2) The addition of the S/P had the effect of delaying setting times – compare Mixes #8 and #1. All S/P are naturally retarders but they usually contain compensating accelerators. This setting delay had the corresponding effect of delaying early age strength gain.

TABLE 2

HVFA TRIAL MIX TEST RESULTS

	Accelerator Series Slabs @ 30 MPa					Low W/C Series Columns @ 40 MPa		
Temperature	S	S	S	W	W	W	S	W
Mix No.	1	2	3	4	6	7	8	9
Accelerator	None (Control)	Low	High	None (Control)	High	None	None	None
Plastic Properties								
Slump, mm	80	90	130	80	100	50/180	60/230	70/230
Air, %	5.6	6.0	6.4	5.3	5.8	7.2	7.0	5.8
Unit weight kg/m³	2422	2403	2370	2411	2380	2345	2344	2381
Water:cement	0.50	0.43	0.45	0.50	0.45	0.33	0.29	0.29
Compressive Strength MPa / Maturity, °C – hr								
1 day	11.0 / 654	7.5 / 827	6.8 / 826	6.5 / 774	4.2 / 707	1.9 / 654	10.3 / 869	2.9 / 697
2 days	17.0 / 1661	12.4 / 1629	11.3 / 1649	10.9 / 1386	8.5 / 1308	6.3 / 1233	17.9 / 1697	10.4 / 1350
3 days	20.4 / 2491	14.7 / 2427	12.6 / 2448	13.1 / 1948	10.6 / 1786	8.6 / 1713	21.4 / 2482	13.0 / 1845
7 days	25.7	18.7	16.7	23.1	17.2	18.7	29.5	24.9
56 days	37.1	32.2	28.1	34.7	30.9	32.8	47.5	43.5
Time of Set, hours								
Initial	5.5	6.75	6.25	10	□ 13	> 15	9.5	> 14
Final	6.5	8.5	8	> 12	> 15	> 24	10.75	> 24

Note: S = Summer - ~ 23°C
W = Winter - 5°C

3) The addition of the Polarset produced no improvement in strength gain or setting. In fact, the accelerator results were lower – see Graph. This was disappointing, particularly after representation by the supplier. This concept must be abandoned. A possible explanation for this poor performance is the fact that the accelerator acts primarily with the C_3A part of the hydrating cement and this C_3A is proportionally reduced in HVFA mixes.

4) These higher fly ash replacements produced dramatic decreases in mixing water content as has been experienced with previous HVFA mixes – see Table 1.

5) With regard to stripping time, Graphs 1 and 2 (also Graphs 3 and 4) show that Ledcor's design values (see Appendix) can be readily achieved for Slabs with the Control mix during Summer but not Winter. None of the HVFA mixes come close to the 15 MPa in 40 hour requirement for Tower Slabs. For the Columns, no mix, including the Control (Mix #4) come close to the 24 MPa in 16 hour requirement – see Graph 3.

6) All mixes, except Mix #3 with high accelerator dosage and Summer exposure, achieved the required 56 day strength. However HVFA mixes did not achieve the same strength as the Control at this age.

7) Good linearity was achieved between strength and log age as predicted by the Maturity principle.

9.0 RELEVANCE TO GWL CONSTRUCTION

These results show that it will be difficult to meet the early age strength requirements, as defined by Fast & Epp. These appear ambitious. Even the Control mixes (20% fly ash) had difficulty meeting those requirements, particularly the 15 MPa requirement in 16 hours for the 40 MPa Column mix – see Graph 3.

It is clear that:

- HVFA mixes are not suitable for high-rise construction elements with demanding early-age requirements.
- Accelerators are not a solution.
- S/P to lower water:cementitius are not a solution because of their early retardation (there are alternate S/P types now available that would improve this situation).

However, there is no reason why HVFA concrete could not be used in elements without demanding early strengths. Most of this concrete is in the podium.

The optimum fly ash replacement will be <45% in cooler weather.

The use of HVFA concrete would be enhanced if the strength acceptance age was increased to 90 days rather than the common 56 days.

The above analysis is conservative and makes no allowance for hoarding and heating that may be done by Ledcor.

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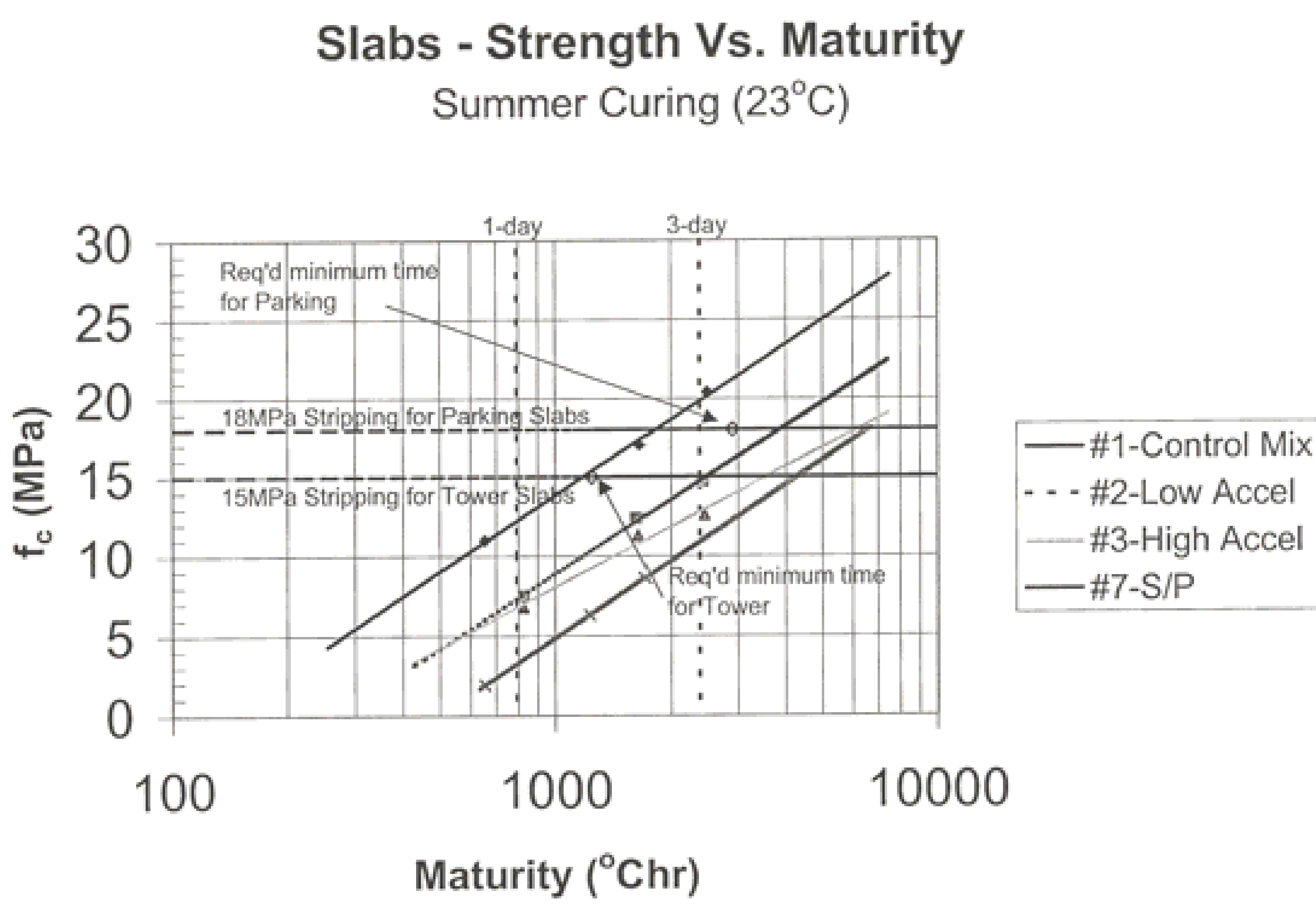

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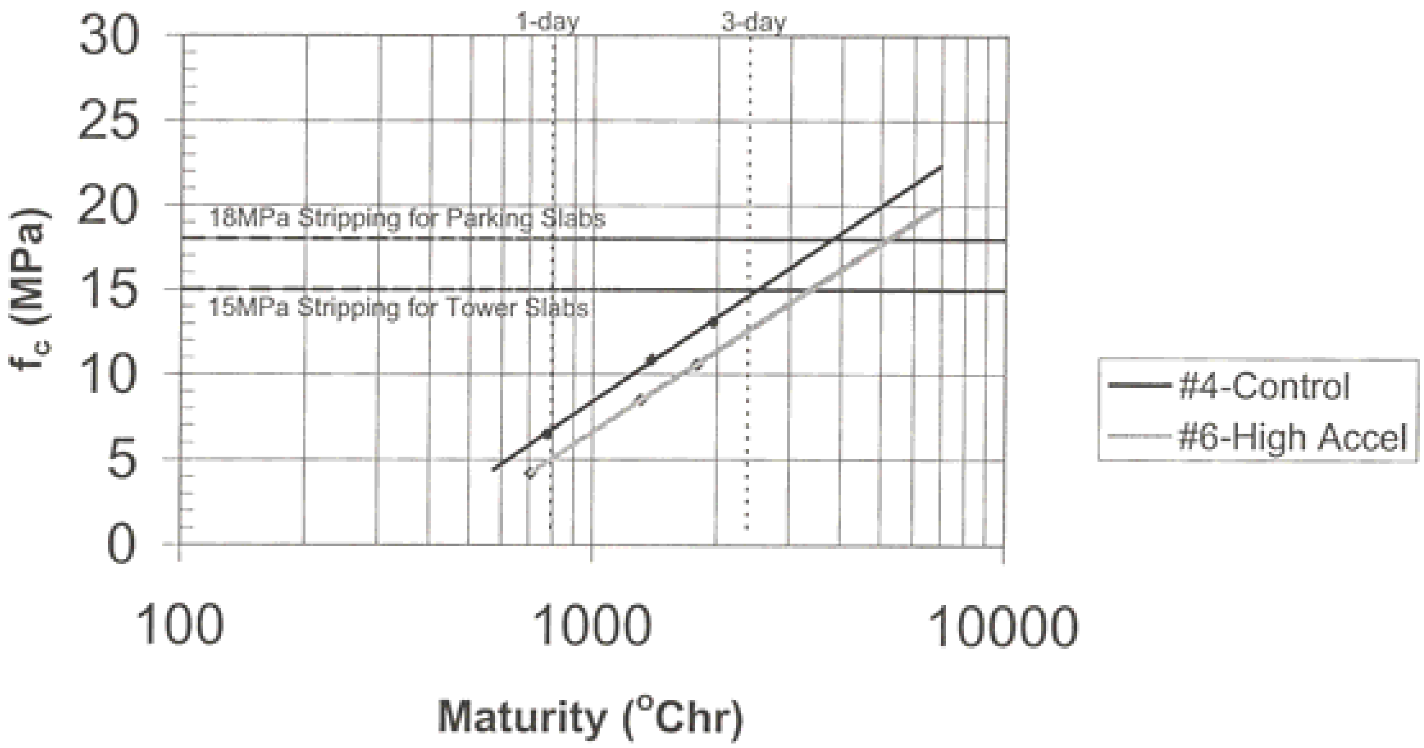
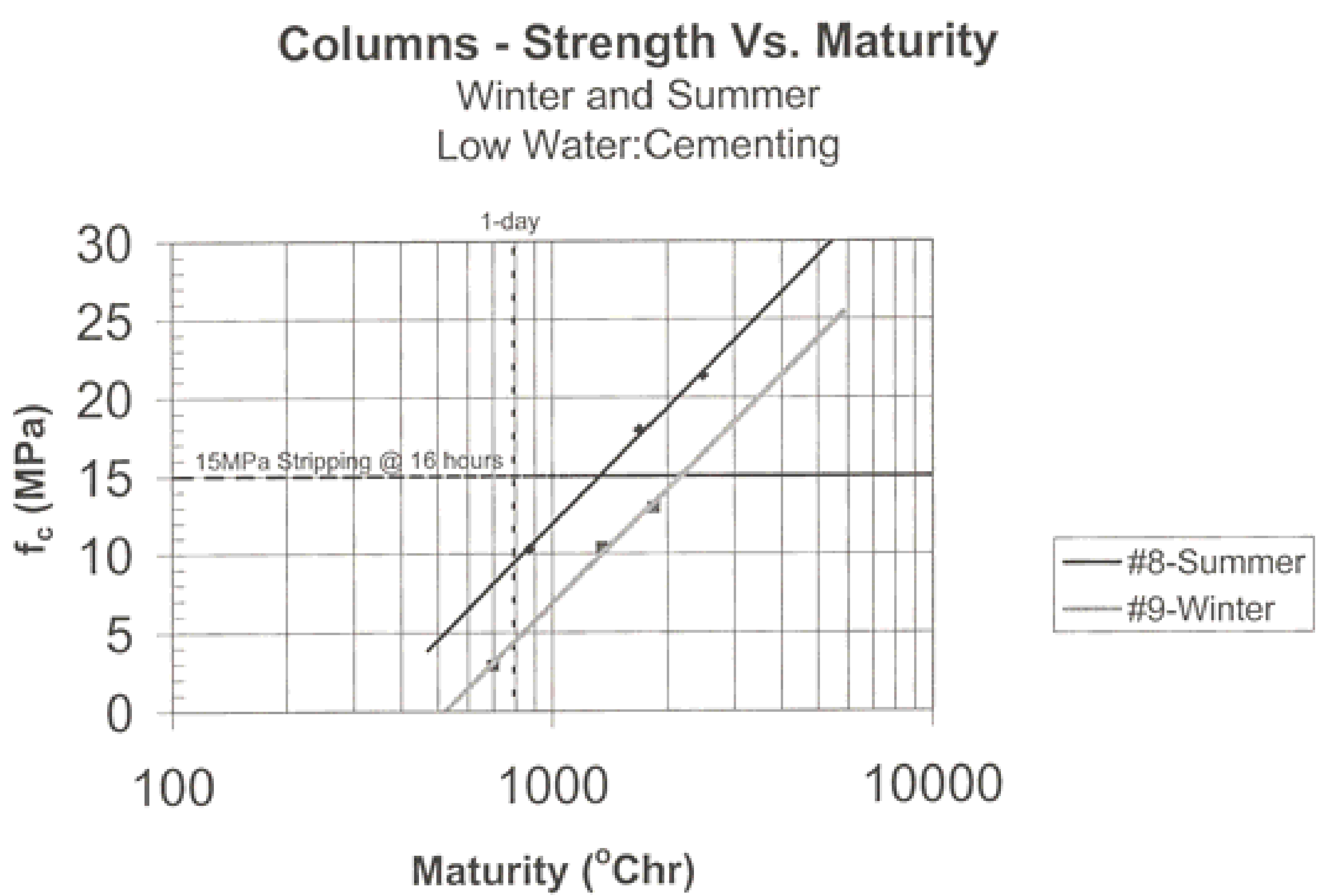
Graph 1

Slabs - Strength Vs. Maturity

Winter Temperature

Curing (+5°C)





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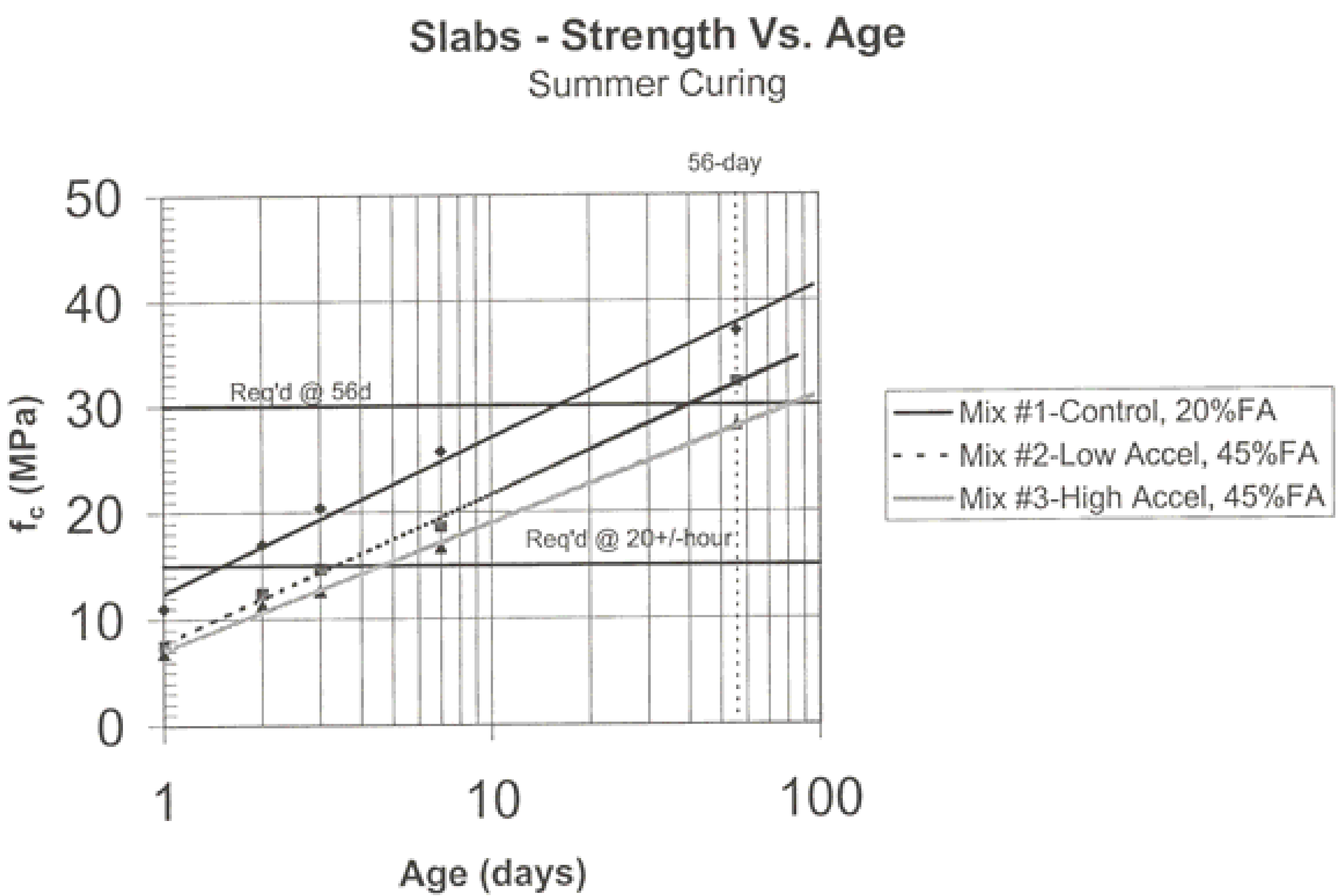
Graph 3



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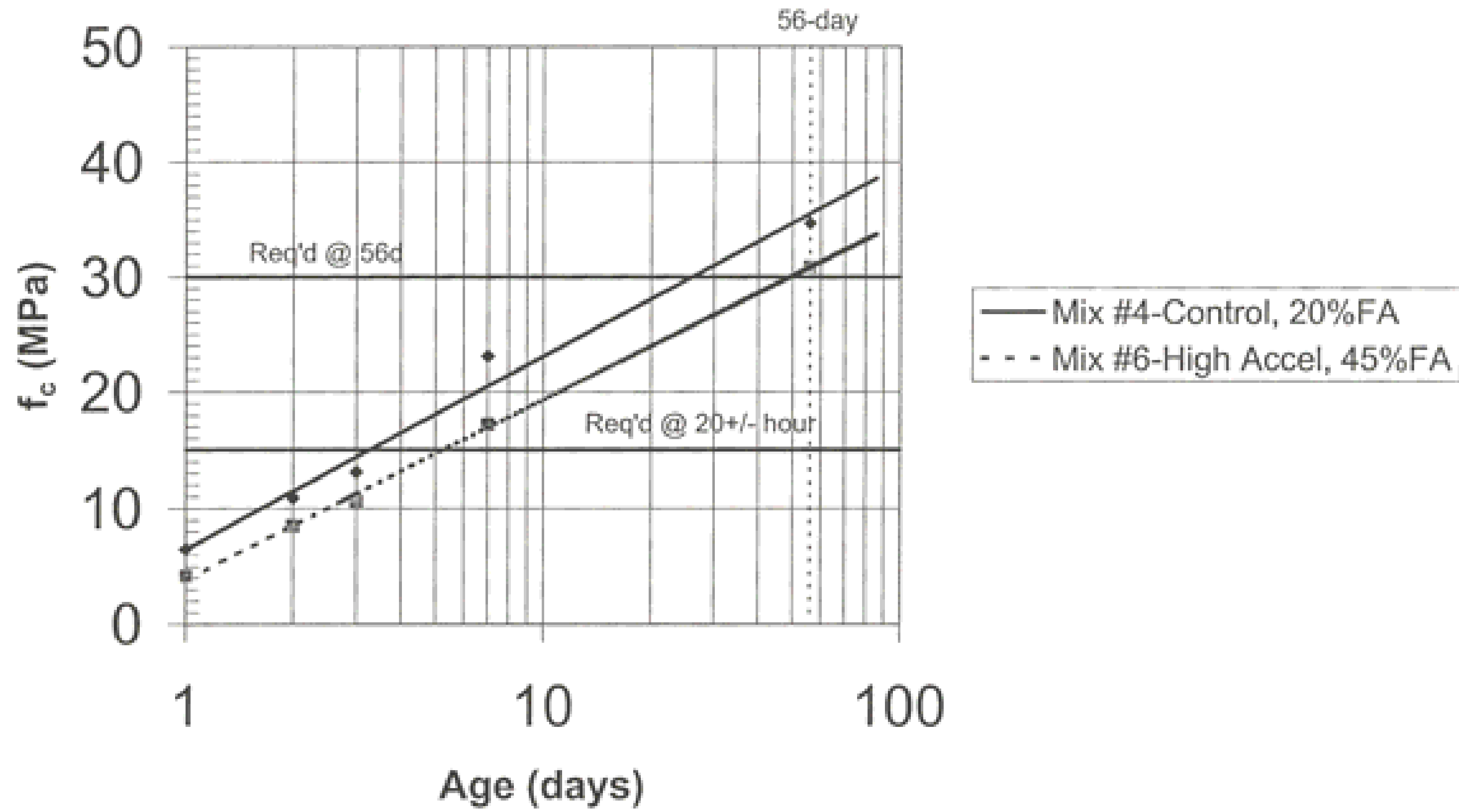
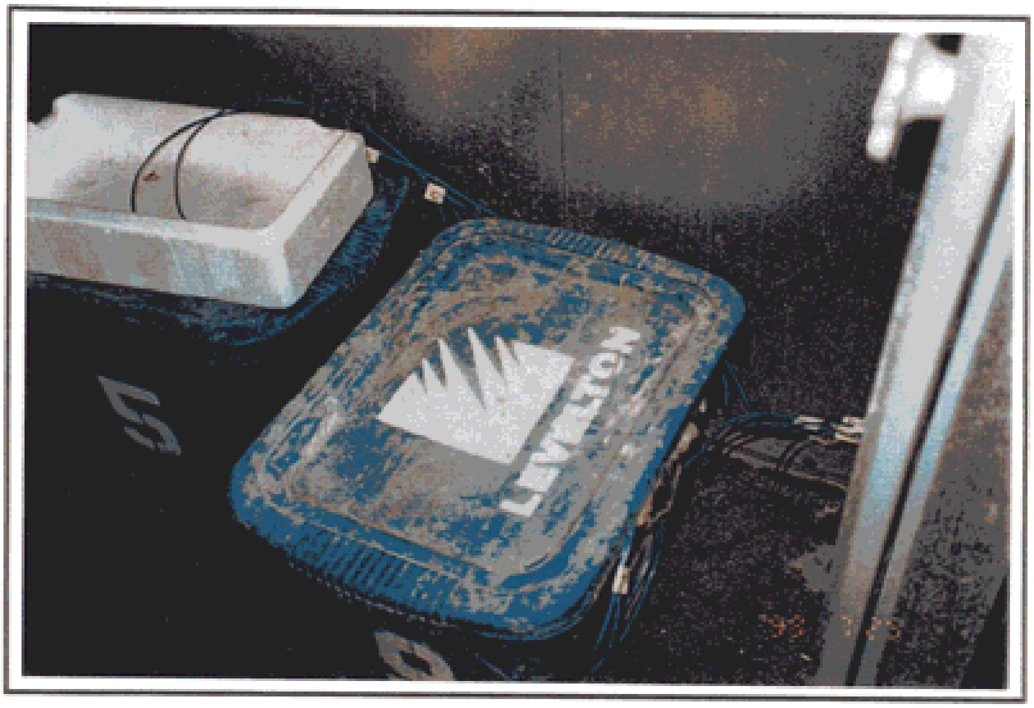
Graph 4

Slabs - Strength Vs. Age

Winter Curing





Photograph 1 - Cylinder storage chest in cold room – this is Levelton's standard cylinder protection box.

Photograph 2 – Measuring maturity of cylinders.

Photograph 3 Time of set petronometer.

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APPENDIX

Rev/0 Rev 1

Supplementary Concrete Supply Specification
July 18, 2000

General

It is the intent of this supplementary specification to provide parameters for the use of higher doses of fly ash than typically used in hi-rise construction. Increased fly ash usage would support Canada's commitment to reduce greenhouse gas emissions. It not only reduces the amount of cement produced it also results in utilization of an otherwise unwanted byproduct.

Levels of fly ash required for each element are shown in column (g) of the table C-1.

Table C-1	(a)	(b)	(c)	(d)	(e)	(f)	(g)
Element	Min 56 day Strength (mPa)	Slump	Max. Aggregate	Exposure Class	Design Stripping Strength * mPa	Time Stripping Strength Required (hrs)	% flyash (of total cementitious material)
Parking Slabs and Slab Bands	35	80	20	C-1	18	88 (min) 112 (typ.)	40
Slab on Grade Interior Parking	30	80	20	C-4	N/A		50
Slab on Grade Exterior	32	80	20	C-2	N/A		30
Core Footing	30	80	40	N	N/A		55
Other Footings	30	80	40	N	N/A		55
Shear Walls and Columns							
Parkade and Commercial	40	80	20	N	15	40	50
4th to 8th Floor	40	80	20	N	15	16	45
8th to 12th Floor	35	80	20	N	15	16	45
12th to 16th Floor	30	80	20	N	15	16	45
16th Floor to Roof & Other Walls	30	80	20	N	15	16	45
Tower Slabs	30	80	20	N	15	40	40
Toppings & Housekeeping Pads	30	80	20	N	N/A		35

- Stripping strength must be achieved within periods shown in column (f)

Compressive strength measurements for final acceptance of all concrete will be taken at 56 days.

Materials
Supplementary cementing materials shall conform to CSA-A23.5. Fly ash shall comply with the CSA 23.5 requirements for TYPE F or Class C1 fly ash.

Early Strengths
In order to maintain the required schedule, the supplier shall ensure that concrete elements must achieve stripping strengths shown in column (e) within times shown in column (f).

Required stripping strengths must be achieved on a consistent basis at all temperatures. Fly ash levels shown in column (g) must be maintained while forecasted low temperatures are 7 degrees Celsius and above for a period of 24 hours after placing.

When forecasted low temperatures are expected to be lower than 7 degrees Celsius for a period of 24 hours after placing fly ash levels may be lowered incrementally but shall not be lowered to below 25% of total cementitious material content for any element regardless of temperature.

Testing

Considerable testing has been done on high volume fly ash concrete to date however to assist suppliers for this project Levelton Engineering Ltd. will also produce an early age screening strength study for a representative mix which will consider various doses of accelerator on the early strength of fly ash. The testing program anticipates interpreting the data in terms of overall requirements and some adjustments to the mix designs may occur as a result of test program results however the supplier should not assume that fly ash replacement percentages will be significantly reduced.

The study will begin on July 17th, 2000 and. The testing program results will be available on completion (mid September).

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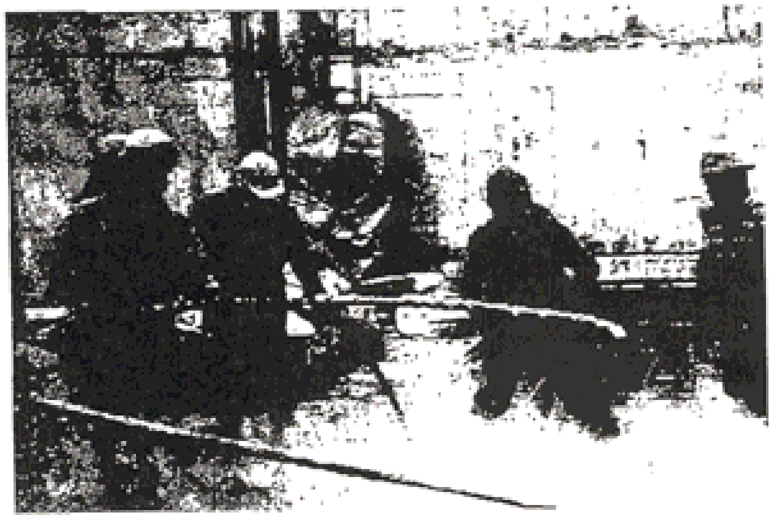
Concrete

ATION

PolarSet®

Non-Corrosive, Non-Chloride Set Accelerating Admixture
ASTM C 494, Type C



Description

PolarSet® is a non-corrosive, non-chloride admixture for concrete. It accelerates cement hydration resulting in shortened setting times and increased early compressive strengths.

PolarSet®

PolarSet does not contain calcium chloride and is completely non-corrosive to reinforcing steel, metal decks, and to all metal components of your admixture storage and dispensing system. It is formulated to comply with ASTM C 494 Type C and can be used at any dosage to comply with ACI 318 guidelines for chloride content of concrete. One Liter of PolarSet weighs approximately 1.35 kg (11.25 lbs/gal).

Uses

PolarSet is specially formulated to reduce concrete setting times and increase early strengths for concrete in very cold conditions, and may be used to reduce the time that concrete must be protected against freezing in ambient temperatures as low as -7 °C (20 °F).

For conditions not subject to freezing, PolarSet may be used to speed finishing operations and/or form removal, leading to savings in concrete construction costs.

Special Feature

PolarSet provides set time acceleration and early strength development similar to that provided by calcium chloride, but without the potential corrosive effects. PolarSet can, therefore, be used where potential corrosion of embedded or stressed steel must be avoided. It can also be used in concrete that is to be placed on steel clad or zinc coated steel decks where corrosion must be similarly avoided.

Chemical Action

In concrete mixes, PolarSet accelerates the chemical reaction between portland cement and water. It speeds up the formation of gel — the binder that bonds concrete aggregates together. Accelerated gel formation in turn shortens the setting time of con-

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crete, compensates for the set-slowing effects of cold weather and contributes to the development of higher strengths. Gel formation promotes heat generation within the mix — helping to protect the concrete from freezing during the critical first hours after placement.

Addition Rates

The amount of PolarSet used will depend on specific job conditions, on local materials and on the degree of set acceleration and early strength development required. Typical addition levels range from 520 to 3910 mL/100 kg (8 to 60 fl oz/100 lbs) of cement, but levels as high as 6520 mL/100 kg (100 fl oz/100 lbs) of cement can be used. For freeze protection purposes typical addition rates are between 3910 to 5220 mL/100 kg (60 to 80 fl oz/100 lbs) of cement.

Compatibility with Other Admixtures

PolarSet is compatible with air-entraining admixtures such as Darex® II, Daravair® and Airalon® 20 AEA; water reducers such as WRDA® with Hycol® or WRDA 79, mid-range water reducers such as Daracem® 50 and 55, and high range water reducers such as Daracem 19 and Daracem 100. Precaution should be taken to avoid mixing PolarSet with other admixtures before they enter the concrete. However, once they have been separately added to the mix, the products will function as prescribed.

Mix Adjustment

Since PolarSet may be used at high dosages, the concrete producer should account for the water contained in the PolarSet. Each Liter of PolarSet added to a concrete mix will contribute 0.78 kg (6.5 lbs/gal) of water to that mix.

Dispensing Equipment

A complete line of accurate dispensers is available. PolarSet may be introduced on the sand, in the water, or at the end of the batch cycles. Similar to all concrete admixtures, PolarSet should not come in contact with other admixtures prior to entering the concrete.

Packaging and Availability

PolarSet is currently available in bulk quantities by Grace metered systems, or in 210 L (55 gal) drums. PolarSet freezes at approximately -23 °C (-10 °F), but its set acceleration, strength gain and non-corrosive properties are completely restored by thawing and thorough agitation.

Architects' Specifications

The set accelerating admixture shall be PolarSet, non-corrosive, non-chloride set accelerator, as manufactured by Grace Construction Products. The admixture shall be used in strict accordance with the manufacturer's recommendations. The admixture shall comply with ASTM Designation C 494, Type C and will not contain purposely added chlorides or contribute to steel corrosion. Certification of compliance will be made available upon request.

Concrete shall be proportioned in accordance with Recommended Practice for Selecting Proportions for Normal Weight Concrete, ACI 211.1 or Recommended Practice for Selecting Proportions for Structural Lightweight Concrete, ACI 211.2, or in accordance with ACI 318.

NOTE TO SPECIFIER: For use in freeze protection, request sample specification available from your Grace Engineering Services Representative.

POLARSET
PAGE 2

W.R. Grace & Co.-Conn. 62 Whittemore Avenue Cambridge, MA 02140

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(c) lowering the concrete temperature;
(d) covering the concrete surface with white polyethylene sheeting between the various finishing operations;
(e) applying fog spray immediately after placement and before finishing. Care shall be taken to prevent accumulation of water that may reduce the quality of the cement paste;
(f) beginning the concrete curing immediately after trowelling; or
(g) placing and finishing at night.

Notes:

(1) *The rate of evaporation can be estimated from Figure D1 of Appendix D using measurements of relative humidity, concrete temperature, air temperature, and wind velocity.*

(2) *There is no way to predict with certainty when plastic shrinkage cracking may occur. Plastic shrinkage cracking is normally caused by loss of moisture from the surface of the concrete due to rapid drying conditions and is usually associated with hot-weather concreting, or when the concrete temperature exceeds the ambient temperature in cool weather. However, it can occur at any time that the rate of evaporation from the surface exceeds the rate of bleeding of the concrete.*

(3) *There are spray-on mono-molecular materials that may control evaporation.*

21.2.3 Cold-Weather Protection

21.2.3.1 Job Preparation

When the air temperature is at or below 5°C, or when there is a probability of its falling below 5°C within 24 h of placing (as forecast by the nearest official meteorological office), all materials and equipment needed for adequate protection and curing shall be on hand and ready for use before concrete placement is started. The extent of such preparation shall be in accordance with the requirements of Clause 21.2.3.4.

21.2.3.2 Concrete Temperature

The temperature of the concrete as placed shall be within the limits shown in Table 14 for the indicated size of concrete section.

Note: *The placing temperature should be kept as close as possible to the suggested minimum temperatures shown in Table 14. Higher temperatures result in an increase in mixing water, increased slump loss, and an increase in thermal shrinkage.*

Table 14
Permissible Concrete Temperatures at Placing

Thickness of section, m	Temperatures, °C	
	Minimum	Maximum
Less than 0.3	10	35
0.3–1	10	30
1 –2	5	25
More than 2	5	20

21.2.3.3 Placing

All snow and ice shall be removed before concrete is deposited on any surface. Calcium chloride or other deicing salts shall not be used as a deicing agent in the forms. Concrete shall not be placed on, or against, any surface that will lower the temperature of the concrete in place below the minimum value shown in Table 14.