Technical Bulletin

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Cold Weather Concreting

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Cold Weather Concreting

INTRODUCTION

Background

This document provides guidelines for using Arxx™ forms to provide required protection for freshly placed concrete during cold weather conditions.

The requirements for protection of concrete are defined in ACI306.1-90 "Cold Weather Concreting Specification" with Cold Weather defined as:

> *A period when for more than three successive days the average daily outdoor temperature drops below 40° F (4.5° C). The average daily temperature is the average of the highest and lowest temperature during the period from midnight to midnight. When temperatures above 50° F (10° C) occur during more than half of any 24 hour duration, the period shall no longer be regarded as cold weather.*

When conditions defined above occur the following requirements of ACI 306.1-90 must be met:

1. Minimum temperature of concrete as placed and maintained during the protection period 55° F (12.8° C).
2. Protection period shall be a minimum of 3 days. The protection period may be reduced to 2 days if use of one or more of the following to alter the concrete mixture is accepted:
   - Type III (Type 30) Portland Cement meeting the requirements of ASTM C 150
   - A strength accelerating admixture meeting the requirements of ASTM C 94.
   - 100 lb/yd^3 of additional cement.

By adhering to these cold weather concreting requirements the full compressive strength of the concrete will eventually be developed even for concrete placed in extreme cold conditions.

Concrete Strength Development

The strength development of concrete is a function of the temperature at which it cures. Normal 28 day concrete compressive strengths are based on the assumption that the concrete is moist cured at an ideal temperature of 72° F (22° C) for the entire time. Temperatures higher than this value will shorten curing time and lower temperatures will increase curing time.

Once the concrete temperature drops below 50° F (10° C) hydration is retarded consequently slowing strength gain. If the concrete temperature falls below approximately 14° F (-10° C), hydration ceases [5] along with strength gain. Once favourable temperatures return hydration will commence again and the full compressive strength can be attained providing the concrete was protected from freezing at an early age.

It is generally accepted [5] that if fresh concrete is prevented from freezing until the degree of saturation of the concrete has been sufficiently reduced by the hydration process then subsequent freezing will not damage the concrete. This point corresponds approximately to a compressive strength of 500 psi (3.4 MPa). Under normal temperatures this strength is reached within the first 24 hrs after placing. At colder temperatures longer periods are required to achieve this strength.

The purpose of the protection period then is to ensure that the degree of saturation of the concrete is low enough and a minimum strength level is achieved before protection measures are discontinued. If the concrete is then frozen following this point the concrete will still develop its full strength when warmer temperatures return. When the contract drawings/specifications specify that a minimum concrete strength (eg 70% of 28 day compressive strength) must be developed prior to continuing construction then the protection period will have to be extended to achieve the desired strength under cold weather conditions. In these circumstances it is recommended that the concrete temperature be monitored and a method such as the maturity factor be used to estimate the concrete strength. This procedure is outlined in ACI 306R-88 "Cold Weather Concreting". Alternately core samples may be taken and compression testing performed to determine when the required strength has been achieved.

GUIDELINES AND PROCEDURES

Cold Weather Concreting using Arxx™ Forms

A test program in conjunction with computer simulations was used to establish the Minimum Average Daily Temperature limit above which Arxx™ forms can safely meet the requirements of ACI 306.1-90 with no additional protection measures required.

The test program consisted of placing freshly poured test samples of each of the different form widths into a conditioned chamber at –20° C (-4° F) for a period of 7 days. The specimens were instrumented with thermocouples and monitored at regular intervals for the entire test period. The results of the tests are provided in Bodycote ORTECH Inc. Report No. 00-06-M018.

The test data was used to validate a 3-Dimensional Finite Element (FE) model of the test samples. The validated FE model was then employed to determine the effect of varying cement content, cement type and concrete placing temperature on the Minimum Daily Average Temperature at which the concrete could be safely placed and maintained at a temperature above 55° F (13° C) for the required protection period. Details of the FE modelling are provided in Ryerson Polytechnic University Research Report No. ML0500/01.

Determining Minimum Average Daily Temperature

The graphs developed using the FE model are provided as Figures 1 through 12. Figures 1 to 6 are presented in metric units and Figures 7 to 12 presents the results in imperial units. Figures 1 to 3 and 7 to 9 are for concrete using Type I (Type 10) cement. Figures 4 to 6 and 10 to 12 are for concrete using Type III (Type 30) cement.

The graphs may be used to determine the Minimum Average Daily Temperature at which concrete can safely be placed in Arxx™ forms without the use of additional protection measures. To make use of the graphs the Arxx™ form size, cement type, concrete mix cement content and minimum concrete temperature at time of placing must be known.

To determine the minimum allowable average outdoor temperature use the following procedure:

1. Select the graph from either Figures 1 to 6 (metric units) or Figures 7 to 12 (imperial units) that corresponds to the cement type and form width that will be used on the project.
2. Locate the cement content of the concrete mix on the X-axis and move up the graph until the appropriate concrete temperature at time of placing line is intersected.
3. Read horizontally across to the minimum external temperature value on the Y-axis. This is the minimum average daily temperature that is permitted during the protection period.
4. Comparison of the temperature obtained in step 3 to the average of the high and low temperatures forecast for the protection period following placing will provide an indication if conditions are favourable. If the temperature is expected to fall below the value determined from the graph then additional protection measures will be required to maintain the concrete temperature above the required value.

Appendix A provides an illustrative example on use of the charts.

Arxx™ Cold Weather Concreting Procedures

The following procedures shall be followed when placing concrete in Arxx Wall System Forms during cold weather periods:

1. The minimum protection period shall be as follows:

   Type I (Type 10) cement – 3 days

   Type III (Type 30) cement – 2 days

2. The substrate (footing, floor, wall etc.) on which the concrete wall is to be placed shall be above freezing temperature for the entire protection period. The method employed to ensure this criteria is met is the responsibility of the contractor. For further details on the methods and procedures for Cold Weather Concreting it is recommended that the user refer to one or all of the following references.

   Standard Specification for Cold Weather Concreting (ACI 306.1-90) - American Concrete Institute

   Cold Weather Concreting (ACI 306R-88) Reported by ACI Committee 306 - American Concrete Institute

   Design and Control of Concrete Mixtures 13th Edition - Portland Cement Association

3. The top of the wall and any exposed surfaces around openings shall be insulated with a minimum of R10 rigid insulation. EPS or XPS insulation is recommended for this purpose. The joint between the edge insulation and the wall shall be taped or otherwise sealed to prevent the concrete from direct exposure to the outdoor air.

4. Records of the actual daily high and low temperatures during the protection period shall be kept.

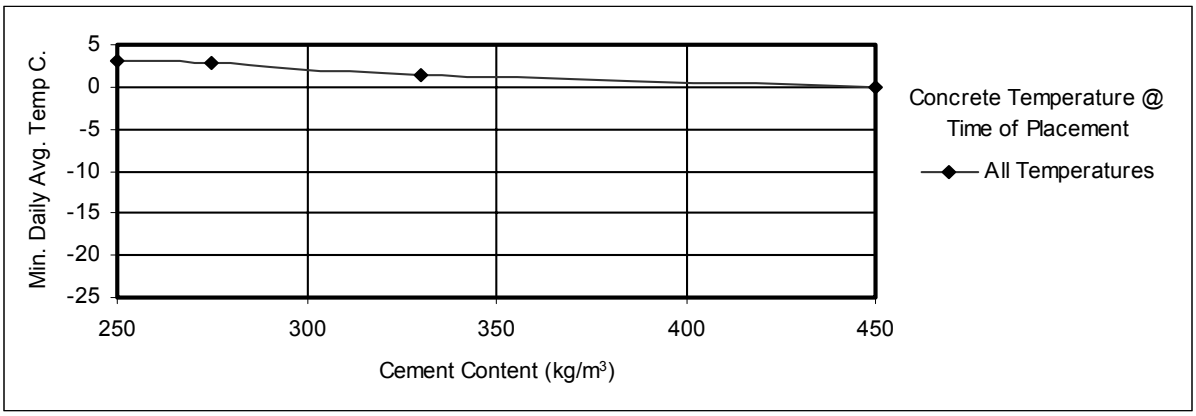

FIGURE 1 - 4" ARXX FORM, TYPE I (TYPE10) CEMENT – METRIC UNITS

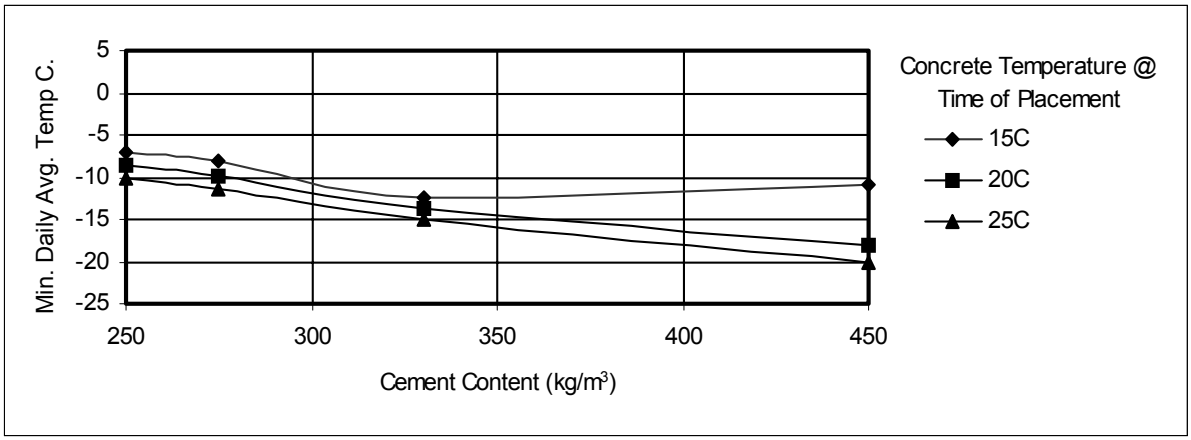

FIGURE 2 – 6 1/4" ARXX FORM, TYPE I (TYPE10) CEMENT – METRIC UNITS

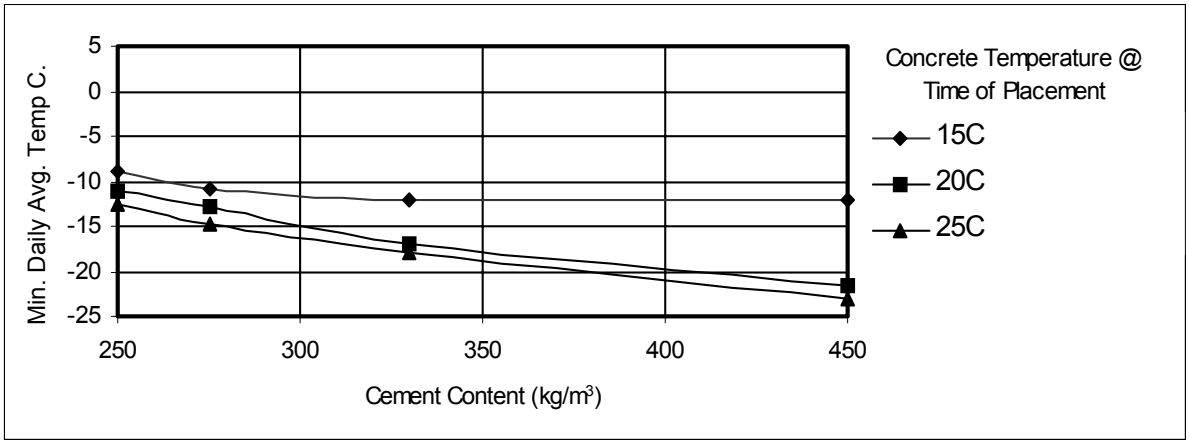

FIGURE 3 – 8" ARXX FORM, TYPE I (TYPE 10) CEMENT – METRIC UNITS

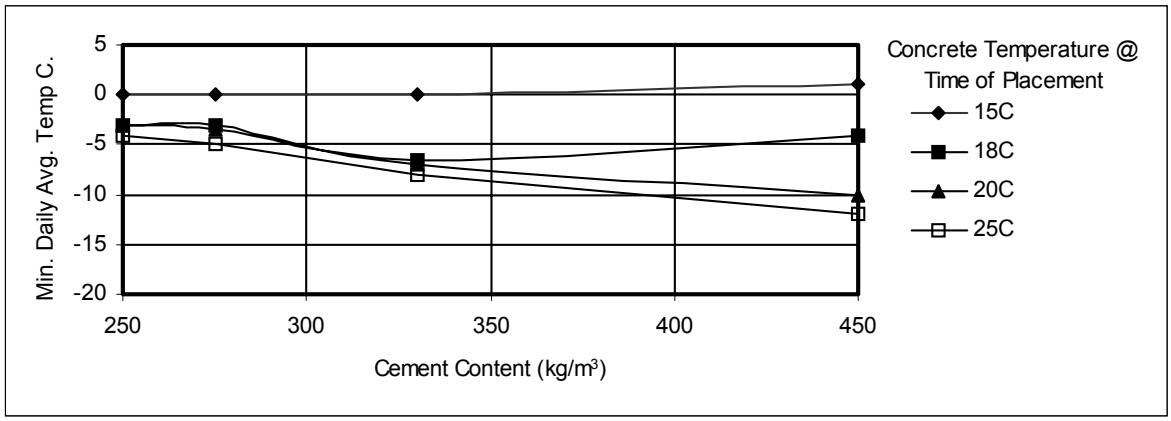

FIGURE 4 - 4" ARXX FORM, TYPE III (TYPE 30) CEMENT – METRIC UNITS

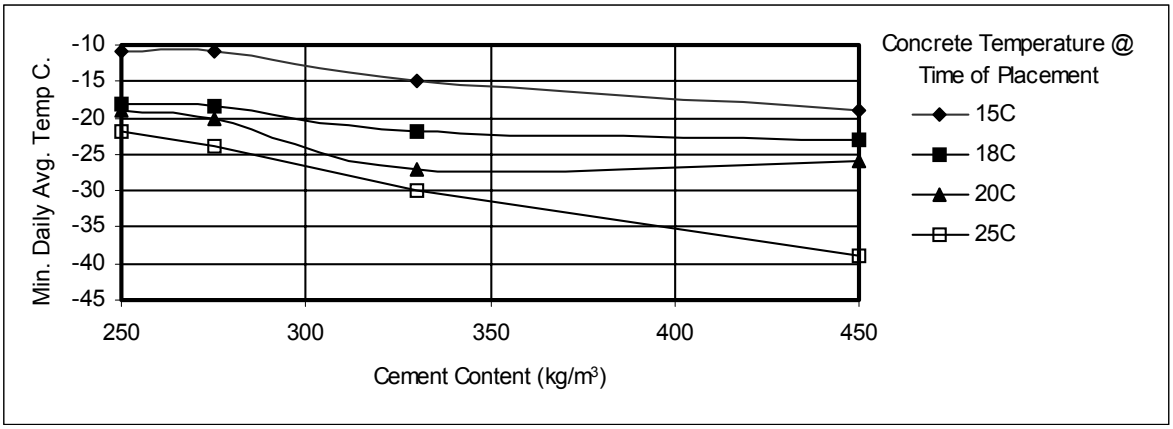

FIGURE 5 - 6 1/4" ARXX FORM, TYPE III (TYPE 30) CEMENT – METRIC UNITS

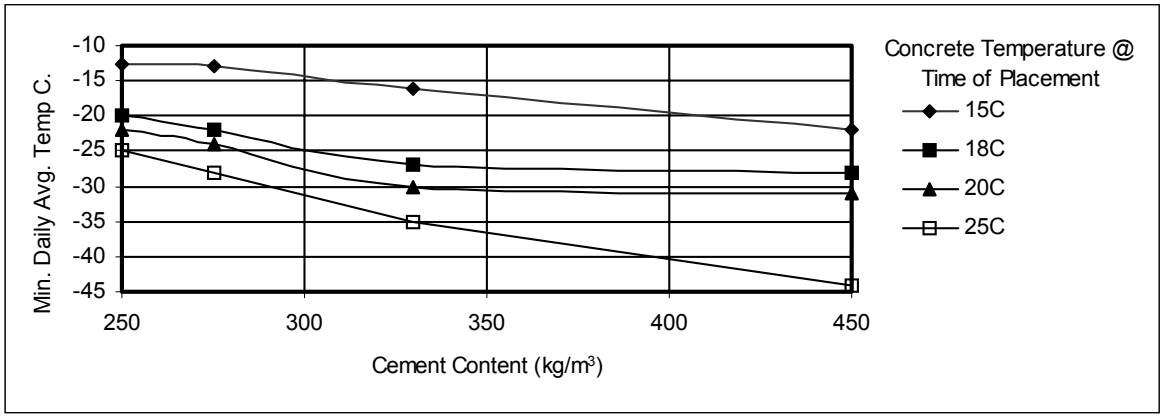

FIGURE 6 - 8" ARXX FORM, TYPE III (TYPE 30) CEMENT – METRIC UNITS

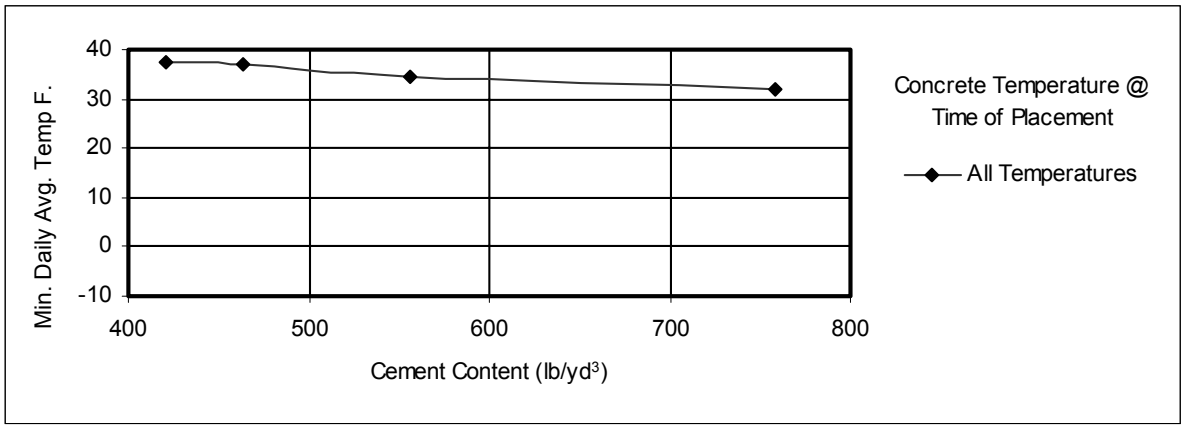

FIGURE 7 - 4" ARXX FORM, TYPE I (TYPE10) CEMENT – IMPERIAL UNITS

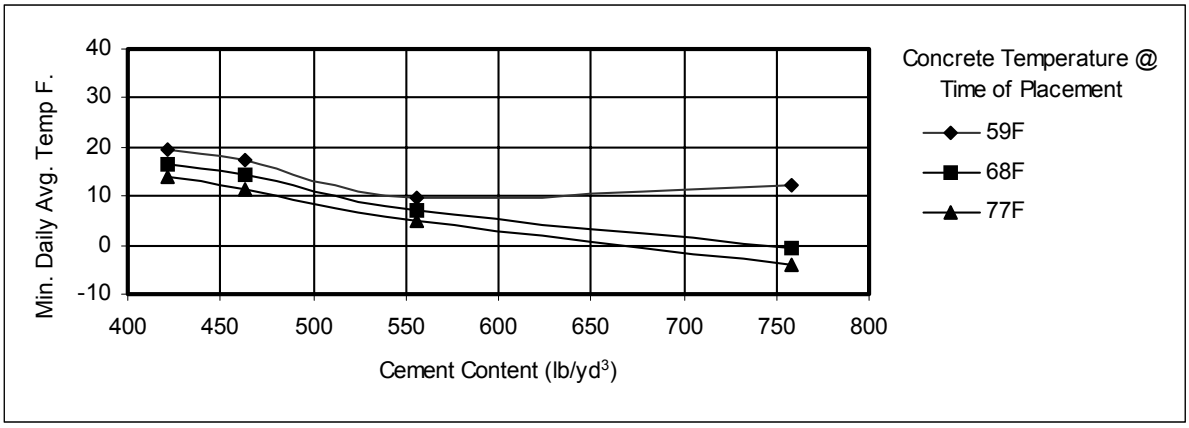

FIGURE 8 - 6 1/4" ARXX FORM, TYPE I (TYPE 10) CEMENT – IMPERIAL UNITS

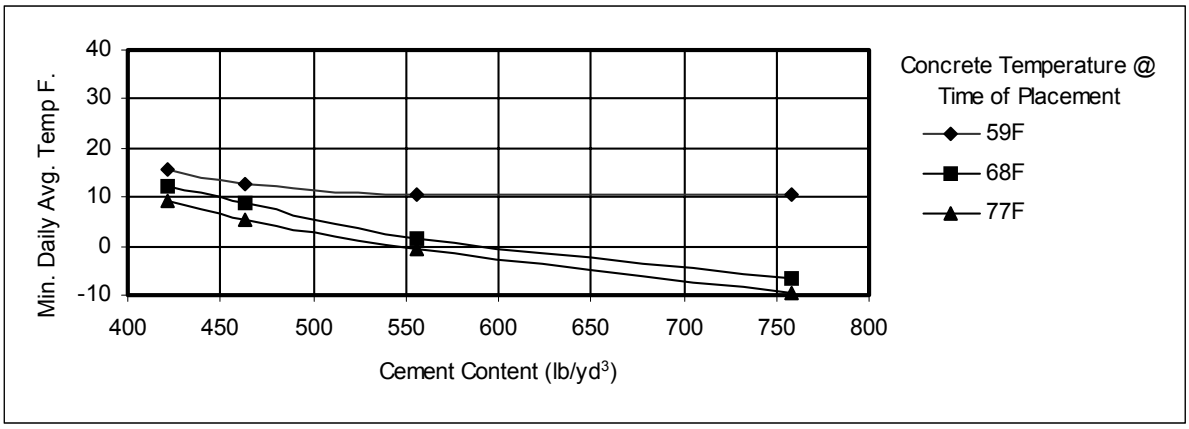

FIGURE 9 – 8" ARXX FORM, TYPE I (TYPE 10) CEMENT – IMPERIAL UNITS

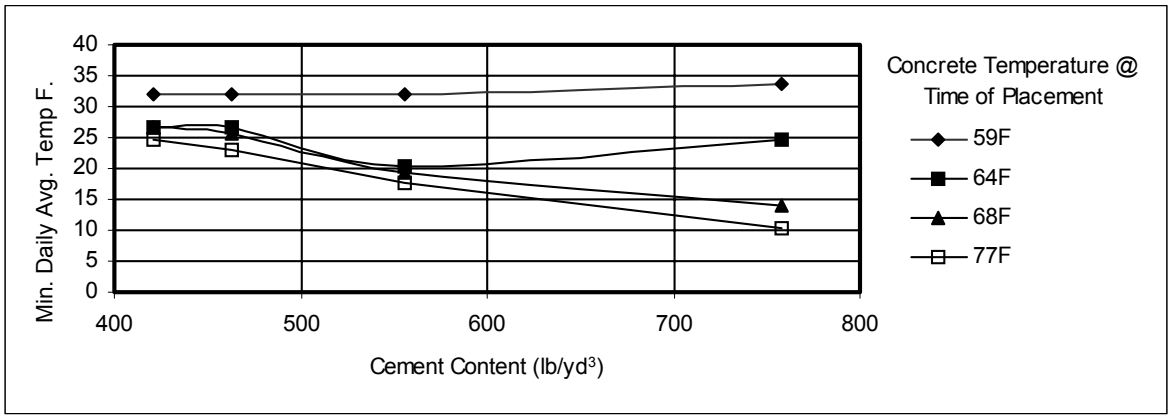

FIGURE 10 - 4" ARXX FORM, TYPE III (TYPE 30) CEMENT – IMPERIAL UNITS

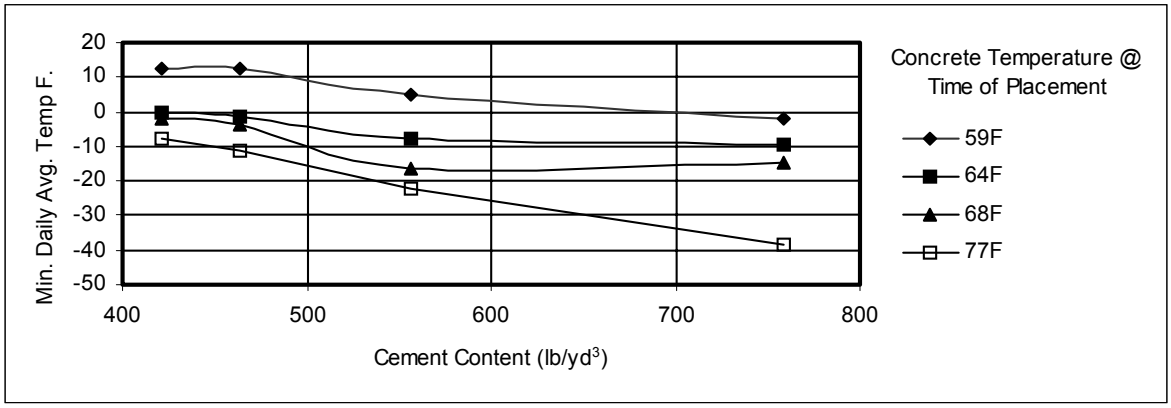

FIGURE 11 - 6 1/4" ARXX FORM, TYPE III (TYPE 30) CEMENT –IMPERIAL UNITS

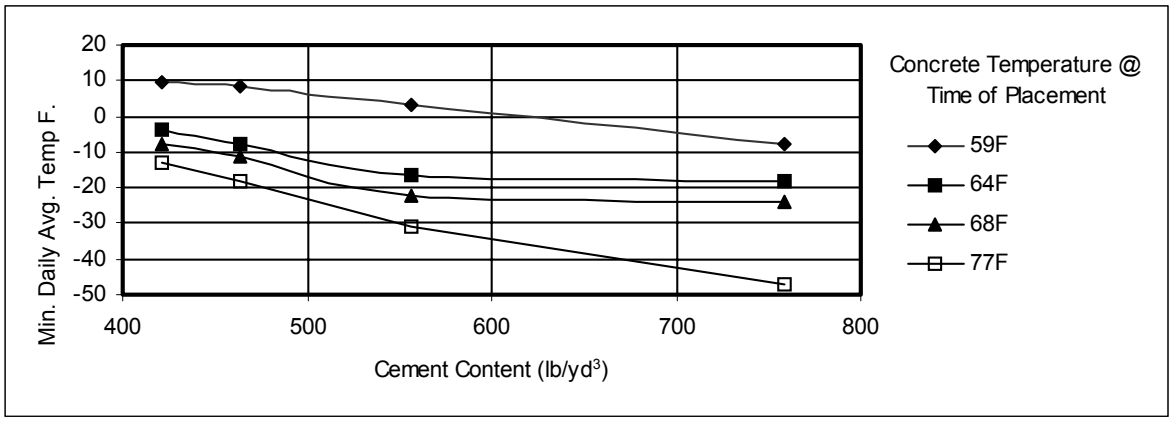

FIGURE 12 - 8" ARXX FORM, TYPE III (TYPE 30) CEMENT – IMPERIAL UNITS

REFERENCES

1. Arxx Cold Weather Concreting - Bodycote ORTECH Laboratory, Report No. 00-06-M018
2. Placing Concrete in Arxx™ Insulated Concrete Forms under Sub-Zero Temperatures: A Finite Element Analysis by Dr. M. Lachemi P. Eng, Ryerson Polytechnic University, Department of Civil Engineering, Report No. ML0500/01
3. Standard Specification for Cold Weather Concreting (ACI 306.1-90) -American Concrete Institute
4. Cold Weather Concreting (ACI 306R-88) Reported by ACI Committee 306 - American Concrete Institute
5. Design and Control of Concrete Mixtures 13th Edition - Portland Cement Association

APPENDIX A

ILLUSTRATIVE EXAMPLE

Example 1 – Metric Units

Form width	6 ¼”
Cement Type	Type 10
Cement Content	325 kg/m³
Concrete Temperature @ time of placement	15° C

Form width and cement content match the parameters for Figure 2

From Figure 2 we read

Minimum Average Outdoor Temperature = -12° C

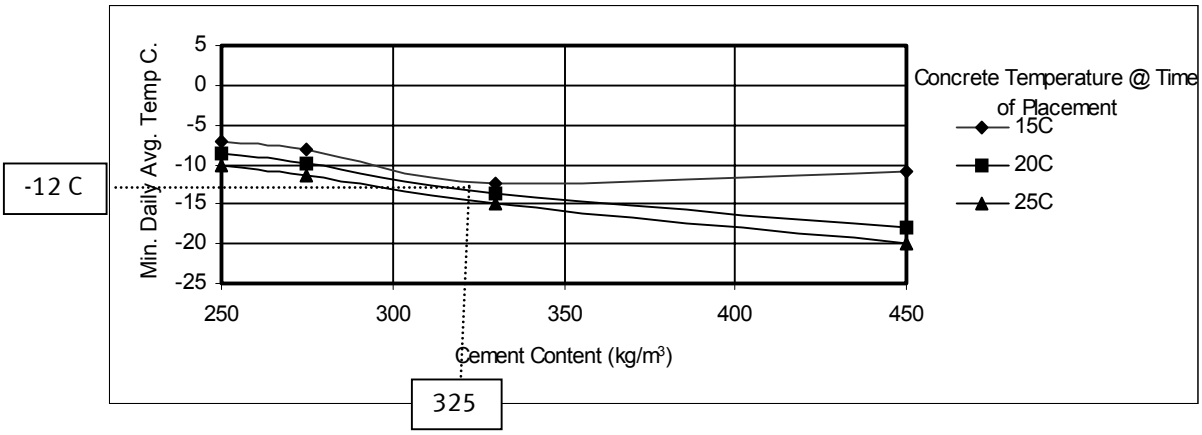

FIGURE A1 – 6 1/4" ARXX FORM, TYPE I (TYPE10) CEMENT – METRIC UNITS

Example 2 – Imperial Units

Form width	6 ¼”
Cement Type	Type I
Cement Content	540 lb/yd^3
Concrete Temperature @ time of placement	59° F

Form width and cement content match the parameters for Figure 8

From Figure 8 we read

Minimum Average Outdoor Temperature = 9° F

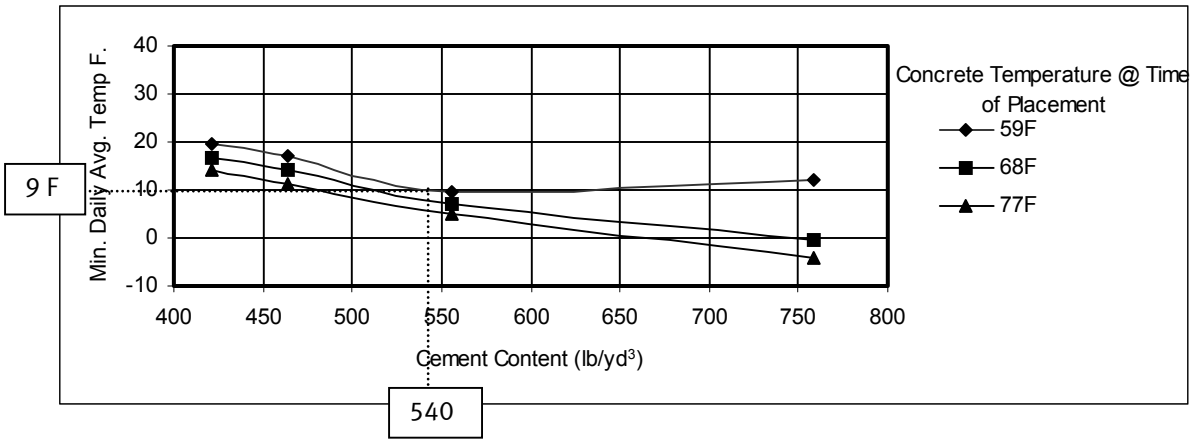

FIGURE A2 - 6 1/4" ARXX FORM. TYPE I (TYPE 10) CEMENT – IMPERIAL UNITS