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DEPARTMENT OF TRANSPORTATION

Influence of Curing Conditions on Concrete Specimens (Cylinders) in Hot and Cold Weather in the Field

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Background

Concrete properties vary depending upon the temperature and humidity that they are subjected to in the first few hours of curing. The ASTM standard that dictates the procedures for making and curing test cylinders, ASTM C31, *Practice for Making and Curing Concrete Test Specimens in the Field* [1], requires that standard cured cylinders for concrete acceptance should undergo initial curing between 60°F and 80°F in the first 48 hours after which they should be transferred to a moist cure room or water tank. However, in the field this may not always be practiced.

Standard Curing Cylinders per ASTM C31: This condition involves subjecting the specimens to standard temperature and humidity conditions and the strength results are primarily used for concrete acceptance and quality control.

Field Curing Cylinders per ASTM C31: This condition involves subjecting the specimens to the temperature and humidity that the actual structure experiences and the strength results are primarily used for determining whether a structure is capable of being put in service and scheduling form work removal.

Purpose of the Investigation

Concrete properties vary considerably depending upon the temperature subject to early time of hydration. This study presents the different curing methods the DOT currently uses in the winter and summer time. All methods were evaluated, in order to determine the best practices to cure specimens in extreme weather conditions.

Test Methodology Details

A 2.5 ft^3 batch was produced at the Material & Research Laboratory for the cold weather condition research. A 4 yd^3 concrete batch was delivered by a ready-mix concrete supplier to Lincoln Material and Research Laboratory for the hot weather condition research. Both mixtures had a IP blended cement content of 564 lbs/yd^3, a water-cementitious materials (w/cm) ratio of 0.41, a type A water reducer, and an air entraining agent. The measured air content was 7.0 and 7.5 percent, respectively. The initial concrete temperature was 71°F.

Cold Weather Curing Methods

A total of 33 4x8 inch cylinders were cast for compressive strength for the cold weather condition. Cylinders were covered with plastic caps and cured in the following six methods immediately after they were made until 48 hours, Figure 1.

1. Wood Box with Insulated walls
2. Metal Box with Insulated cut out
3. Cooler
    - Covered with a frost blanket
    - Covered without a frost blanket
4. Cylinders outside with no protection (no picture shown)
5. Inside- No Box- Maturity Method (no picture shown)

Figure 1- Cold Weather Curing Methods

Figure 2- SmartRockTM sensor used in the cold and hot curing methods

SmartRockTM was used to measure the temperature for each curing method and a SmartRock was also placed in a cylinder, Figure 2, for each curing method. Temperature was measured at 24 and 48 hours. One sensor was used to capture the ambient temperature.

The average daily temperature during the course of the study was recorded via the SmartRock; however, the data logger used to retrieve all data was lost. Therefore, the cold and hot weather temperatures that where recorded are not available.

Cold Weather Test Results

The compressive strength results for the curing conditions at the various test ages for cold weather are illustrated in the Figure 3. An average of two compressive strength was tested on 3, 7, and 14 days in accordance to ASTM C39, *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens* [2].

Figure 3 - Winter Data (Cold Weather)

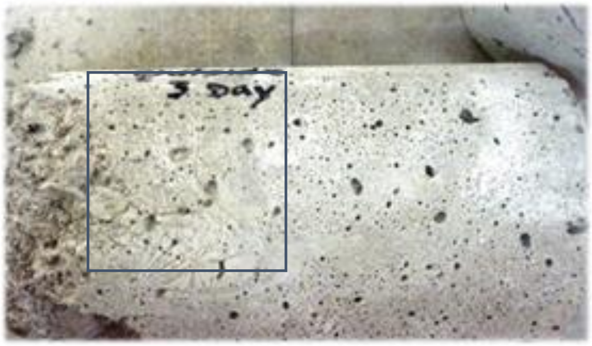

Figure 4- Cylinder exhibiting froze damage

Cylinders with no protection had the lowest compressive strength. Figure 4 shows the specimens displaying frost damage. This represents a potential condition where test cylinders are not protected during the initial curing period in the field during cold weather condition.

This study demonstrates the effects of curing test specimens in cold temperatures. Cylinders that were cured by open insulated curing wood box, solid foam insulated metal box, cooler and cooler covered with a frost blanket showed a very similar compressive strength at 7 and 14 days. However, the highest compressive strength at 3 days was with the solid foam insulated metal box.

Hot Weather Curing Methods

A total of 48 4x8 inch cylinders were cast for compressive strength for the hot weather condition. Cylinders were covered with plastic caps and cured in one of the following eight methods immediately after they were made until 48 hours. See Figures 5 and 6 for hot weather cuing methods.

1. Cooler with water
2. Cooler without burlap
3. Cooler with burlap
4. Metal box with the insulation cut out
5. Cylinders in the direct sun
6. Wood box with insulated walls
7. Cooler in the shade covered with burlap
8. Cylinders in the shade covered with burlap

Figure 5- Hot Weather Curing Methods

Figure 6- Hot Weather Curing Methods

Hot Weather Test Results

The compressive strength results for the curing conditions at the various test ages for cold weather are illustrated in the Figure 7. An average of two compressive strength was tested on 3, 7, and 14 days in accordance to ASTM C39.

The research demonstrates the effects of curing test specimens in high temperatures. Cylinders that were cured in direct sunlight had the lowest compressive strength. The cooler with water showed the highest compressive strength and met the requirements of ASTM C31. The other two curing methods that performed well was the metal box with the insulation removed for the cylinders and cylinders in the shade covered with burlap, confirming that good curing practices substantially improve concrete compressive strength.

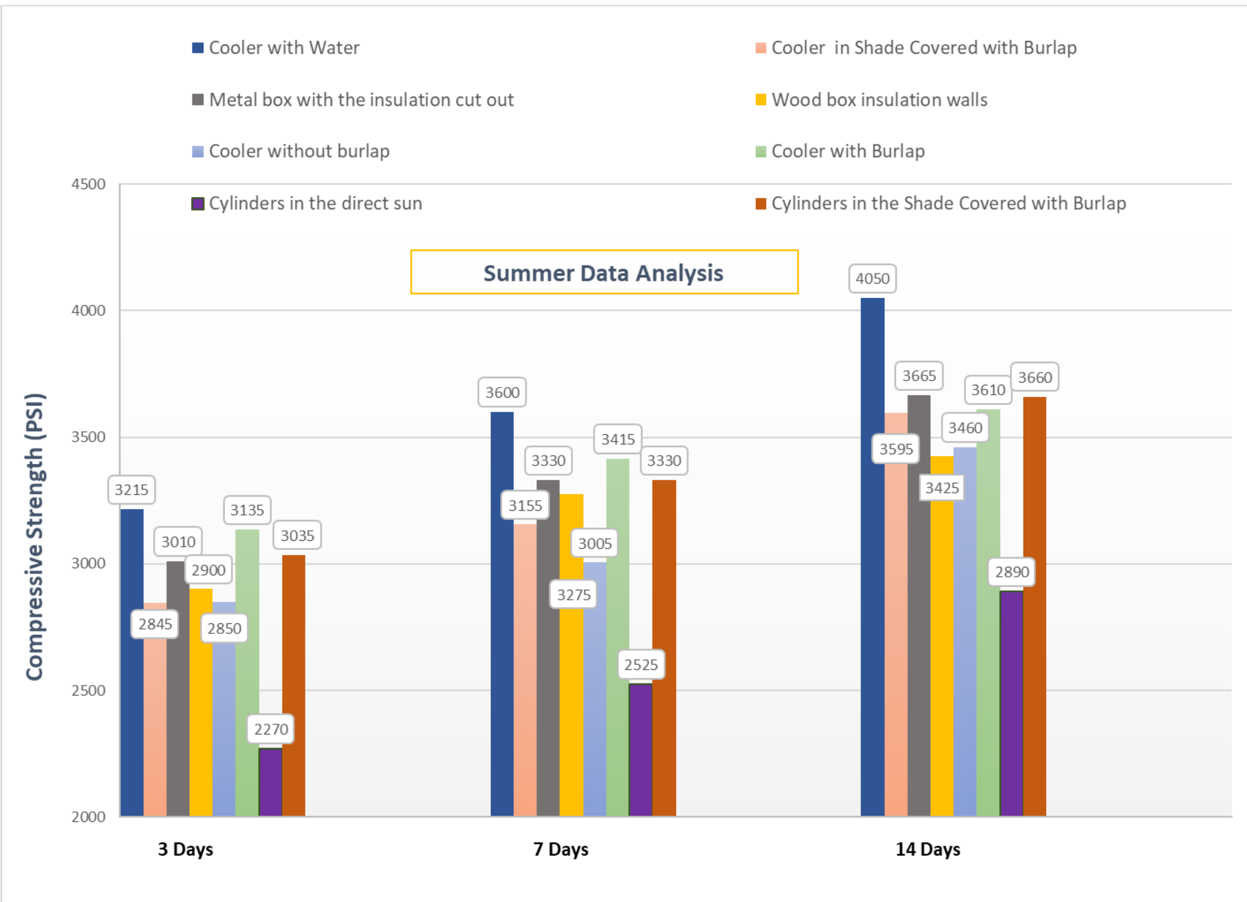

Figure 7- Summer Data (Hot Weather)

Conclusions and Recommendations

The curing conditions of cylinders was found to have a significant effect on the compressive strength of the cylinders used for acceptance. Therefore, care must be taken in the curing and protecting concrete cylinders to minimize the effect of cold and high ambient temperatures. Adequate protection of cylinders during the first 48 hours after casting is essential to stay within specifications requirements; therefore, based on this study the Department will recommended, the following:

- Cold Weather Conditions: The use of curing box should be used on a project during cold weather conditions. Other necessary steps may include using a frost blanket and creating heat during initial set with hand warmers.

- Hot Weather Conditions: Water should be used in the coolers when ambient temperatures are above 80°F for several days in a row. The water should cover a minimum of 75% of the concrete cylinder.

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References

[1] ASTM C31, 2019, "Practice for Making and Curing Concrete Test Specimens in the Field", ASTM International, West Conshohocken, PA, 2019, DOI: 10.1520/C0031_C0031M-19, www.astm.org

[2] ASTM C39, 2018, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens", ASTM International, West Conshohocken, PA, 2018, DOI: 10.1520/C0039_C0039M-18, www.astm.org