International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 4, Issue 2, February 2014)

Concreting at Low Ambient Temperatures at Salma Dam Project Afghanistan - A Case Study

Raj Kumar[1], A.N.N. Prasad[2], N. V. Mahure[3], Pankaj Sharma[4], S. L. Gupta[5], Murari Ratnam[6]
[1,3,4,5 & 6]*Central Soil and Materials Research Station, New Delhi, India*
[2]*WAPCOS, Gurgaon, India.*

***Abstract*— The kinetics of hydration of cement directly influences the development of strength and other intrinsic properties of concrete. Meteorological conditions such as temperature, humidity in the atmosphere, wind speed or combinations of these conditions which prevail at the time of concreting and its subsequent curing periods regulate the kinetics of hydration of cement. If these conditions happens to be extreme, due precautions are needed to be taken to achieve desired properties and performance of concrete. The paper presents the outcome of the comprehensive study carried out at Salma Dam, Afghanistan to assess the effects of mixing and curing temperature on the various properties of concrete like compressive strength, workability, air entrainment etc.**

***Keywords*— Extreme weather, Placement, Aggregates, Curing**

I. INTRODUCTION

In extreme weather conditions properties and performance of concrete are likely to be affected. In such aggravated conditions proper care and precautions must be taken at the time of concreting and also during its subsequent curing periods. The initial rate of development of strength is slow in cold weather. During setting if concrete is exposed to icing temperatures it may lead to expansion due to ice in the pore structures. When the concrete hardens it may lead to damage due to alternate freeze and thawing. Any concreting operation done at a temperature below 5°C is termed as cold weather concreting [1]. Concreting in such conditions is generally not recommended without special precautions. The paper presents detailed study carried out at the time of concreting under such extreme cold conditions encountered at Salma Dam, Afghanistan. Various handy arrangements/techniques adopted for achieving the best concrete strength are also highlighted.

II. REVIEW

The time of setting of concrete increases as temperature decreases [2]. The concrete temperature at placement significantly influences the magnitude of the developed thermal stress.

The effects of temperature and moisture early in the life of concrete strongly influence early strength development and long-term durability [3]. The concrete temperature development during the first 24 to 72 hours after placement has a major impact on long-term pavement performance [4, 5].

The primary concern during concreting in cold weather conditions is to maintain an adequate temperature during curing, protect the concrete from freezing, and avoid large thermal shocks to the concrete when it is exposed to the cold [6]. The concrete must be kept warm by insulation or heated enclosures while it cures. The concrete in such conditions should set more quickly and gain strength more rapidly than it ordinarily would. Likewise, strength develops more slowly at lower temperatures. Concrete cured in cool weather ultimately becomes stronger than that cured in hot weather; the construction schedule is slowed down. The lowest temperature allowed at which concrete can be placed is 5 °C [7]. Recommended practice to avoid the adverse effects of cold weather condition are temperature control of concrete aggregates [1], use of insulating formwork [8], proportioning of concrete ingredients such as air entraining agents/accelerating admixtures etc.[9, 10], placement, protection and curing or delayed removal of formwork. Large temperature differentials within the concrete member may promote cracking and has a harmful effect on the durability. Such differentials are likely to occur in cold weather at the time of removal of formwork.

III. SALIENT FEATURES OF THE PROJECT

Salma Dam Project is situated 2 Km D/s of Salma village on Hari Rud river in Chisht-e- sharif District, Herat Province, Afghanistan for generating 42 MW power and irrigation purposes.

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 4, Issue 2, February 2014)

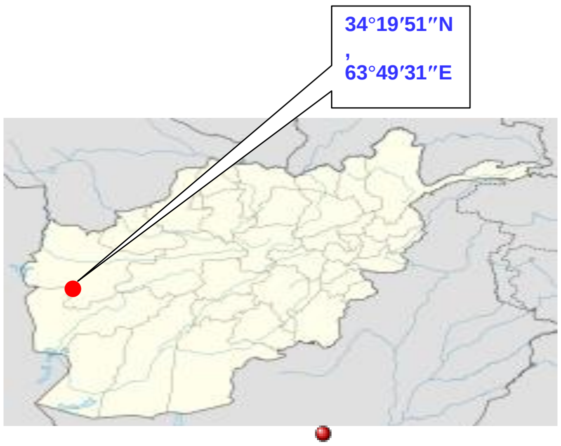

Figure 1. Location of Salma Dam, Afghanistan

It is 107.5 m high Earth & Rockfill Dam having 551 m length at the top. It has Chute Spillway, power house, switch yard in which concrete is being used. Other features are:

- Design discharge: 2100 m^3/sec
- Power Sluice : 3.25m X 6.72m (63 m^3/sec discharge)
- Penstock : 4.25m dia. /2.46 m(after trifurcation)
- Irrigation Sluice : 15 m^3 /sec Discharge
- Diversion Tunnel : 630 m long, 8.5 m dia (Horse Shoe Shape)
- Power House tunnel/ Pressure shaft : 4.25 m dia & length 457m

IV. THE ENCOUNTERED PROBLEM

During cold climate the surrounding temperature becomes very low. Also the temperature of the river water (which is generally used for concreting and curing) falls below 2°C.

V. PRACTICES FOLLOWED TO COUNTER THE PROBLEMS

A. Controlling Temperature of Concrete Aggregates

For concreting in the cold weather climatic conditions when the surrounding temperature falls below 2 to 3 °C, efforts are made to maintain 10 °C temperature for mass concrete and 12 °C for structural concrete. To keep concrete temperature above the permissible limit, minimum temperature of the ingredients is controlled by using hot mixing water.

Coarse Aggregate

Fine Aggregate

Figure 2. Observing Temperature of Aggregate

Temperature of mixing water greatly influences the properties of concrete [11]. Figure 3 illustrates a local arrangement to heat water. Controlled heating of water is done so as to avoid appreciable batch to batch fluctuation in temperature.

Figure 3. Local Arrangements to Obtain Hot Water

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 4, Issue 2, February 2014)

As per IS: 7861 (Part II)-1981 [1], the required temperature of mixing water to produce specified concrete is achieved. The heated water which comes in direct contact with aggregate raises its temperature. Suitability of mixing and curing water is ascertained by analyzing water samples as per analytical procedure laid down in IS 3025-1986 [12].

B. Use of Insulating Covers

Sufficient amount of heat is generated during hydration of cement. This heat is conserved by placing layers of tarpaulin/plastic insulating covers (figure 4) with air gaps as insulation.

Figure 4. Use of Insulation Cover

C. Proportioning of Concrete Ingredients

To counter the cold conditions and obtain good strength following additional ingredients are used

- Water Reducing Admixture @ 1% dose of cement content.
- Air entraining admixture @ the 0.3% dose of cement content to entrap the air 3 to 5% in plastic concrete.
- Antifreeze having Calcium Nitrate to protect the concrete from freezing condition

D. Placement, Protection and Curing

Before placement of the concrete, the entire hardened surface is cleaned thoroughly by using air/water Jet. Concrete is pumped using 100 mm dia concrete pump for delivery of concrete at pouring site. More than 1.5 m free fall of concrete is not allowed (figure 5). For curing purpose bore well ground water having temperature in the range of 15–17 ^{o}C is used instead of river water which is icy cold. Curing is properly monitored (figure 6). Temperature of fresh concrete is constantly observed.

Figure 5. Placement of concrete

Figure 6. Curing of concrete

Figure 7. Concreting upstream area

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 4, Issue 2, February 2014)

E. Removal of formwork

The appropriate time for removal of formwork is ascertained from the strength of test cubes kept at site under the site conditions.

- Vertical form work : 16-24 h
- Soffit form work to slab : 3 days
- Soffit form work of beam : 7 days
- Props to slabs; spanning up to 4.5 m: 7days
- Spanning above 4.5 m : 14 days
- Beam & arches 6 m and above : 14 days & above 21 days

VI. Ascertaining The Compressive Strength

Due practices for countering low ambient temperatures are followed for concreting. The compressive strength for M12.5 A40 and M20 A40 concrete achieved at different temperatures are presented in figure 8 and 9 respectively.

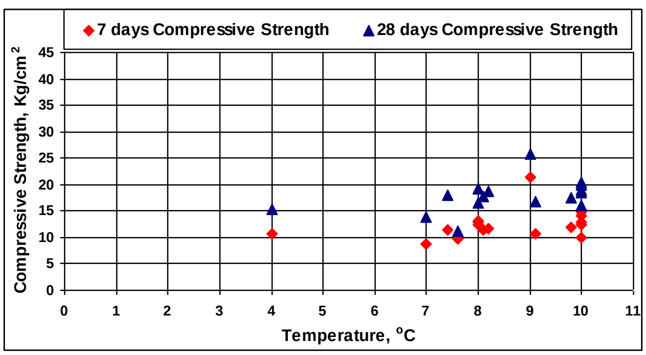

Figure 8. Compressive strength for M12.5 A40 concrete placed at low temperature

7 days and 28 days compressive strength for M12.5 A40 concrete for the concreting at temperature below 10 ^{o}C is found to be between 8.65 – 21.48 kg/cm^2 and 11.11 – 25.78 kg/cm^2 respectively

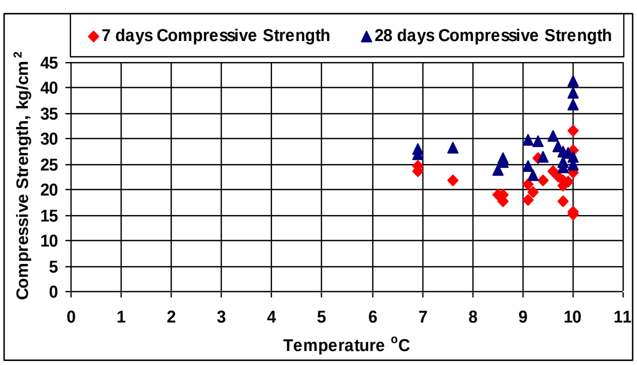

Figure 9. Compressive strength for M20 A40 concrete placed at low temperature

7 days and 28 days compressive strength for M20 A40 concrete for the concreting at temperature below 10 ^{o}C is found to be between 15.19 – 31.63 kg/cm^2 and 22.81 – 41.48 kg/cm^2 respectively.

VII. Conclusion

Although low temperatures pose a variety of problems for concreting yet desirable compressive strength can be achieved if certain recommended practices are followed. At Salma Dam, Afghanistan various handy arrangements/ techniques such as temperature control of concrete aggregates, use of insulating formwork, addition of concrete ingredients such as air entraining agents/accelerating admixtures, placement, protection, curing and delayed removal of formwork are adopted to avoid the adverse effects of cold weather condition. Thus adequate 7 as well as 28 days compressive strength have been achieved.

Acknowledgements

The authors gratefully acknowledge and thank the authorities at Salma Dam, Afghanistan, WAPCOS, New Delhi, India and Central Soil and Materials Research Station, New Delhi, India for the support extended by them. We also extend our sincere gratitude to all the authors whose publications provided us directional information from time to time.

REFERENCES

[1] 'IS: 7861 (Part II)-1981 Code of practice for extreme weather concreting: Part II Recommended practice for cold weather concreting', reaffirmed 1996

[2] Vance H. Dodson, "Time of Setting," Significance of Tests and Properties of Concrete and Concrete-Making Materials, ASTM STP 169 C, Chapter 11, ASTM, West Conshohocken, Pa., 1994.

[3] SHRP-C-321. A guide to evaluating thermal effects in concrete pavements. Strategic Highway Research Program, National Research Council, Washington, D.C., 1993.

[4] Hankins, K., Suh, Y.C., and McCullough, B.F. Field Evaluation of Coarse Aggregate Types: Criteria for Test Sections. Research Report 422/1244-1, Center for Transportation Research, The University of Texas at Austin, 1991.

[5] McCullough, B.F., Zollinger, D. and Dossey, T. Evaluation of the performance of Texas pavements made with different coarse aggregates. Research Report 3925-1F, The Center for Transportation Research, The University of Texas at Austin, 1999.

[6] Charles Korhonen, The findings of the experiments carried out at U.S. Army Engineer Research and Development Center's Cold Regions Research and Engineering Laboratory (CRREL)

[7] ACI (1988) "Cold Weather Concreting," Committee 306. American Concrete Institute, Farmington Hills, Michigan.

[8] AC1 306-1966, Recommended practices for cold weather concreting, ACI manual of concrete practice, Part (I); 1974, 306-1-19.

[9] Korhonen, C. (1999) Expedient low-temperature concrete admixtures for the Army. U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire, Special Report 99-17.

[10] Korhonen, C., and R. Ryan (2000) "New Low-Temperature Admixtures," *Concrete International*, Vol. 22, No. 5, May 2000

[11] G. D. Stefanou and Ch. Larsinos,"Influence of Mixing Water on the Setting Time of Concrete," The International Journal of Cement Composites and Lightweight Concrete, February 1981, pp. 45-48.

[12] IS 3025-1986 "Methods of Sampling and Test (Physical and Chemical) for Water used in the Industry".