Influence of cold temperature on performance of concrete in J&K – Comparison studies

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Abstract: Cold weather concrete construction under sub-zero temperatures presents challenging problems for the professionals involved in construction industry and are the main reason for poor development of such regions. Freezing of concrete before it gains required minimum strength at early age together with considerable retardation in setting time due to freezing temperatures are the two major problems with cold weather concreting. The professionals in Srinagar, J&K also face the above problems during winter months and needs to be addressed with cost effective measures. Although there are many accelerators present in the market the performance depends on humidity and temperature changes in the region. Accordingly, a specific study related to performance of various accelerators under the average temperature range of -7˚C to 7˚C (prevailing during winter) was carried out for choosing the accelerator suitable for the region. The freezing and thawing effect on hydration of cement paste, initial and final setting time and strength gain were evaluated. The 3 day, 7 day and 28 day performance was compared to a standard concrete mixture without additives which served as baseline for comparison.

Keywords: cold weather, delayed hardening, accelerators, tensile strength.

1. Introduction

Apart from adverse environmental consideration during cold winter in Srinagar region of J&K, there are numerous other shortcomings with use of concrete in construction industry as far as its proper preparation and final placement is concerned. [1-9] Admixture usage has been steadily increasing due to the awareness among the professionals of construction industry in the Srinagar region. Although the origin of accelerators as an admixture is not well documented, but it does have a deep-rooted history [10-12]. It has been used centuries ago in civilizations in Rome, China, Mesoamerica and Peru and certain parts of Europe. Most commonly used materials were milk, eggs, rice paste, lacquer, oil, molasses, boiled bananas and latex from rubber plants [13-15]. In cold regions, temperature variation during night and day varies anywhere between 8-10˚C. In the recent past several researchers have studied the effect of accelerators on the strength of concrete, but there has not been enough research data on cold weather concreting specifically related to the humidity, pressure and temperature variation in the Srinagar region of J&K. The current study employs four of the most commonly used accelerators available locally, i.e. rapidite, calcium chloride, calcium nitrite and calcium thiocyanate (the best non-alkali form of thiocyanate). An accelerating additive is used to accelerate the rate of hydration (i.e. setting) and strength development of concrete at an early age. The role of accelerating admixture added to concrete is to increase the rate of hydration of tricalcium silicate (C3S) and tricalcium aluminate (C3A) constituents of cement, which results in quicker release of heat and faster gain in strength of concrete. It may be observed that accelerators do not change the freezing point of water significantly and should not be referred to as anti-freeze admixtures. The accelerating effect on both setting and strength due to suitable admixtures is most pronounced at temperatures below 30˚C. This study was carried out during the months of December/January hence as mentioned above the average temperature would range from -7˚C to 7˚C. It was important to study the immediate effect of these accelerators on the concrete mixture through change in setting time. Therefore, at three different
temperatures the effect on setting time was experimentally recorded. Consecutively, the best performing accelerator was based on strength value of respective concrete samples.

2. Experimental study
As mentioned in the previous section, the first parameter that needs to be studied was the effect of the accelerators on the change in setting time. The slump test was also carried out simultaneously. It was found that slump value of the mix was affected insignificantly; therefore this parameter was not taken into consideration. Test specimens were casted for compression test, flexural test and split tensile test respectively. Relevant testing was first carried out on specimens of plain concrete serving as baseline and was then repeated on specimens with incremental percentage of admixture. Weight batching was adopted to ensure accuracy of results. The concrete mix used was M20. The ingredients were mixed in the ratio of 1: 1.5: 3, with constant water cement ratio of 0.45. The concrete specimens were tested for compressive strength after 3, 7 and 28 days of water curing. The compression testing was conducted on standard cubes (150mm size) using 2000KN capacity compression testing machine (CTM). Six samples were casted for each group, two of which were tested after 3 days, another two after 7 days and last two after 28 days. Flexural strength test of concrete was performed on beam of length 500mm. The loading applied on the beam was a four-point loading in which loads were applied at (1/3)rd points of the beam. The beam was placed in the testing machine in such a way that the load points were 16.6 cm apart from each other as well as from each support. The load was increased until the specimen failed. The split tensile test was carried out by placing a cylindrical specimen, horizontally between the loading surfaces of a Compression Testing Machine and the load was applied until the specimen split along the vertical diameter. The loading condition produces a high compressive stress near the two surfaces (over 1/6th diameter) at which the load was applied, whereas the central portion corresponding to 5/6 of vertical diameter was subjected to a uniform tensile stress acting horizontally. Specimen dimensions considered for various tests are given in Table 1, whereas list of accelerators are given are given in Table 2.

| Table 1. Specimen dimensions considered for various tests | Table 2. List of accelerators used |
|--------------------------------------------------------|----------------------------------|
| S. No | Specimen | Dimension (mm) | S. No | Type of Accelerator |
|-------|-----------|----------------|-------|---------------------|
| 1.    | Cube      | 150 x 150 x 150 | 1.    | Rapidite            |
| 2.    | Beam      | 500 x 100 x 100 | 2.    | Calcium Nitrite     |
| 3.    | Cylinder  | 300 x 150       | 3.    | Calcium Chloride    |
|       |           |                 | 4.    | Calcium Thiocyanate |

Figure 1. Comparison of initial setting time of the accelerating admixtures used

2.1. Materials Used
2.1.1 Cement. Ordinary Portland Cement (OPC) from a single slot (grade 43) was used throughout the course of the investigation, which conformed to Indian Standard IS: 8112 [16]. All the tests were carried out as per recommendations of IS 4031 [17]. The contact of cement with moisture was
prevented by proper storage, to retain its original properties.

2.1.2 Fine aggregates. River sand was used as fine aggregate conforming to IS 383 [18], zone II. Lumps present in clay and other foreign matter were separated out, before using it in concrete preparation.

2.1.3 Coarse aggregate. Locally available crushed stone aggregates of 10mm and 20mm nominal maximum size conforming to IS: 383 [18] were used as coarse aggregate.

2.1.4 Admixture. Rapidite, calcium nitrite, calcium chloride and calcium thiocyanate were used as respective admixture (conformed to relevant IS code/s) for each group of mix in dosage of 1 to 3% by weight of cement.

2.1.5 Water. Throughout the investigation, potable water was used for mixing and curing of concrete specimens.

2.2. Mix design
M-20 grade of concrete was prepared by adopting the mix proportions as per the recommendations given by Indian standard IS 10262 [20] shown in Table 3.

Table 3. Mix design for M20 grade concrete

| S. No | Mix designation          | Water [kg/m³] | Cement [kg/m³] | Fine aggregate [kg/m³] | Coarse aggregate [kg/m³] |
|-------|--------------------------|---------------|----------------|------------------------|--------------------------|
| 1     | Control mix              | 194.6         | 389            | 712.22                 | 1096.87                  |
| 2     | Specimen for strength test | 194.6         | 389            | 712.22                 | 1096.87                  |

3. Results and discussion
Following tests on fresh and hardened SCC were conducted. Fig. 1 shows the comparison of initial setting time corresponding to four different accelerating admixtures used against the three varying temperatures i.e., 4, 2 and -2 degree centigrade. The test results are given in the sub-sections as under:

3.1. Workability Test
Immediately after preparing concrete, the workability of concrete was determined by slump cone test and compaction factor test conforming to IS 1199 [21]. The results of slump cone test and compaction factor test are given in Table 4.

Table 4. Results of slump cone test and compaction factor test

| S.No | Mix               | Slump value [mm] | Acceptable limit [mm] | Compaction value [mm] | Acceptable limit [mm] |
|------|-------------------|------------------|-----------------------|-----------------------|-----------------------|
| 1    | Baseline          | 98               |                       | 0.91                  |                       |
| 2    | Admixed1%         | 96               |                       | 0.87                  |                       |
| 3    | Admixed1.5%       | 98               | 100-150               | 0.88                  | 0.7-0.95              |
| 4    | Admixed2%         | 105              |                       | 0.95                  |                       |
| 5    | Admixed 2.5%      | 92               |                       | 0.92                  |                       |
| 6    | Admixed3%         | 101              |                       | 0.75                  |                       |

3.2. Strength Tests
Figure 2 shows the variation in compressive strength for different concrete mixes for 7-days and 28-days. 2 to 2.5%, admixed specimens performed well from compressive strength point of view. Figure 3 and 4 shows the variation in flexural strength and split tensile strength for different concrete mixes respectively for 7-days and 28-days. The 7-day admixture strength was found to have higher strength compared to the baseline model but at the end of 28-day the strength of both types of specimens were approximately the same.
4. Conclusions and recommendations
The present research work initially aimed at selection of such an accelerator out of the four available accelerators which shows optimum improvement in structural properties under cold temperature conditions of Srinagar region of J & K. Calcium chloride was found as the efficient accelerating admixture, hence adopted for further relevant tests. The main conclusions drawn from the results are summarized below:

- The early compressive strength, flexural strength and split tensile strength of concrete specimens increased with the increase in percentage of sodium chloride up to 2.5%.
- From five trial mixes, a mix with calcium chloride percentage of 2.5% was found to possess
maximum compressive strength at day 3 and 7. Whereas the 28th day strength is approximately same for all specimens. It was also found that beyond the 3% mark the strength characteristics of concrete begin to deteriorate.

- In the temperature and environmental conditions tested, calcium chloride was found to have the lowest setting time.

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