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# An Experimental Study on Early Compressive Strength Development for Different Grades of Concrete

**Zahid Bashir Bhat**
*Lecturer*
*Department of Civil Engineering*
*NIT Sgr*

**Irfan Latief**
*Lecturer*
*KITE Polytechnic Rangret*

**Muneeb Anwar Shah**
*Civil Engineer*
*Al-Madad Infratech*

**Sahil Bhat**
*Project specialist*
*Ericsson*

**Danish Iqbal**
*Assistant Engineer*
*PWD (R&B Department) J & K*

## Abstract

Keeping in view problems of cold weather concreting resulting in prohibition of concrete construction activities in author's native land Kashmir, an attempt to overcome the problem of delayed setting and hardening of concrete leading to frost action and subsequent damage to concrete is made by studying the effect of chemical admixture (sodium nitrite) on early strength development for different grades of concrete. Three Grades of concrete selected for experimental study were M-15; M-20 & M-25.Five samples were prepared in each concrete grade having Sodium Nitrite dosage of 1%, 1.5%, 2%, 2.5% and 3% by weight of cement. The concrete specimens were tested for 3 day, 7 day and 28 day compressive strength and the results obtained were compared with those of normal concrete. The optimum percentage of accelerator that could be used without harming the properties of concrete was also assessed. The results concluded permissibility of using accelerating admixture (Sodium Nitrite) up to 2.5% by weight of cement and also the optimum percentage of accelerating admixture was found to be 2.5% with value of compressive strength being maximum at the age of 3 days and 7days for each grade, thereby validating the optimum dosage arrived experimentally.
**Keywords: Accelerator, Chemical, Compressive strength, Splitting tensile strength, flexural strength**

## I. INTRODUCTION

On adding water to cement, paste is formed which gradually stiffens and then hardens. The stiffening of cement paste is called setting [1]. Actually, setting is a process of transformation from an initial state, a scattered concentrated suspension, to a final state, a connected and strengthened system of particles [2]. This transformation in the practice of cement and concrete is obtained by chemical reactions between cement particles and water (i.e. hydration of cement)[3]. Normal setting of cement is associated with the hydration of Alite ($C_3S$) and formation of calcium silicate hydrate (C-S-H) phase [4]. Cement paste / concrete sets gradually under the standard laboratory conditions (temperature ~ 23°C and relative humidity not less than 90%)[5]. But outside the laboratory concreting has to be done under the prevailing climatic conditions.

In many countries or certain regions of countries, fresh concrete is subjected to cold weather. American Concrete Institute (ACI) defines cold weather when two conditions exist for three consecutive days : i) The average daily temperature falls below 5°C, and ii) Air temperature does not rise above 10°C for more than half a day in any 24 hour period[6]. Cold weather, as defined, usually starts during fall and continues till spring and the same is witnessed in Authors's native land Kashmir (India).

Cold weather leads to delay in setting and hardening of concrete, freezing of concrete at early age and thawing which leads to formation of ice needles in concrete and thus cavities are formed after thawing of ice needles which seriously impair the structural integrity of concrete and results in considerable loss of strength. In extreme cases, effects of cold weather may make the concrete an absolutely useless friable mass. On the other hand, if the concrete is sufficiently hardened when freezing conditions are likely to prevail, there will not be much harm to structural integrity of concrete. If the concrete has sufficiently hardened, the water that has been mixed for making concrete will have been utilized either being used up in hydration process or lost by evaporation. Due to the formation of cement gel, the capillary cavities also will have been very much reduced, with the result that there exists very little of free water in the body of concrete to freeze.

Accelerating admixture is an admixture that accelerates the hardening or the development of early strength of concrete[7].The rates of chemical reactions between clinker materials in cements and water, may be altered by adding small amounts of chemical substances to the cement-water mix. Substances affecting these rates to give an overall increase in the hydration rate, i.e. an accelerating effect, are termed accelerating admixtures or simply accelerators. Hence, an accelerator is added to concrete for the purpose of shortening setting time and/or increasing early strength development. In the first case the main action of the accelerator occurs in the plastic state of the cement paste, while in the latter case the accelerator acts primarily in the hardened state. Some accelerators affect either setting or hardening, while several accelerate both setting and hardening. Accelerating admixtures are usually termed ‘chloride based’ or ‘chloride free’ and may be principally set or hardening accelerators. Care is needed to ensure that the correct one is selected for the required application. Most Concrete specifications restrict the use of calcium chloride or admixtures containing calcium chloride to plain unreinforced concrete and ban it for structural concrete that contains embedded metal.

In this research, sodium nitrite is used as accelerating admixture in the dosage range of 1% to 3% by weight of cement. The mechanism of function of accelerating admixture (sodium nitrite) is that it increases the rate of hydration of tricalcium silicate ($C_3S$) and tricalcium aluminate ($C_3A$) phases of cement, thereby providing earlier heat evolution and strength development. It acts as a catalyst in the hydration oftricalcium silicate ($C_3S$) and tricalcium aluminate ($C_3A$) [8]. Concrete specimens of three different grades with varying percentage of sodium nitrite were tested for compressive strength. The results obtained were compared with results of normal concrete mix for each grade and it was found that maximum increase in compressive strength occurred for concrete mix containing 2.5% sodium nitrite by weight of cement at 3 days age and 7 days age. However, there was no considerable increase in compressive strength at 28 days age. The results indicated the absolute possibility of using sodium nitrite as accelerating admixture in concrete subjected to cold weather.

## II. MATERIALS USED

### A. *Cement and Aggregates:*

Khyber ordinary Portland cement of 43 grade confining to IS 8112 [9] was used throughout the work. Fine aggregates used throughout the work comprised of clean river sand with maximum size of 4.75mm conforming to zone II as per IS383-1970 [10] with specific gravity of 2.6. Coarse aggregates used consisted of machine crushed stone angular in shape passing through 20mm IS sieve and retained on 4.75mm IS sieve with specific gravity of 2.7.

### B. *Sodium Nitrite:*

Sodium nitrite was used as accelerating admixture and was purchased from local chemist. Sodium nitrite was in fine powder form so it was easy to add it in mix. Fig. 1 shows sodium nitrite and Fig. 2 shows mixed ingredients of concrete for mix preparation.

## III. EXPERIMENTAL INVESTIGATION

### A. *Mix Proportion:*

The concrete mix designs were proposed by using IS 10262 [11]. The grades of concrete used were M-15, M-20 & M-25 with water to cement ratio of 0.5. The mixture proportions for M-15, M-20 & M-25 used in laboratory for experimentation are shown in TABLE 1, TABLE 2, and TABLE 3 respectively.

### B. *Test on Fresh Concrete:*

The workability of all concrete mixtures was determined through slump test utilizing a metallic slump mould. The difference in level between the height of mould and that of highest point of the subsided concrete was measured and reported as slump. The slump tests were performed according to IS 1199-1959 [12].

### C. *Tests on Hardened Concrete:*

From each concrete mixture, cubes of size 150mm x 150mm x 150mm have been casted for the determination of compressive strength. The concrete specimens were cured under normal conditions as per IS 516-1959 [13] and were tested at 3 days, 7 days and 28days for determining compressive strength as per IS 516-1959 [14].

## IV. RESULTS AND DISCUSSION

### A. *Fresh Concrete:*

The slump values of all the mixtures of grades M-15, M-20 & M-25 are represented in TABLE 1, TABLE 2, TABLE 3 respectively. No considerable change in slump value was observed in fresh concrete samples containing sodium nitrite as admixture as compared to slump value of normal concrete. The variation of slump with varying dosage of sodium nitrite content for different concrete grades is depicted in Fig. 3.

### B. Hardened Concrete Compressive Strength:

The compressive strength tests are presented in TABLE 2. Compressive strength was carried out at 3, 7 and 28 days. An increase in compressive strength was observed up to 2.5% addition of sodium nitrite as admixture and there after strength decreased. The maximum compressive strength measured at 3 days was 40%, 47% and 67% more than that of reference mix at 3 days for M-15, M-20 & M-25 respectively, corresponding to concrete mix containing 2.5% sodium nitrite by weight of cement. The maximum compressive strength measured at 7 days was 45%, 45% and 46% more than that of reference mix at 7 days for M-15, M-20 & M-25 respectively, corresponding to concrete mix containing 2.5% sodium nitrite by weight of cement. Percentage increase in compressive strength was observed to be 6%, 2% & 3% for M-15, M-20 & M-25 respectively at 28 days with respect to reference mix. Compressive strength for concrete mix with 3% sodium nitrite by weight of cement was found to be less than that of reference mix in all the three grades of concrete used. The variation of compressive strength with varying admixture percentage for different grades of concrete at the age of 3, 7 and 28 days are shown in Fig.4, 5, 6 respectively.


Fig. 1: Sodium nitrite.

Fig. 2: Mixing of ingredients for making concrete.

Table – 1
Mixture Proportion for M 15

| Sodium Nitrite % | W/C ratio | Water ($Kg/m^3$) | Cement ($Kg/m^3$) | Sodium Nitrite ($Kg/m^3$) | Fine Aggregate ($Kg/m^3$) | Coarse Aggregate ($Kg/m^3$) | Slump (mm) |
|---|---|---|---|---|---|---|---|
| 0 | 0.5 | 191.6 | 383 | 0.00 | 710 | 1591 | 12.8 |
| 1 | 0.5 | 191.6 | 383 | 3.83 | 710 | 1591 | 12.0 |
| 1.5 | 0.5 | 191.6 | 383 | 5.75 | 710 | 1591 | 13.2 |
| 2 | 0.5 | 191.6 | 383 | 7.66 | 710 | 1591 | 13.0 |
| 2.5 | 0.5 | 191.6 | 383 | 9.57 | 710 | 1591 | 13.4 |
| 3 | 0.5 | 191.6 | 383 | 11.50 | 710 | 1591 | 13.0 |

Table – 2
Mixture Proportion for M 20

| Sodium Nitrite % | W/C ratio | Water ($Kg/m^3$) | Cement ($Kg/m^3$) | Sodium Nitrite ($Kg/m^3$) | Fine Aggregate ($Kg/m^3$) | Coarse Aggregate ($Kg/m^3$) | Slump (mm) |
|---|---|---|---|---|---|---|---|
| 0 | 0.5 | 191.6 | 383 | 0.00 | 546 | 1188 | 15.5 |
| 1 | 0.5 | 191.6 | 383 | 3.83 | 546 | 1188 | 15.0 |
| 1.5 | 0.5 | 191.6 | 383 | 5.75 | 546 | 1188 | 15.2 |
| 2 | 0.5 | 191.6 | 383 | 7.66 | 546 | 1188 | 16.0 |
| 2.5 | 0.5 | 191.6 | 383 | 9.57 | 546 | 1188 | 15.8 |
| 3 | 0.5 | 191.6 | 383 | 11.50 | 546 | 1188 | 14.5 |

Table – 3
Mixture Proportion for M 25

| Sodium Nitrite % | W/C ratio | Water ($Kg/m^3$) | Cement ($Kg/m^3$) | Sodium Nitrite ($Kg/m^3$) | Fine Aggregate ($Kg/m^3$) | Coarse Aggregate ($Kg/m^3$) | Slump (mm) |
|---|---|---|---|---|---|---|---|
| 0 | 0.5 | 191.6 | 383 | 0.00 | 356 | 800 | 16.0 |
| 1 | 0.5 | 191.6 | 383 | 3.83 | 356 | 800 | 13 |
| 1.5 | 0.5 | 191.6 | 383 | 5.75 | 356 | 800 | 13.6 |
| 2 | 0.5 | 191.6 | 383 | 7.66 | 356 | 800 | 15.0 |
| 2.5 | 0.5 | 191.6 | 383 | 9.57 | 356 | 800 | 15.0 |
| 3 | 0.5 | 191.6 | 383 | 11.50 | 356 | 800 | 14.0 |

 

Table – 4
Compressive strength results.

| *Sodium Nitrite %* | *Average cube compressive strength (N/mm²)* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | *3 days* | | | *7 days* | | | *28 days* | | |
| | *M 15* | *M 20* | *M 25* | *M 15* | *M 20* | *M 25* | *M 15* | *M 20* | *M 25* |
| *0* | *7.20* | *10.80* | *12.20* | *8.80* | *13.00* | *15.2* | *15.20* | *20.80* | *26.00* |
| *1* | *8.40* | *13.00* | *14.40* | *9.20* | *14.90* | *16.4* | *15.40* | *21.70* | *26.40* |
| *1.5* | *8.90* | *13.20* | *17.20* | *10.00* | *15.90* | *18.9* | *15.40* | *21.66* | *26.80* |
| *2* | *9.60* | *15.00* | *19.20* | *11.80* | *18.60* | *21.4* | *15.60* | *21.20* | *28.00* |
| *2.5* | *11.20* | *15.90* | *20.40* | *12.80* | *18.70* | *22.2* | *16.20* | *21.34* | *26.80* |
| *3* | *10.40* | *9.10* | *20.20* | *12.40* | *11.30* | *22.0* | *16.00* | *20.00* | *26.40* |

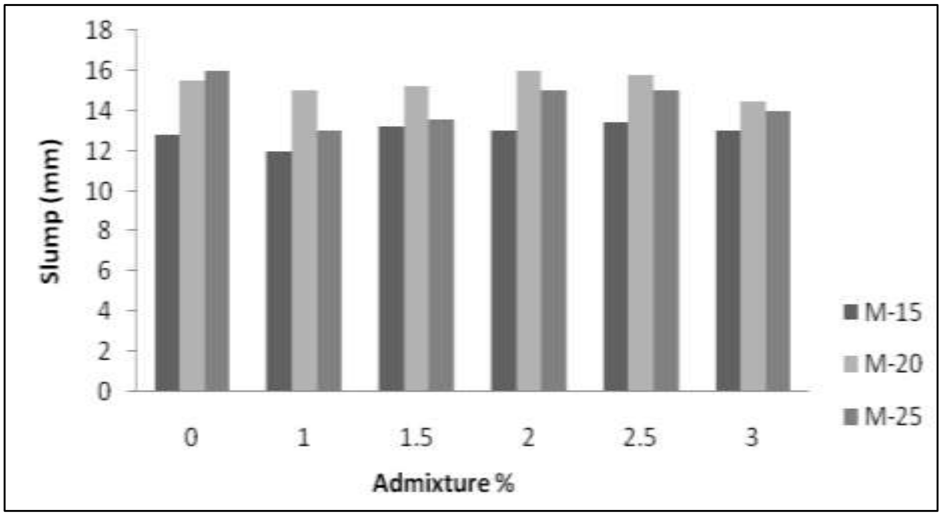


Fig. 3: variation of slump with admixture% for different concrete grades

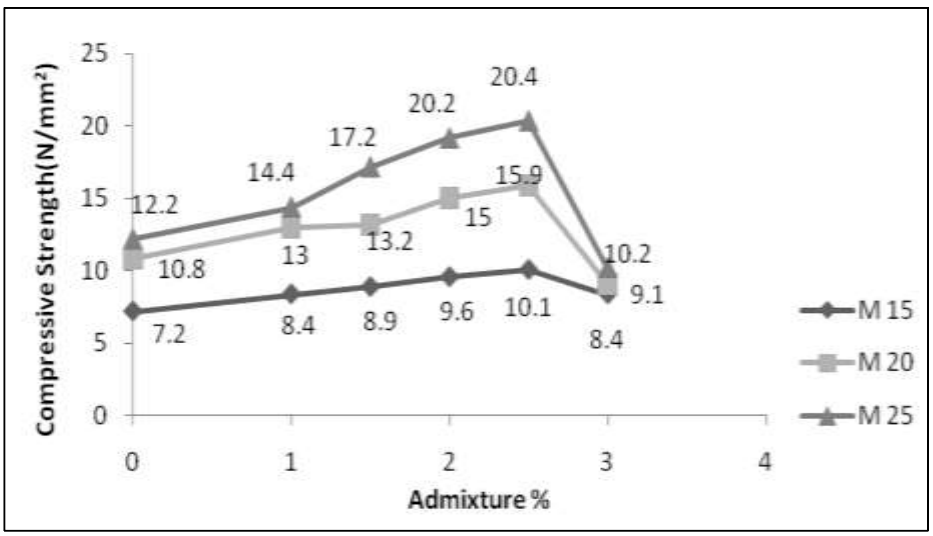


Fig. 4: variation of 3 days compressive strength with admixture% for different grades of concrete

 

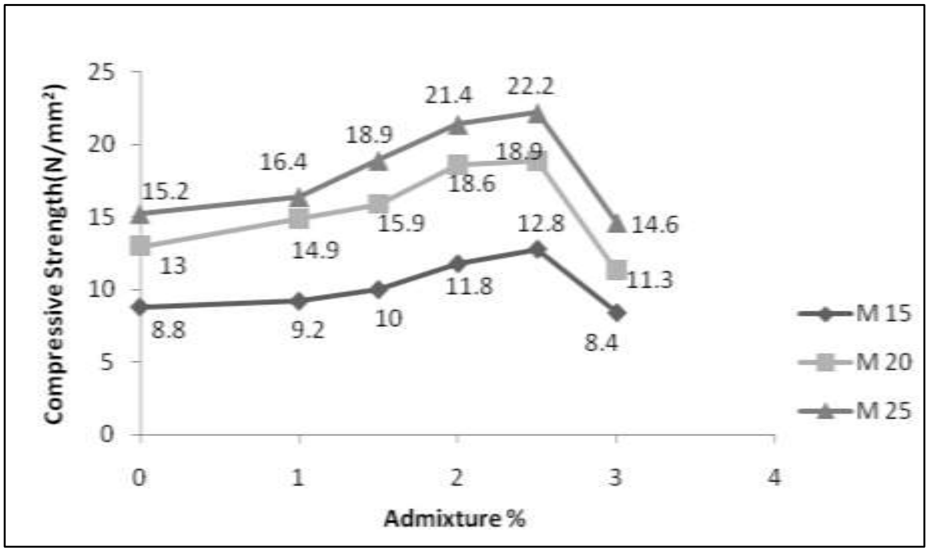


Fig. 5: variation of 7 days compressive strength with admixture% for different grades of concrete

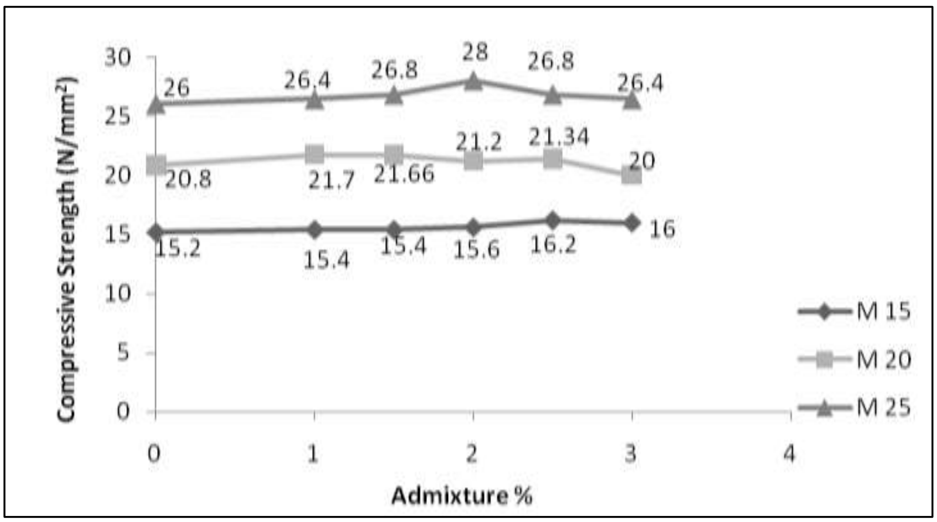


Fig. 6: variation of 28 days compressive strength with admixture% for different grades of concrete

## V. CONCLUSION

On the basis of results obtained, following conclusions can be drawn:

1) 2.5% sodium nitrite addition as accelerating admixture showed 40%, 47% and 67% increase in compressive strength of concrete with respect to reference mix for M-15, M-20 and M-25 grades respectively.
2) The average compressive strength of cubes containing admixture percentage of 3% is less as compared to average compressive strength of plain concrete cubes. This indicates a harmful effect on the compressive strength of concrete on addition of 3% sodium nitrite for all grades of concrete.
3) The peak increase in 3 day and 7 day compressive strength occurs on addition of 2.5% sodium nitrite.
4) The difference in the average 28 day compressive strength between admixture concrete cubes and plain concrete cubes is not considerable .This indicates little effect on increase in compressive strength at age of 28 days at all admixture percentages for all concrete grades.
5) From trial mixes in each grade, a mix containing sodium nitrite percentage of 2.5% was found to possess maximum compressive strength in each grade.
6) Workability of concrete is not much effected with admixture percentage.
7) Sodium nitrite can be used as accelerating admixture particularly in cold climates at 2.5% dosage by weight of cement without any pronounced harmful effects.

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