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Effect of Accelerating Admixture on Properties of Concrete

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***Abstract*: -** The problems of cold weather concreting arise from the action of frost on fresh concrete. If the wet concrete is allowed to freeze, the mixing water converts to ice and there is an increase in overall volume of concrete. Since there is now no water available for chemical reactions, setting and hardening of concrete are delayed. In this paper, the issue of delayed setting and hardening of concrete are addressed by the use of accelerating admixture(Sodium Nitrite) in concrete. Sodium Nitrite as accelerating admixture was added in five samples 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, flexural strength and splitting tensile 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, flexural strength and splitting tensile strength being maximum at the age of 3 days and 7days.

Keywords :- *Admixture, Sodium nitrite, 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 of tricalcium silicate (C_3S) and tricalcium aluminate (C_3A) [8]. Concrete specimens with varying percentage of sodium nitrite were tested for compressive strength, splitting tensile strength and flexural strength. The results obtained were compared with results of normal M-20 concrete mix and it was found that maximum increase in compressive strength, splitting tensile strength and flexural 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, splitting tensile strength and flexural 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

2.1. 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.

2.2.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

3.1. Mix Proportion

The concrete mix design was proposed by using IS 10262 [11]. The grade of concrete used was M-25 with water to cement ratio of 0.45. The mixture proportions used in laboratory for experimentation are shown in TABLE 1.

3.2. 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].

3.3. Tests on hardened concrete

From each concrete mixture, cubes of size 150mm x 150mm x 150mm, 150mm x 300mm cylinders and 500mm x 100mm x 100mm beams have been casted for the determination of compressive strength, splitting tensile strength and flexural strength respectively. 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], splitting tensile strength as per IS 5816-1999 [15] and flexural strength as per IS516-1959 [16].

IV. RESULTS AND DISCUSSION

4.1. Fresh concrete

The slump values of all the mixtures are represented in TABLE 1. 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 sodium nitrite content is depicted in Fig. 3.

4.2. Hardened concrete

4.2.1. Compressive strength

The compressive strength tests are presented in TABLE 2. Compressive strength tests, splitting tensile strength tests and flexural strength tests were 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 decreasing. The maximum compressive strength measured was 47% and 44%more than that of reference mix at 3 days and 7 days respectively, corresponding to concrete mix containing 2.5% sodium nitrite by weight of cement. 6%

increase in compressive strength was observed 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.

1.2.2. Splitting tensile strength

The splitting tensile strength tests are presented in TABLE 3. Splitting tensile strength witnessed an increase of 33%, 14% and 10% at 3, 7 and 28 days of age respectively, corresponding to concrete mix containing 2.5% sodium nitrite by weight of cement.

1.2.3. Flexural strength

The flexural strength tests are presented in TABLE 4. Flexural strength witnessed an increase of 21%, 25% and 25% at 3,7 and 28 days of age respectively, corresponding to concrete mix containing 2.5% sodium nitrite by weight of cement. Both splitting tensile strength and flexural strength for concrete mix with 3% sodium nitrite by weight of cement was found to be less than that of reference mix. Fig. 4, 5 and 6 present compressive strength of all mixtures at 3, 7 and 28 days respectively. Fig. 7, 8 and 9 present flexural strength of all mixtures at 3, 7 and 28 days respectively. Fig. 10, 11 and 12 present splitting tensile strength of all mixtures at 3, 7 and 28 days respectively.

Fig. 1. Sodium nitrite.

Fig. 2. Mixing of ingredients for making concrete.

TABLE 1 – Mixture Proportion.

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 2 – Compressive strength results.

Sodium Nitrite	Average cube compressive strength (N/mm^2)		
%	3 days	7 days	28 days
0	10.80	13.00	20.80
1	13.00	14.90	21.70
1.5	13.20	15.90	21.66
2	15.00	18.60	21.20
2.5	15.90	18.70	21.34
3	9.10	11.30	20.00

TABLE 3 – Splitting tensile strength results.

Sodium Nitrite %	Average cylinder splitting tensile strength (N/mm^2)		
	3 days	7 days	28 days
0	1.58	2.22	2.28
1	1.72	2.47	2.57
1.5	1.78	2.68	2.72
2	1.84	2.72	2.75
2.5	1.92	2.78	2.84
3	1.42	2.08	2.12

TABLE 4 – Flexural strength results.

Sodium Nitrite %	Average flexural strength (N/mm^2)		
	3 days	7 days	28 days
0	1.34	2.35	3.10
1	1.36	2.23	2.96
1.5	1.54	2.47	3.02
2	1.67	2.52	3.26
2.5	1.78	2.68	3.42
3	1.22	1.94	3.08

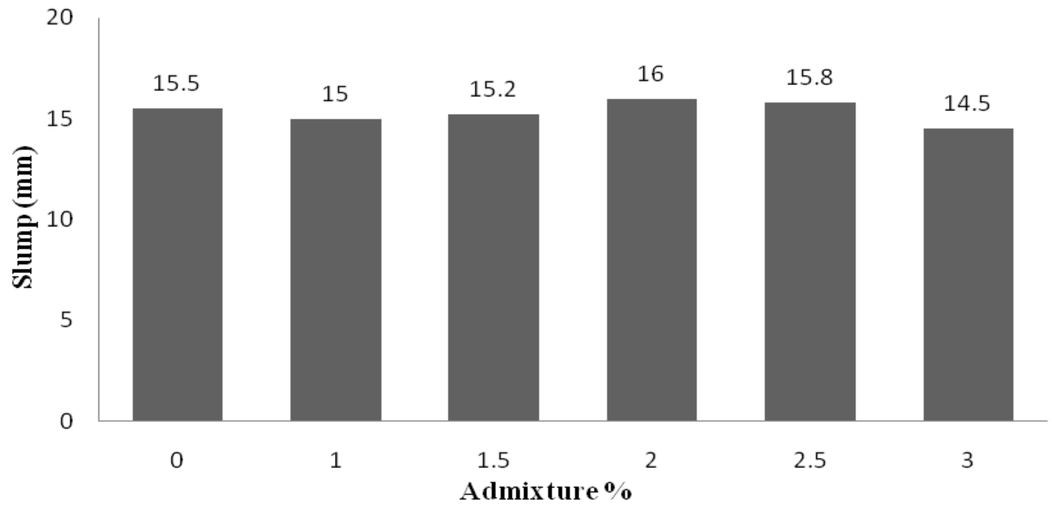

Fig. 3. Variation of Slump with Sodium Nitrite content

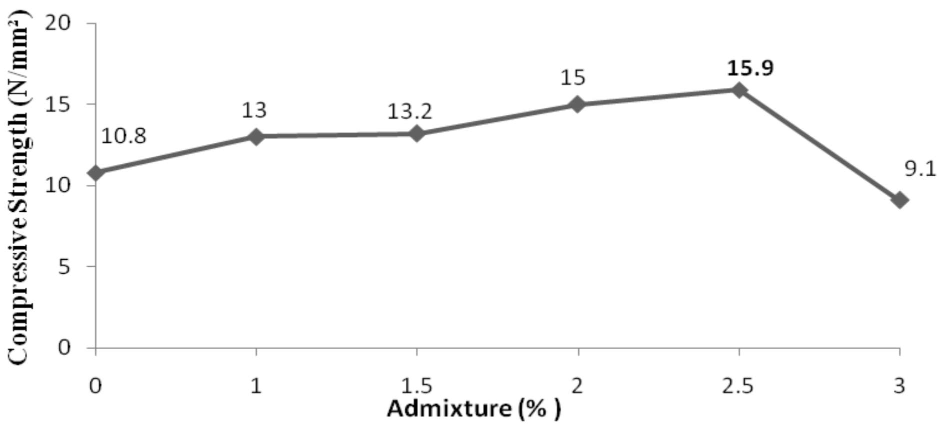

Fig.4. Compressive Strength of cubes at 3 days

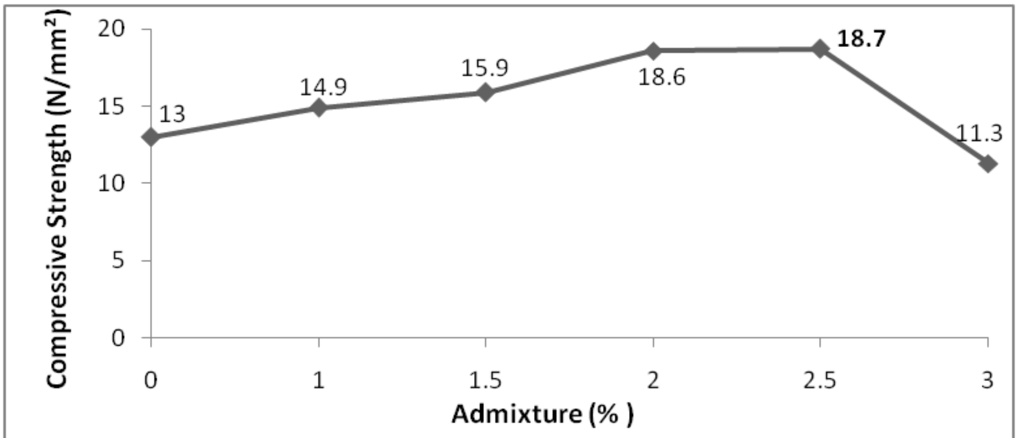

Fig.5. Compressive Strength of cubes at 7 days

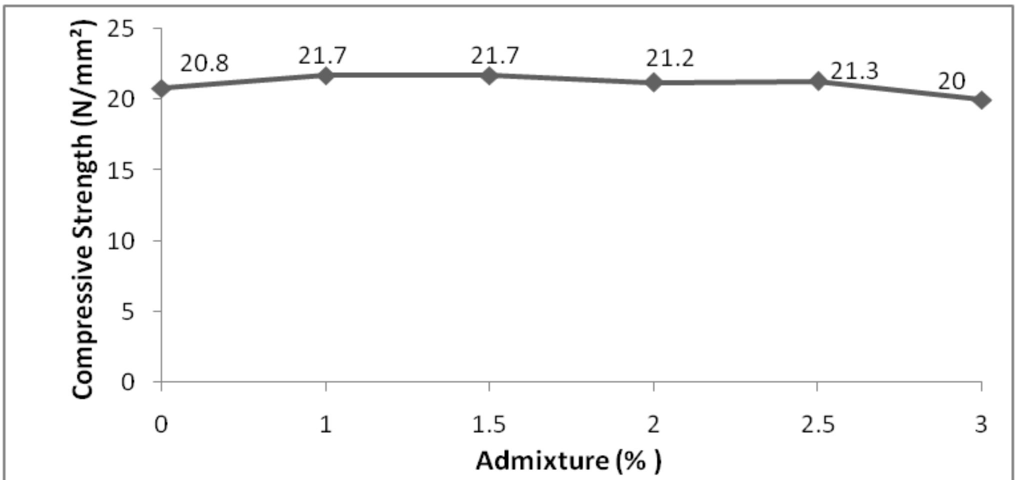

Fig.6. Compressive Strength of cubes at 28 days

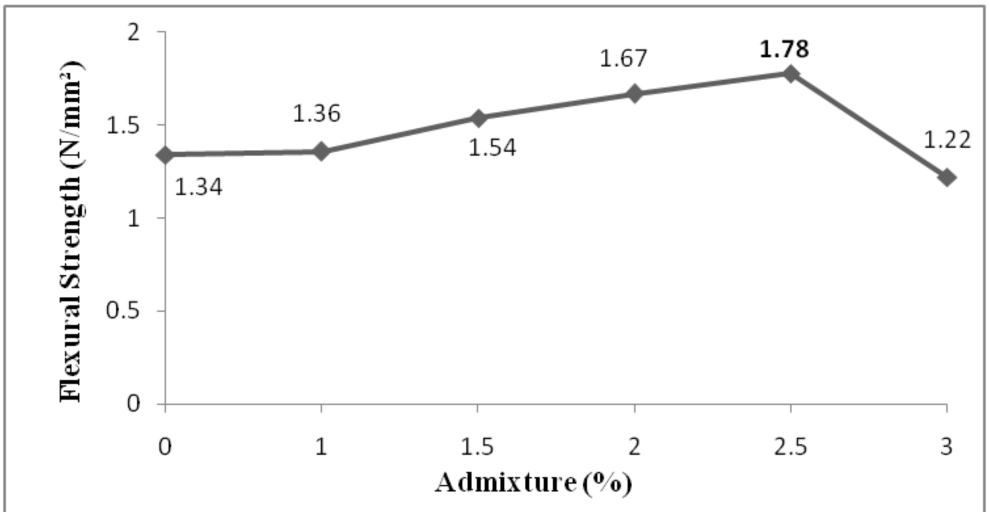

Fig.7. Flexural Strength of beams at 3 days

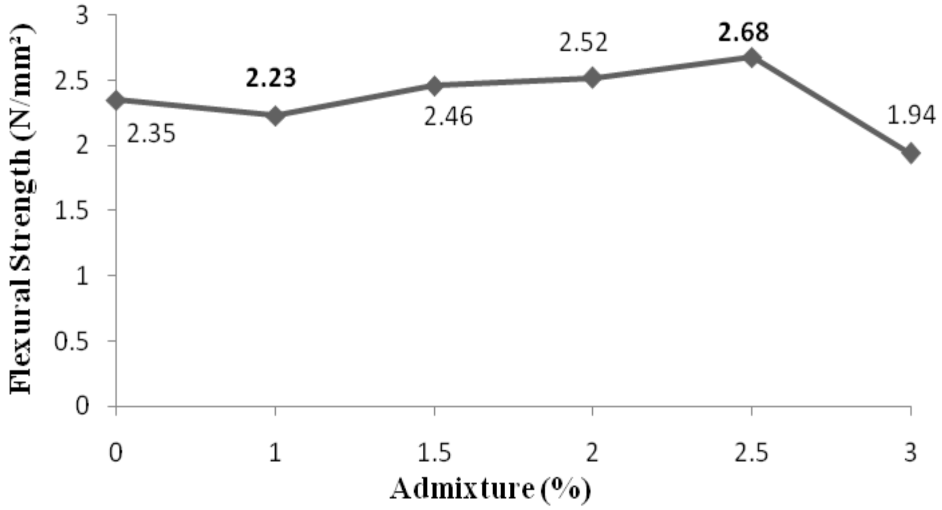

Fig.8. Flexural Strength of beams at 7 days

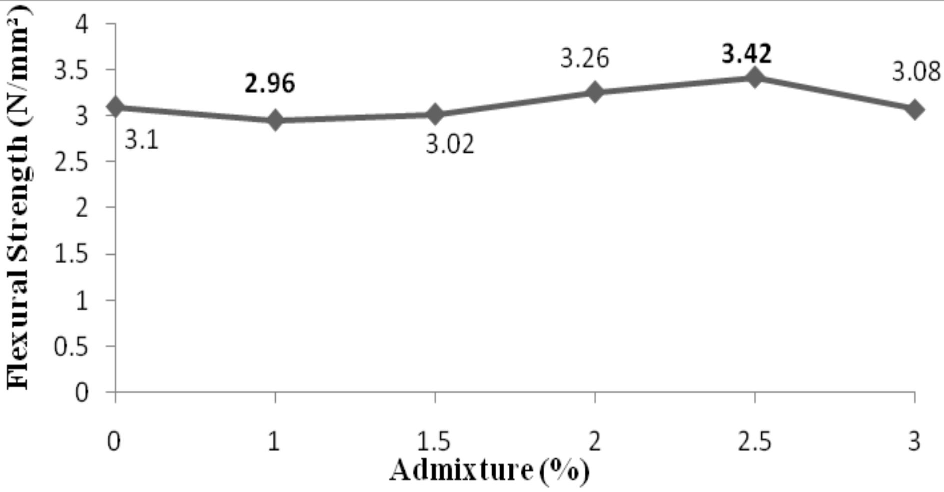

Fig.9. Flexural Strength of beams at 28 days

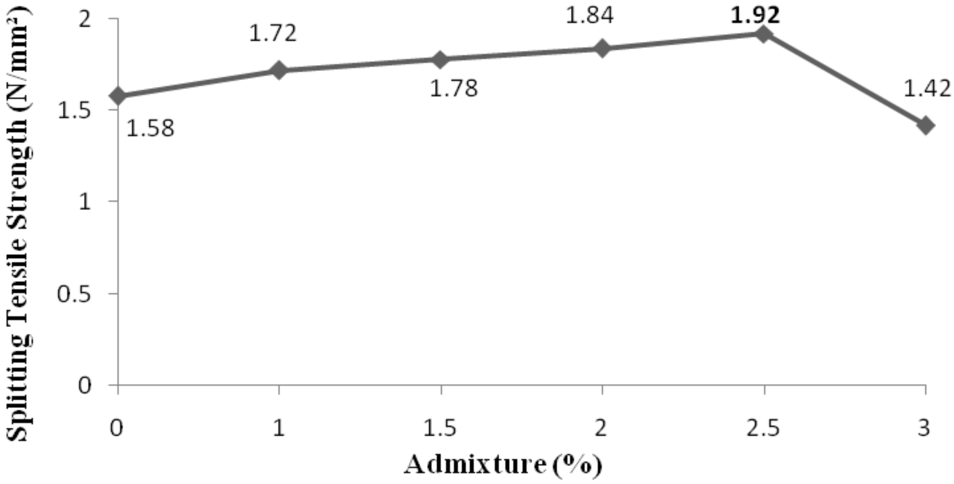

Fig.10. Splitting Tensile Strength of cylinders at 3 days

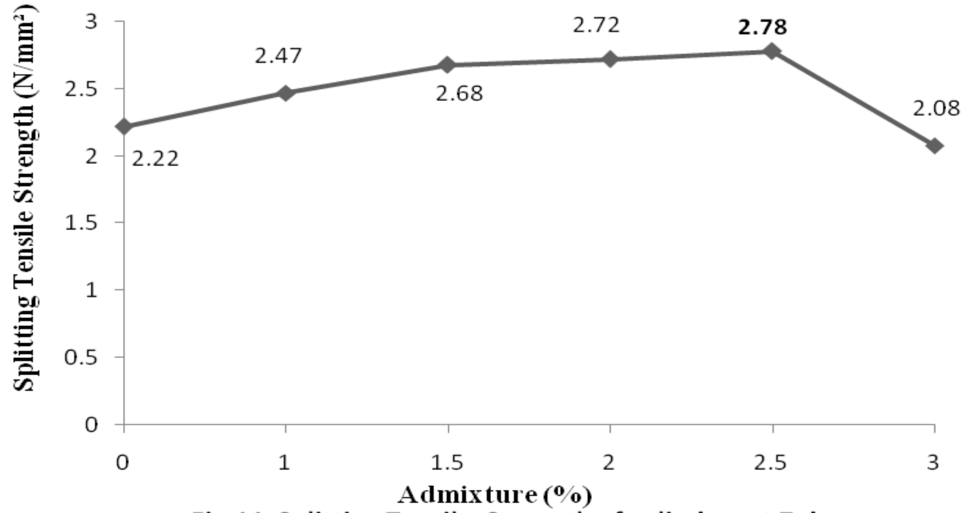

Fig.11. Splitting Tensile Strength of cylinders at 7 days

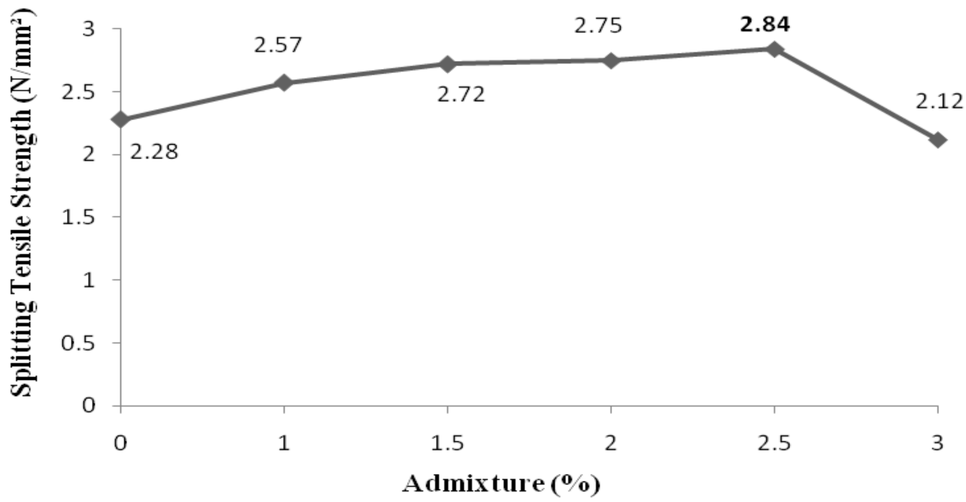

Fig.11. Splitting Tensile Strength of cylinders at 28 days

V. CONCLUSION

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

1. 2.5% sodium nitrite addition as accelerating admixture showed 47%, 44% and 6% increase in compressive strength of concrete with respect to reference mix at 3, 7 and 28 days.
2. 2.5% sodium nitrite addition as accelerating admixture showed 33%, 14% and 10% increase in splitting tensile strength of concrete with respect to reference mix at 3, 7 and 28 days.
3. 2.5% sodium nitrite addition as accelerating admixture showed 21%, 25% and 25% increase in flexural strength of concrete with respect to reference mix at 3, 7 and 28 days.
4. Percentage increase of compressive strength, splitting tensile strength and flexural strength for concrete mixes containing sodium nitrite less than 2.5% was less than that occurred at 2.5% addition.
5. Compressive strength, splitting tensile strength and flexural strength for concrete mix containing 3% sodium nitrite by weight of cement was less than that of reference mix.
6. A decrease of 5% and 4.5% was observed in flexural strength for concrete mix containing 1% sodium nitrite, therefore nullifying its possibility of use as far as flexural strength is concerned.
7. An increase of compressive strength, splitting tensile strength and flexural strength at 3 and 7 days corresponding to 2.5% sodium nitrite addition specifies its absolute possibility of usage as accelerating admixture.
8. Workability of concrete is not effected rather it increases slightly.
9. Sodium nitrite can be use as accelerating admixture particularly in cold climates at 2.5% dosage by weight of cement without any pronounced harmful effects.

10. For M20 mix having w/c as 0.5, 2.5% sodium nitrite by weight of cement is recommended as accelerating admixture in cold weather.

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