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Performance of concrete with chemical admixtures cured in cold condition

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Abstract— Cold weather concreting requires an understanding of various factors that affect concrete properties like setting time, strength, thermal cracking etc. The concrete cured in cold weather doesn't gain early strength and lead to improper setting and uneven strength gain due to the freezing of the water mixed with the cement. Hence there are many strength related problems faced at site due to cold weather particularly in parts of north India where temperature reaches below freezing point of water during winter season. This paper provides a comparative study between concrete cured in controlled and cold temperature (-5°C). The mixes used contain varying amount of accelerators, super plasticizers and air entraining admixture. The results for compression strength show that the concrete mix with higher dosage of admixture and rapid chloride penetration test showed low permeability.

Index Terms—Accelerator, Air entraining admixture, Cold curing, contol curing, super plasticizer, RCPT

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1 INTRODUCTION

Concrete is a composite material widely used in the construction industry as a building material. It has a versatile nature as it can be casted into any shape making it widely used in all the region of the world. As a construction material, concrete has been used since very long to construct buildings to provide shelter, workspaces, roads and bridges to facilitate movement, dams to store water and now for modern day applications like skyscrapers, nuclear reactors etc. Concrete has high compressive strength, high fire resistance and durability. The functional and aesthetic properties offered by concrete, along with the flexibility it offers for its properties to be varied has mainly contributed in making concrete the primary construction material worldwide.

Concrete has become a universal building material and has become an indispensable part of human society. It is very strong under compression and weak under tension, brittle and limited ductile. Hence being widely used in construction concrete is used is very extreme climate condition all around the world. The countries like Russia, Norway, Canada, USA etc. has extreme cold weather in the winter seasons. In India the region near extreme north in the foot hills of Himalayas particularly covering states Jammu & Kashmir, Himachal Pradesh, Sikkim, Darjeeling in West Bengal experiences the extreme cold weather with temperature falling to – 5^{o}C at the few places along with snow fall in the winter season.

Cold weather as a period of three or more successive days during which the average daily outdoor temperature drops below 4 C and the air temperature is not greater than 10 C for more than one-half of any 24-h period. At temperatures below 5 C, 92% of the water in fresh concrete turns into ice. Consequently, strength development essentially stops, but there is little water to react with the cement. [1] These short coming of concreting in cold weather has led to considerable research aimed at developing new approaches to modify the concrete properties of concrete so that it facilitates the concreting in cold weather. The conventional methods are thawing the aggregates and adding hot water, heating the region of casted concrete until development of strength. Successful cold weather concreting requires an understanding of various factors that affect concrete properties. Antifreeze admixtures have been used in cold weather concreting to reduce the time that concrete needs to be kept warm.[2] Also chloride based accelerators were used traditionally as an antifreeze admixture to accelerate the strength of concrete. The use of calcium chloride in concrete containing embedded metal is the cause of corrosion.[3] Hence the shift of research took place towards non chloride based accelerator. Also the use of admixture like super plasticizer are widely being used in concreting to ease the operation of handling, transporting, placing and finishing of concrete.

2 METHODOLOGY

2.1 Objectives of the work

The present study is going to account the use of various types of industrially available admixture in india for improving the concreting in cold cured condition and for early strength development.The objective of the work are as follows,

1. Comparative study of the compressive strength characteristic of concrete cured in cold condition to that of normal curing with the use of industrial available admixtures.
2. To study the performance of cold cured concrete by rapid chloride penetration test.

2.2 Sequence of work

All the basic ingredient materials required for casting the test specimens were collected and tests were carried out to determine their physical properties. The mix proportion of a representative M30 grade concrete mix was arrived at as per IS 10262-2009 guidelines. The mixing and casting of these test specimens were carried out and the strength behaviour of the resulting concrete mixes in their fresh and hardened states were evaluated.

The temperature for the curing of concrete is fixed as – 5°C as this the minimum temperature that is found in India at the day time.

The temperature of the mixing water was kept at 10° C hence the temperature of the concrete casted would be between 20 to 25°C and hence will be greater than 18°C which is the minimum temperature required or casting.

3 Tests On Materials

The following materials were used in the present study.

- Ordinary Portland Cement 53 grade
- Coarse aggregates 20 mm down
- Fine aggregates
- Water
- Chemical Admixture.

The materials used in the making of concrete have equally diverse properties and behaviour. The properties of these materials were determined in the laboratory as per standard specifications, results of which are as follows

3.1 Cement

Ordinary Portland cement of 53 grade conforming to IS 12269:2013 was used for the laboratory investigations. The required tests for assessing the properties of cement were carried out according to IS 4031. The test results are shown in Table 1

Table 1
CEMENT TEST RESULTS

Sl No.	Properties	Values Obtained	Requirement as per IS 12269:2013	Remarks
1	Specific gravity	3.15	---	The cement satisfies the requirement for 53 grade OPC stipulated by IS 12269:2013.
2	Standard consistency	29%	---	
3	Fineness	328m²/kg	Should not be less than 225m²/kg	
4	Initial setting time	60min	Should not be less than 30min	
5	Final Setting Time	310 minutes	Should not be more than 600 minutes	
6	Soundness (By Le ChatelierMould)	2 mm	Should not exceed 10 mm	
7	Compressive strength of mortar cubes	3days – 28.6N/mm2 7days – 40.6N/mm2 28days - 55N/mm2		

3.2 Coarse Aggregate

Locally available crushed stone coarse aggregates of size 20 mm down were used. The aggregates were composed of a mixture of rounded and angular aggregates. The various properties of aggregates were determined as per IS 2386 (Part III, IV): 1963 and the specifications are checked as per IS 383: 1970 requirements. The physical properties of coarse aggregates are shown in Table 2 and Table 3 gives the results of the sieve analysis results conducted on the coarse aggregates

TABLE 2
TEST RESULTS FOR COARSE AGGREGATES

Sl. No.	Property		Value
1	Specific Gravity		2.74
2	Bulk Density	Loose	1493 kg/m3
		Compacted	1712 kg/m3
3	Percentage of Voids	Loose	45.5%
	Percentage of Voids	Compacted	37.5%
4	Moisture Content		Nil
5	Water Absorption		0.5%

TABLE 3
SIEVE ANALYSIS RESULTS FOR CA (SAMPLE WT. 5KG)

IS Sieve Size (mm)	Weight Retained (kg)	% Weight Retained	Cumulative % Weight Retained	% Passing	IS 383:1970 Requirement (percentage passing for graded aggregate of nominal size 20mm)
40	0.00	0.0	0.0	100	100
20	0.23	4.6	4.6	95.4	95-100
10	3.41	68.2	72.8	27.2	25-55
4.75	1.33	26.6	99.4	0.6	0-10
Pan	5.00	-	100.0	176.8	

Fineness modulus = 5+ (176/100) = 6.7

3.3 Fine Aggregate

Locally available river sand conforming to zone II (IS 383:1970), passing through 4.75 mm sieve was used as fine aggregate. The sand was free from organic matter and silt. The properties of sand such as fineness modulus and specific gravity were determined as per IS 2386-1963 (Part I). The physical properties of sand are tabled in Table 4, sieve analysis results are given in Table 5 and the grading curve is shown in Fig. 1

TABLE 4
TEST RESULTS FOR FINE AGGREGATES

Sl. No.	Property		Value
1	Specific Gravity		2.62
2	Bulk Density	Loose	1440 kg/m3
		Compacted	1680 kg/m3
3	Percentage of Voids	Loose	45.04%
	Percentage of Voids	Compacted	36.65%
4	Moisture Content		0.5%
5	Water Absorption		2%

TABLE 5
SIEVE ANALYSIS RESULTS FOR FA (SAMPLE WT. 1KG)

IS Sieve Size (mm)	Weight Retained (kg)	% Weight Retained	Cumulative % Weight Retained	% Passing	IS 383:1970 Requirement (percentage passing for graded aggregate of nominal size 20mm)
10	--	--	--	--	100
4.75	11	1.1	1.1	98.9	90-100
2.36	12	12	2.3	97.7	75-100
1.18	343	34.3	36.6	63.4	55-90
0.60	449	44.9	81.5	18.5	15-59
0.30	100	10.0	91.5	8.5	8-30
0.15	85	8.5	100	0	0-10

Fines modulus of fine aggregate = (314/100) = 3.14

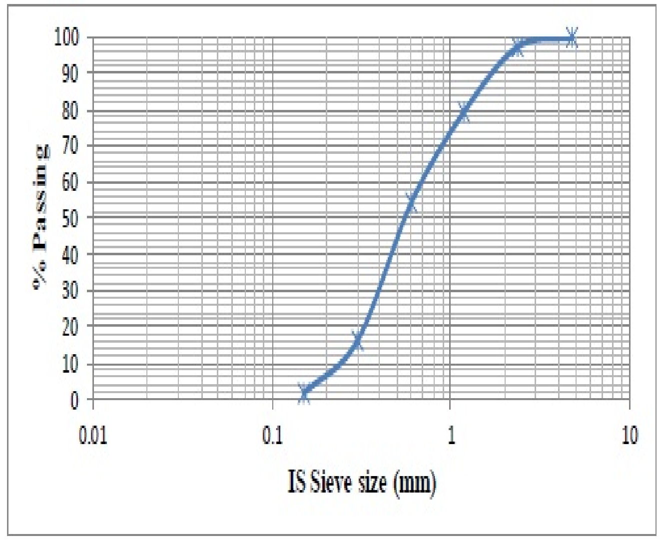

Fig. 1 Partical size distribution curve for FA

3.4 Water

Normal tap water is used for casting. The same water was cooled to 10°C temperature to be used as mixing water in tests to be done herein.

3.5 Chemical Admixture

The admixture used in concrete mixing are in combination of non chloride based accelerators, polycarboxylic ether based super plasticizer and air entraining admixture commercially available by BASF company. These admixtures were conforming to the Indian standards for admixture. [4]

4 Mix Design

Designing of a proper mix for a particular strength and workability is very important for assessing the properties of the materials used in concrete. Each material will influence the properties of concrete in its own way. Concrete mix of M30 grade was designed following the guidelines in IS 10262:2009. [5] The mix proportion is shown in Table 6.

TABLE 6
MIX PROPORTION OF REFERENCE CONCRETE (M30, KG/M^3)

Cement	Fine Aggregate	Coarse Aggregate	Water	Accelerator	AEA	Superplasticizer
385	680	1265	153	7.93	0.154	0.385

5 Mixing, Casting & Curing

In order to achieve cold climate conditions Deep freezer with temperature controller is used for curing the test specimens.

Cement, Coarse aggregate, fine aggregate are added and dry mixed followed by adding of water. Wet mix of the concrete is made with 70% of the mixing water and the admixture are mixed and poured with the remaining water.

The concrete are then poured in moulds of cube and cylinder of 100x100x100mm for strength test and 100 x 200mm cylinders for RCPT respectively and compaction is done with the help of table vibrator

The concrete with the moulds are immediately transferred to the cold freezer for cold curing, demoulded after 24 hours and kept back in the freezer. The control samples were normally cured in water tank after demoulding. The RCPT cylindrical samples were later cut at depth of 50mm for pllacing them in the RCPT specimen

For hardened concrete the 3 day, 7 day and 28 days strength was checked as per Indian standards of testing. [6] The chloride ion penetration for 28 days cold cured concrete was checked. Also the control sample was checked for the above stated tests and a comparative study was done.

TABLE 7
MIX COMPOSITION

	Mix1	Mix 2	Mix 3	Mix 4	Mix 5
W/C ratio	0.45	0.40	0.40	0.40	0.40
AEA	0.1%	0.1%	0.04%	0.05%	0.05%
Accelerator	5 lit/cum	5 lit/cum	7 lit/cum	10 lit/cum	14 lit/cum
Super Plasticizer	0.5%	0.2%	0.2%	0.15%	0.10%

6 Results Obtained

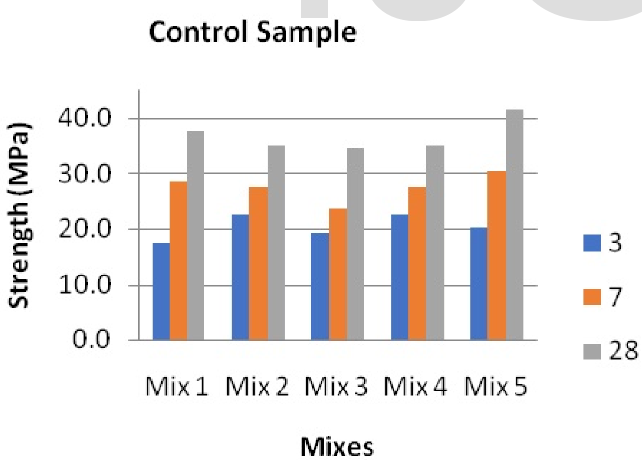

Fig 2. Compressive strength of control samples

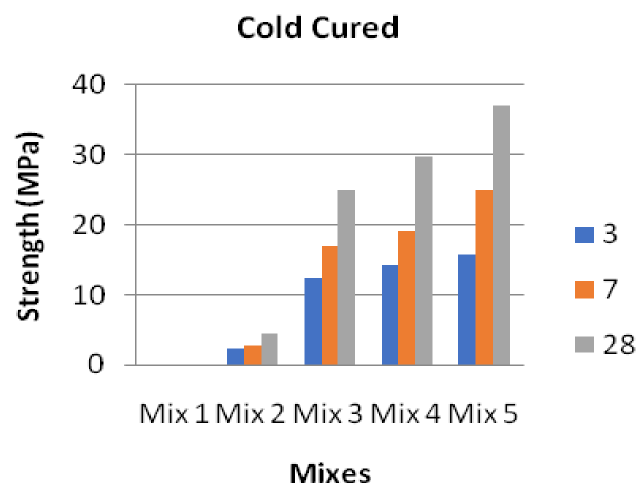

Fig 3. Compressive strength of cold cured samples

The RCPT test for the specimen of mix 5 cured for 28 days was done.The value of both control specimen and cold cured specimen were between 1000 to 2000 coulombs and hence the chloride penetration is low. The passage of charge in case of cold cured specimen was found to be higher than that of normal cured specimen. The value of both fall in the range of low chloride ion permeability and hence can be comparable to each other.

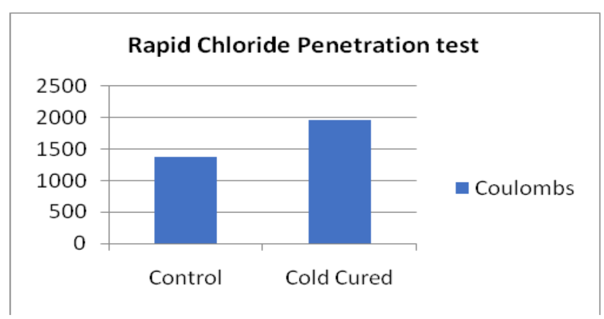

Fig. 4. Mix 5 28 days cured rapid chloride penetration test passage of charges in coulombs

7 Conclusion

1. In case of cold curing the Mix 5 gave better result.
2. The lean mixes with high water cement ratio like the mix 1 and mix 2 dint gain high strength due to high

water cement ratio

3. The super plasticizer optimum dosage and reduction of water content due to it and the increase of the accelerator lead to the increase in the strength of concrete.
4. The accelerators generally reduces the eutectic point of water due to which water freezes below zero degree Celsius due to which the hydration of cement continues and hence leads to gain in strength.
5. The stiffer mixes gave better results in case of cold cured concrete hence during casting at site workability and also the temperature condition if variable, the test results may vary.
6. The mix 5 had more amount of accelerator and less amount of super plasticizer compared to the Mix 4.
7. The control specimen cured for 28 days had lesser chloride penetration than the cold cured sample, all though result of both are in the range of low permeability and hence is comparable

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