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Experimental Study on the Roll of Waterproofing Admixtures on the Strength and Durability of Concrete

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Abstract: This study deals, the durability and strength of concrete using admixtures. This addition of water proofing admixtures turns concrete into a construction material in harmony with sustainable building development. The addition of water proofing admixtures also increases the various strength of concrete. These studies were carried out by conducting tensile, compressive and flexural strength tests of the concrete specimen with and without admixtures for various dosages and various curing periods of 7 and 28 days. For flexural strength concrete prism of size 100×100×500 mm, for compression test cube of 150×150×150 mm, for split tensile test cylinders of 150×300 mm. For durability study permeability tests were conducted on the cube specimen of size 150×150×150 mm. The results showed that the presence of waterproofing admixtures always improves the corrosion resistance and thus, increases the strength of concrete.

Key words: Admixtures, concrete, durability, permeability, corrosion, tensile strength, compressive strength, flexural strength, waterproofing

INTRODUCTION

Insufficient durability of concrete structures has become a serious problem. One of the most important parameters influencing the durability of concrete is its permeability. The permeability of concrete determines the ease with, which gases, liquids and dissolved deleterious substances such as carbon-di-oxide or oxygen or chloride ions penetrate the concrete.

If the corrosion process has started the rate of corrosion is still dependent on the supply of oxygen. The permeability of concrete is a major factor affecting the service life of reinforced components (Anonymous, 1981).

Addition of water proofing admixtures reduces the permeability of concrete and thus, protects the coated reinforcement for corrosion.

Concrete has traditionally been regarded as a durable material requiring little or no maintenance. However experience shows that this is not the case, many concrete structures are now showing signs of deterioration despite being only 20-30 years old. The major cause of deterioration is the chloride contamination of concrete and hence, reinforcement corrosion by Shetty (2002).

The addition of water proofing admixtures increases various strength of concrete. In this study, the compressive strength, tensile strength, flexural strength was investigated using waterproofing admixtures.

MATERIALS AND METHODS

Cement: Ordinary Portland cement of 53 grade is used in this investigation. The physical properties of the cement are shown in Table 1.

Aggregates: The physical properties of fine and coarse aggregates are shown in Table 2 and 3.

Table 1: Properties of cement

Tests	Results
Specific gravity	3.15
Fineness	2%
Standard consistency	31%
Compressive strength	
7 days	34 N mm^{-2}
28 days	54 N mm^{-2}
Setting time	
Initial	30 min
Final	585 min

Table 2: Properties fine aggregates

Tests	Results
Specific gravity	2.6
Fineness Modules	2.2

Table 3: Properties of coarse aggregates

Tests	Results
Specific gravity	2.50
Fineness Modules	5.73

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Chemical admixtures: The following water proofing admixtures were used for this investigation.

- Naphtha based chemicals
- Lignosulphonate based chemicals
- Melamine based chemicals
- Polymer based chemicals
- Stearate based chemicals

Mixture proportion: For the entire test, M20 designed mix (1:1.55:3.1) was taken. The water cement ratio was 0.55 by mass. The each chemical is used in various dosages (DI, DII, DIII).

Preparation and casting of test specimens mixing of concrete: Hand mixing has been carried out, in this investigation. This was done over an impervious concrete floor. The measured quantity of the filler coarse aggregate and fine aggregate were spread out in alternate layers. The measured quantity of cement was poured on the top of it and mixed dry by shovel, turning the mixture over and over again until uniformity of color was achieved. The required dosage of the chemical was mixed with the required amount of water. The measured amount of water was sprinkled over the mixture and simultaneously turned over. This operation continued until uniform, homogenous concrete was obtained.

Casting and curing of test specimens: Concrete specimens were casted using the following moulds.

- 150×300 mm cylinder-tensile strength test
- 150×150×150 mm cube-compressive strength test
- 100×100×500 mm prism-flexural strength test
- 50×150×150 mm cube-permeability test (Table 4)

After 24 h, the specimens were remolded and cured in a water tank, until the time of test was reached.

Testing of specimens: All the tests were done in UTM of 100 tons capacity. All the specimens were cured for 7 and 28 days before testing with and without chemical of various dosages.

Durability test (permeability): Concrete prism specimens were manufactured with a designed concrete mix M 20 with water cement ratio 0.55 with and without water proofing admixtures. Each water proofing admixture was added at 3 different dosages by weight of cement. Then they are allowed to cure in ordinary potable water for 7 and 28 days.

Experimental investigation

Compressive strength: The specimens were taken out from the water only after 7 and 28 days. The specimen were placed or kept on the plate and the loads were applied gradually. The ultimate loads were observed. The load is applied till the failure of the specimen occurs by Shetty (2002).

Tensile strength: The specimens were taken out from the water only after 7 and 28 days. The specimen were placed or kept on the plate and the loads were applied gradually. The ultimate loads were observed. The load is applied till the failure of the specimen occurs.

The tests were conducted over the specimen for chemicals of various dosages. After obtaining the failure load, the split tensile strength (f_{ct}) can be determined by the following equation:

$$F_{ct} = 2P/\pi DL \text{ N mm}^{-2}$$

where:

F_{ct} = Flexural stress (N mm^{-2})
P = Failure load (kg)
D = Diameter of the specimen 150 mm
L = Length of the specimen 300 mm

The third point loading test is used for flexural strength test because, ideally, in the middle third of the span, the span is subjected to pure moment with zero shear by Mindess and Young (1981). The experimental set up is shown in Fig. 1.

Table 4: The test details of all the specimens

Specimen size (mm)	Description	Curing 7 days	Curing 28 days	No. specimen
Cube 150×150×150 compression test	Without chemical	3	5	8
Cube 150×150×150 compression test	With chemical	45	75	120
Cylinder 150×300 tensile test	Without chemical	3	5	8
Cylinder 150×300 tensile test	With chemical	45	75	120
Prism 100×100×500 flexure test	Without chemical	3	5	8
Prism 150×100×800 flexure test	With chemical	45	75	120
Cube 150×150×150 permeability test	With out chemical	3	3	6
Cube 150×150×150 permeability test	With chemical	45	45	90
	Total specimens tested	-	-	480

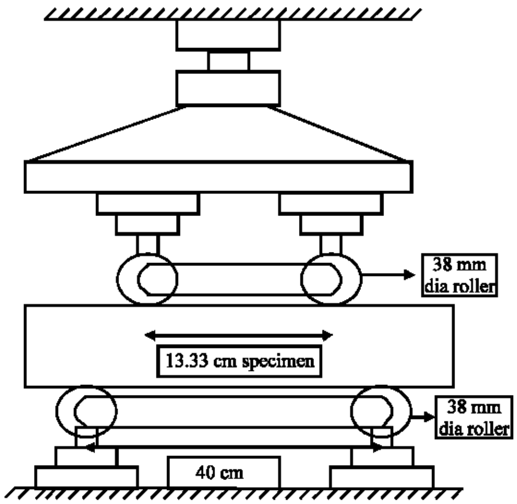

Fig. 1: Experimental set up

Two dial gauges were being used for this investigation. One was placed at center and the other was placed at one-third distance from two supports of the beam. The load was applied through two similar rollers mounted at third points of the supporting span that is 13.3 cm center to center. The load was applied without shock increasing continuously at the rate of 180 kg min^{-1}. Until the failure of the beam. Deflections were taken at the mid point and one-third point. The load at failure and deflections were noted. The distance of the cracks from the support was also noted down. L is the length of the specimen with reference to concrete technology by Shetty (2002).

Permeability test: After 28 days of curing, specimens were placed properly in the permeability cell as shown in Fig. 2. A Rubber sheet of 8 mm thick and 150×150 mm size was taken and a hole of 100×100 mm was made in the center. This rubber sheet was then placed on the top and bottom surface of the cube in the permeability cell. Cover plate was then tightened properly. The rubber sheet acts as a washer and prevents the leakage of water through the annular space between specimen and cell.

The test was conducted continuously for 100 h. After 100 h cubes were then taken out from the cell. If any permeation of water was there, then the quantity of permeated water was measured and value calculated using the steady flow method. And if there was no permeation the cubes were splited and depth of penetration was measured and value calculated using the depth of penetration method. The measure of water penetration is achieved by measuring the average depth of discoloration, due to wetting by Ramachandran (1995) and Aldred (1988).

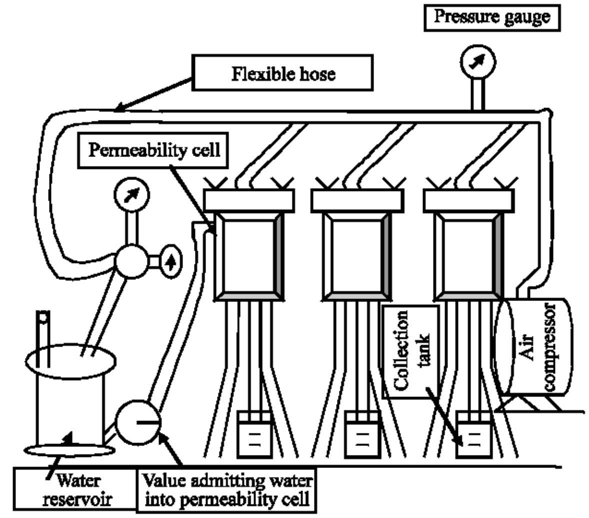

Fig. 2: Experimental set up for permeability test

In study flow method, the coefficient of permeability can be calculated using the equation:

$$K = QL/ATH$$

where,

K = Coefficient of permeability (m sec^{-1})
Q = Quantity of percolated water (m^3)
L = Length of the specimen (m)
A = Area of cross section of the specimen (m^2)
T = Total duration (sec)
H = Head of water (m)

In depth of penetration method, the co-efficient of permeability can be calculated using the equation:

$$K = D^2P/2TH$$

where,

D = Depth of penetration (m)
P = Porosity of concrete

RESULTS AND DISCUSSION

Compressive strength: The compressive strength of concrete with and without admixtures at the age of 7 and 28 days are shown in Table 5. The compressive strength of concrete with water proofing admixtures was higher than that of reference concrete (without admixtures) at the age of 7 and 28 days. The compressive strength of concrete using 0.1% of naphtha based chemical by weight of cement gives 10.6% more than that of reference concrete.

Table 5: Results of compression, tension and flexure tests

Description	Compressive strength (N mm^{-2}) 7 days	28 days	Tensile strength (N mm^{-2}) 7 days	28 days	Flexural strength (N mm^{-2}) 7 days	28 days
Without admixtures	16.35	25.22	2.70	3.11	2.02	3.14
With admixtures naphtha based chemicals DI	18.08	28.95	3.08	3.27	2.51	3.57
Naphtha based DII	19.09	29.27	3.29	3.58	3.31	4.04
Naphtha based chemicals DIII	20.60	31.64	3.56	3.87	3.37	4.52
Melamine based DI	19.03	31.70	3.34	3.85	2.65	3.50
Melamine based DII	20.50	32.36	3.71	4.33	2.82	3.82
Melamine based DIII	21.00	34.47	3.91	4.76	3.48	4.31
Ligno based DI	16.89	26.07	4.31	5.12	2.63	3.37
Ligno based DII	18.90	27.83	4.59	5.28	3.44	3.67
Ligno based DIII	20.65	29.89	5.00	5.54	3.09	3.61
Polymer based DI	27.36	35.03	3.23	3.81	2.65	4.29
Polymer based DII	29.82	36.78	3.59	4.20	2.82	4.31
Polymer based DIII	31.65	37.78	3.71	4.60	3.48	4.53
Stearate based DI	26.50	31.78	4.08	4.51	3.33	4.22
Stearate based DII	28.49	32.92	4.30	4.78	3.56	4.48
Stearate based DIII	29.18	36.11	4.56	5.02	3.78	4.73

It is 39.50% higher strength of 28 days cured concrete without admixtures. It increases with the increasing of dosages of chemicals. The results of these tests indicate that the addition of these water proofing admixtures increases the compressive strength.

Tensile strength of concrete: The split tensile strength of concrete with water proofing admixtures was higher than that of ordinary concrete at the age of 7 and 28 days. The tensile strength of concrete using 0.12 kg of 100 kg of melamine based chemicals by weight of cement gives 23.70% more strength than that of reference concrete. It is 7.40% higher strength than 28 days cured concrete without admixtures. It increases with the increasing of dosages, which is shown in Fig. 3.

Relation between tensile and compressive strength: The relation between tensile and compressive strength of concrete with admixture is shown in Fig. 4. A very high correlation between compressive and tensile strength was observed. Therefore, the tensile strength of ordinary concrete is much smaller than the compressive strength and the ratio.

The ratio between tensile strength to compressive strength is about 1.4-1.8. It increases with admixtures is about 1.5.5-1.9.

Flexural test: The addition of admixtures increases the flexural strength. It reduces the mid and 1/3 deflection while, increases the dosage of chemicals. The increasing factor varying from 1.29-1.94 for 7 days and 1.01-1.49 for 28 days. Figure 5 shows the load vs. deflection curve for the flexure test.

Permeability test: The addition of admixtures reduces the permeability of concrete, which is given in Table 6.

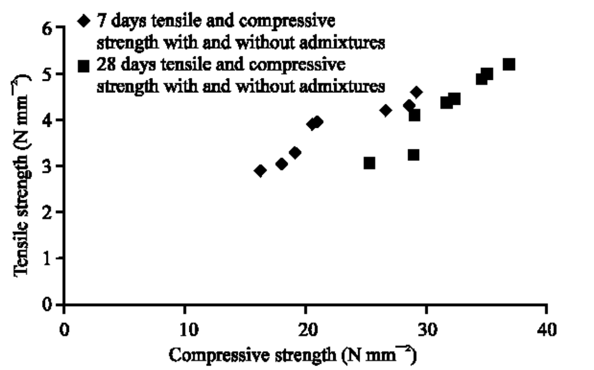

Fig. 3: Relation between tensile and compressive strength

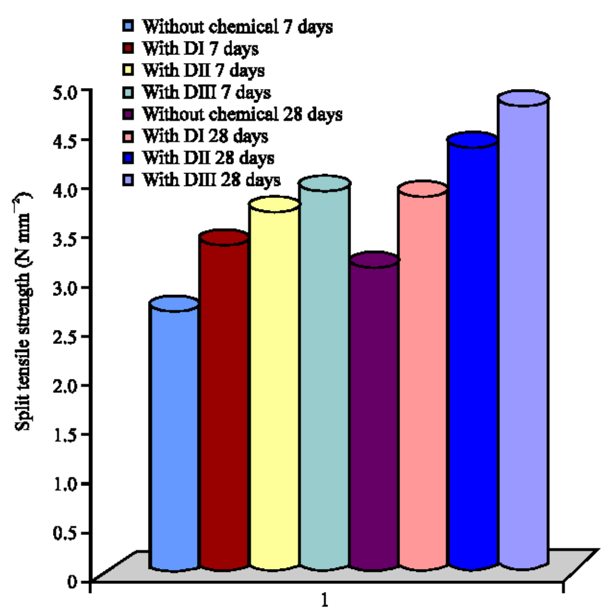

Fig. 4: Split tensile strength increases with dosage and curing period for melamine based chemicals

Table 6: Results of permeability test

	Average value of permeability (k) m sec^{-1} (7 days)			Average value of permeability (k) m sec^{-1} (28 days)		
Name of the chemical	DI	DII	DIII	DI	DII	DIII
Naphtha based	6.5582	6.1419	5.7689	6.0853	5.2449	5.0140
Melamine based	6.3060	6.0036	5.7045	5.5649	5.3069	5.0547
Ligno based	6.3703	6.1516	5.7530	7.0992	5.8668	5.2115
Polymer based	5.9585	5.6763	5.5634	5.8001	5.7798	5.6454
Stearate based	6.1367	5.8527	5.5925	6.2364	5.9523	5.70143
Without chemical	$K = 7.0749\times10^{-11}$ m sec^{-1}			$K = 5.9534\times10^{-11}$ m sec^{-1}		

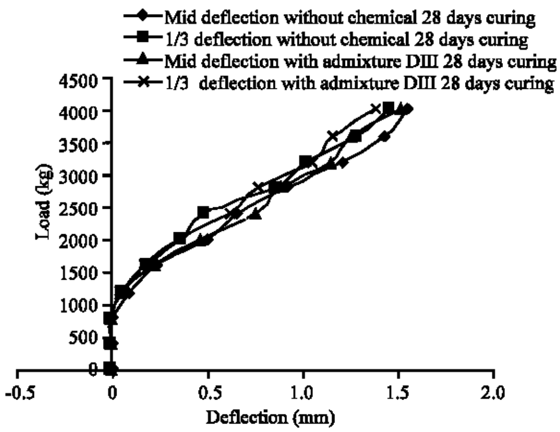

Fig. 5: Load vs. deflection curve for flexure test (for stearate based chemical)

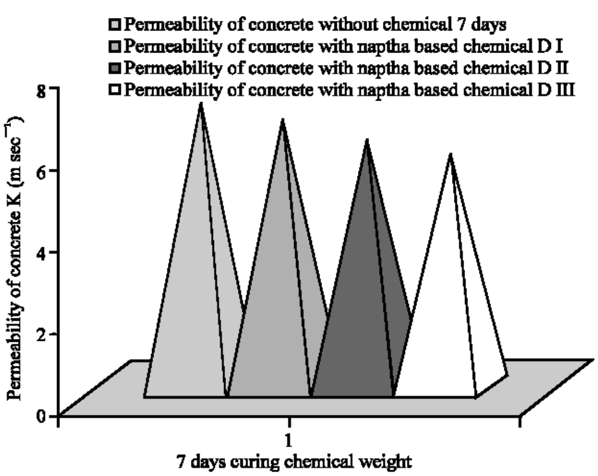

Fig. 6: Permeability of concrete with and without chemical for naphtha based chemical 7 days curing

Increasing the dosage reduces the permeability, which is given in the Fig. 6. Addition of 0.1% of chemicals by weight of cement reduces the permeability of 6.46% in 7 days cured concrete. Similarly, in 28 days cured concrete also, given better result, which are shown in Table 6.

CONCLUSION

On the basis of the results of these concrete tests, the following conclusions can be stated.

- Addition of water proofing admixtures increases the compressive strength and it also encourages the early strength
- The addition of water proofing admixtures increases the tensile strength
- The deflection at the middle and 1/3 of the beam due to load decreases, while increasing the dosage of chemicals
- The addition of admixtures reduces the permeability of concrete
- The increasing percentage of admixtures reduces the permeability
- The relation between tensile and compressive is varying linearly

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