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An Experimental Study on Effect of Aluminum Oxide on Strength and Corrosion Resistance of Concrete

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***Abstract* - This paper presents the effect of aluminum oxide on strength and corrosion resistance of concrete. A total of 45 concrete cubes of size 100mm x 100mm x 100mm were cast by mixing deliberately 3% sodium chloride by weight of cement, which simulates the corrosive effect of sea water. The aluminum oxide admixture dosage was varied from 0% to 15% in increments of 5% by weight of cement. The cubes were tested for compressive strength at the age of 7days, 14 days and 28 days. The concrete samples after compression test were crushed to powder and extracts prepared in the standard manner were tested for contents of alkalinity and free chloride. The test results reveals that by adding aluminum oxide in the range of 10 to 15% by weight of the cement free chloride content can be reduced considerably and neither the compressive strength nor the P^H was adversely affected by this admixtures, in fact strength was increased in the range of 4 to 20% depending on the curing period.**

I. INTRODUCTION

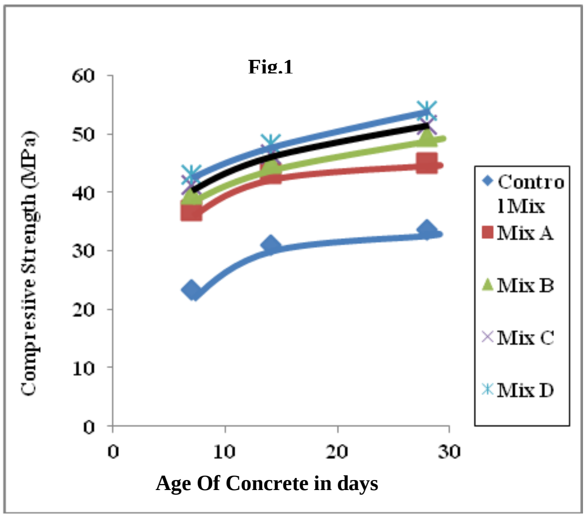
Structural Engineers have always concerned themselves with structural safety. In many cases, design for serviceability or durability has been inadequate, partially due to the nature of the materials and design methods used and partially due to the lack of information on serviceability limitations. The use of high strength steels and ultimate strength design methods has led to slender sections and thus leading to limits on deflections and crack widths. Design engineers realized that serviceability (or) durability is as important as strength. One important serviceability criterion is corrosion resistance. Corrosion of reinforced concrete can be viewed under two general groups viz., normal weather corrosion and corrosion under the action of externally applied chemical agents. Normal weather corrosion takes place under the combined action of oxygen and moisture and is more extensive in polluted air environments of a big city or industrialized area. Corrosion is well more serious when active external chemical agents such as chlorides or sulphates are present. They may be contained in the soil and be carried to the structure by seeping moisture. Salt used as de-icer on bridge decks frequently penetrates the concrete structural members and exposure to sea water results in a similar chloride condition. Chloride-induced corrosion of reinforcing steel is recognized as a primary factor contributing to the deterioration of concrete structural elements (i) Moisture, (ii) Dissolved oxygen in moisture and (iii) Aggressive ions (particularly chlorides) are the three important factors contributory for induction of corrosion of re-bars. If oxygen and water are eliminated completely, then corrosion will be arrested completely. But, it is normally impossible to in the structure, but it is possible to remove the aggressive ions (particularly chlorides) from the structures by electrochemical (desalination) or chemical (complex formation, adsorption) methods. The electro-chemical method of removing free chloride is found to be 100 percent feasible for concrete structures under immersed conditions. But, for atmospherically exposed bridges, the method is not found to be suitable, owing to the high electrical resistivity of the concrete. Considering the climatic conditions in India, the bridges are under dry exposure conditions, most of the time. Under these circumstances, it would be difficult to implement electrochemical method of removing chloride. Moreover, the electro-chemical method involves enormous engineering inputs such as anode design, distribution of anodes and distribution of electric current. The method proposed in this experimental work is very simple to use. It can be very easily implemented during the time of construction of bridges or during the manufacture of cement itself.

II. EXPERIMENTAL WORK

The scheme of experimental work consists of (i) Casting and curing of 45 concrete cube specimens (ii) testing for the compressive strength of the concrete cube specimens and (iii) carrying out chemical analysis on the powdered samples of the above tested specimens.

Table 1. Compressive strength results of cubes

Description of the Mix	Average Compressive strength (N / mm^2)					
	Curing Period in days					
	7 days		14 days		28 days	
	Strength	% increase over Mix A	Strength	% increase over Mix A	Strength	% increase over Mix A
Control mix (C)	23.34	-	31.00	-	33.67	-
Mix A (C + 3% NaCl)	37.00	-	43.30	-	45.00	-
Mix B (C + 3% NaCl + 5% Al_2O_3)	39.67	7.21	45.00	3.92	49.60	10.22
Mix C (C + 3% NaCl + 10% Al_2O_3)	41.30	11.62	46.60	7.62	51.67	14.82
Mix D(C + 3% NaCl + 15% Al_2O_3)	43.00	16.21	48.30	11.54	54.00	20.00



A. Materials:

Portland cement of 43 grade cement was used for the entire work. Local clean river sand was used as fine aggregate locally available graded aggregate of nominal size passing through 10mm and retained on 4.75 mm sieve was used as coarse aggregate. The materials used for chemical analysis were AgNo3 solution, K2cro4 (potassium chromate) indicator and Whatman filter paper No. 42.

B. Preparation of Concrete Cube Specimens:

Concrete cubes of size 100mm x 100mm x 100mm were cast in cube moulds using the design mix of 1:1.10:2.1 with w/c ratio of 0.42. During casting sodium chloride amounting to 3% by weight of cement was added deliberately to simulate the affect of sea water. The admixture aluminum oxide was varied as 0%, 5%, 10% and 15% by weight of cement. For each of above percentage of aluminum oxide, 9 cubes were cast i.e., 3 cubes were cured for a period of 7 days, 3 for 14 days and 3 cubes for 28 days. To ensure uniform distribution of salts in concrete, the salts added were first dissolved in distilled water and then mixed with water. During casting, moulds were mechanically vibrated. 24 hours after casting, the cubes were demoulded and cured by complete immersion in distilled water for 7, 14 and 28 days.

C. Testing:

After curing period of 7, 14 and 28 days, the concrete cubes were taken out from curing tank and air dried for 24 hours had then tested for compressive strength using compression testing machine of capacity 2000 KN. The compressive strength results are shown in Table.1. The results are plotted in Fig. 1.

D. Chemical Analysis:

After testing for compressive strength, core samples of concrete inclusive of fine aggregate and coarse aggregate collected from 100mm x 100mm x 100mm cubes were crushed to powder. Then 100 gms of powdered sample were shaken with 200ml of distilled water in a conical flask using flask shaker for one hour. The extract was then filtered through a Whatman filter paper (No. 42). The extract prepared from the powdered samples was then analyzed for alkalinity and free chloride content.

i. Test for alkalinity:

50CC of filtered solution was taken in 100 ml beaker and the alkalinity of the sample was measured in terms of PH using standard P^H meter. The results were given in Table.2. The results shown in the table.2 showed no significant variation of P^H even after 28 days curing, indicated that the alkalinity of concrete was not affected by adding the admixture.

Table.2. Results of alkalinity test

Percentage of admixture	Initial P^H	Final P^H (28 days)
0	12.51	12.51
15	12.45	12.42

ii. Test for free chloride content:

50 CC of filtered solution was taken and the free chloride was estimated by standard silver nitrate solution using potassium chromate as indicator. The amount of chloride present was expressed in terms of parts per million on the basis of weight of sample taken for analysis. When enough silver nitrate was added to sample containing chlorides, all the chloride was precipitated as silver chloride which was a white precipitate. Since all the chloride was precipitated, further addition of even one or two drops of silver nitrate reacts with potassium chromate indicator to produce a red precipitate of silver chromate and this change in color indicated the end point of titration. The free chloride contents were estimated and given in Table. 3.

Table.3. Free chloride Contents estimated

Concrete Mix	Curing Period (days)					
	7		14		28	
	Fc ppm	RC Percent	Fc ppm	RC Percent	Fc ppm	RC Percent
Mix A	2567	0	2267	0	1707	0
Mix B	2467	3.89	1987	12.35	1547	9.37
Mix C	1880	26.76	1647	27.34	1207	29.30
Mix D	1667	35.06	1400	38.24	1027	39.83

Note: FC = Free Chloride Contents; RC = Reduction Chloride level

The data clearly indicates that the compressive strength of concrete increases with aluminum oxide content. The covalent bond developed in the related compounds and complexes lead to increase in strength. This strength increase itself indicated the formation of chloro aluminate complexes.

During hydration of Portland cement concrete, calcium silicate contributes most to binding power and strength whereas calcium aluminate contributes to early set and early strength.

Aluminum oxide as an admixture performs dual action. A part of it combines with calcium hydroxide and chloride to form chloroaluminates (chloride scavenger), while the rest of it combines with silicates to form aluminum silicates (strengthening phase).

The free chloride contents estimated are reported in Table. 3. The free chloride content in control concrete (without admixture) was 2567 ppm and after adding the admixture the free chloride contents were 2467 ppm, 1880 ppm, 1667 ppm for 5%, 10% and 15% added admixture levels respectively. The percentage reduction in chloride was 35.06 at 15% admixture level after 7 days of curing and 38.24 at 15% admixture level after 14 days of curing. A maximum of 39.83% chloride was reduced in concrete after 28 days of curing.

III. CONCLUSIONS

1. In the present investigation, a method to reduce chloride in concrete has been attempted using aluminum oxide as an admixture.
2. By adding aluminum oxide in the range of 10 to 15% by weight of cement, free chloride content can be reduced considerably.
3. Neither the compressive strength nor the P^H was adversely affected by this admixture in fact there was increase in compressive strength.

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