EFFECTS OF SULPHATE AND CHLORIDE CONTAMINATED WATER ON CONCRETE

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Abstract- One of the main causes of deterioration of concrete structures is the distress of concrete due to its exposure to harmful chemicals that may be found in contaminated water. It is found that the most aggressive chemicals that affect the durability of structures are chlorides, sulphates and acids. The effects of chemicals on quality characteristics of concrete have been evaluated on the basis of tests performed in laboratory. Compressive strength, mass loss and petrography tests were executed for analysis of the effects of respective ions on concrete. It has been deduced that the compressive strength of concrete progressively decreases with longer curing period under internal and external exposure of water having sulphate and chloride ions and the concrete mass loss increases with the length of curing period. Petrography tests show the prominence of voids and micro cracks in concrete.

Index Terms- Quality characteristics of concrete, deterioration, compressive strength, mass loss, and petrography test

I. INTRODUCTION

At present the concrete is the most versatile and widely used construction material. Durability is an important engineering property of concrete, which determines the service life of concrete structures significantly (Turkel 2007). Due to the interactions of concrete with external influences (e.g. industrial process, free acids in natural water etc.) , the mechanical and physical properties of concrete are changed and cause the cement deterioration. Some examples of deterioration mechanisms, involving chemical processes, are acid attack (e.g. concrete exposed to agricultural or industrial environments), chloride attack (in reinforced concrete made with chloride reactive reinforced steel) and sulphate attack. The chemical nature of concrete deterioration is often unappreciated. The lack of understanding of chemical deterioration of concrete results in the violation of some basic chemical principles that in turn, lead to concrete deterioration and loss of its service life. The sulphate attack is related to the expansive characteristic of 'ettringite' formation by reaction of internal (into the concrete) or external (from the environment) sulphates with the hydrated calcium aluminates of the hardened cement matrix. The chemical reactions related to sulphate attack are as follows.

$$Na_2SO_4 + Ca(OH)_2 + 2H_2O \longrightarrow CaSO_4.2H_2O + 2NaOH \ldots 1$$

$$MgSO_4 + Ca(OH)_2 + 2H_2O \longrightarrow CaSO_4.2H_2O + Mg(OH)_2 \ldots 2$$

(Gypsum)

$$3CaO.Al_2O_3.12H_2O + 3(CaSO_4.2H_2O) + 13H_2O \longrightarrow 3CaO.Al_2O_3CaSO_3.31H_2O \ldots 3$$

(Ettringite)

$$MgSO4 + C\text{-}S\text{-}H \longrightarrow CaSO4.2H_2O + M\text{-}S\text{-}H \ldots 4$$

The problem of chloride attack arises usually when chloride ions ingress from outside (Neville Adam 1995). This can be caused by de-ionizing salts. Chlorides penetrate concrete by transport of water containing the chlorides as well as by diffusion of the ions in the water by absorption. Reactions related to chloride ions are as follows.

$$Ca(OH)_2 + 2HCl \longrightarrow CaCl_2 + 2H_2O \ldots 1$$

$$Ca(OH)_2 + 2HNO_3 \longrightarrow Ca(NO_3)_2 + 2H_2O \ldots 2$$

The main objective of this work is to study the adverse effect of high sulphate and chloride concentrations in water (to be used for concrete preparation and for curing) on the quality characteristics of concrete (internal effect).

II. MATERIAL AND METHODS

The concrete mix design of M20 grade is done according to IS 456:2000 [6]. The details of the constituents for preparing concrete are given in the following table.

Table 1: Concrete constituents-

Constituents	*Property*	*value*
Portable water	pH	6.8±0.1
Portland pozzo-lona cement	Compressive strength	43 N/mm^2
Fine aggregate	Fineness modulus	2.643
Coarse aggregate	Maximum size	20mm

The w/c ratio is taken as 0.5 according to 75mm workability. The mix design ratio of Cement: Sand: Coarse aggregate is 1:1.5:3. In the next step the same concrete mix design was repeated but with the

sulphate and chloride concentration of 2000 mg/L each, separately in water to determine the effect of these chemicals on concrete. Concrete cubes of 150mm X 150mm X 150mm of plain concrete and sulphate & chloride concentrated concrete were prepared. Curing is done for time intervals of 28, 60, 90, 120 days. Concrete cubes prepared by potable water (without any acid) and contaminated water (with sulphate and chloride) are cured in potable tap water. For external attack of sulphate the cubes are cured in sulphated contaminated water. The Curing and other details of these concrete cubes have been given in the table 2.

Table 2: Testing Methodology –

Type of concrete	Type of chemical		No. of cubes				No. of cubes
		Curing period (Days)	28	60	90	120	
		Concentration (mg/L)					
PCC	Control sample	0	3	3	3	3	12
PCC	Sulphate (internal)	2000	3	3	3	3	12
PCC	Sulphate (externall)	2000	3	3	3	3	12
PCC	Chloride (internal)	2000	3	3	3	3	12
					Total		48

After the curing period, the concrete cubes were taken out from the water and tested for compressive strength, mass loss and petrography examination.

III. RESULTS AND DISCUSSIONS

Compressive strength of concrete decreases with addition of chemicals namely sulphate and chloride under both internal and external exposure for curing period ranging from 28-day to 120-day as shown in Fig.1. Optimum compressive strength of concrete was obtained at 60-day curing period for different concentration of chemicals. The concrete mass loss increases with the length of curing period (under both internal and external exposure) as shown in Fig.2, 3 & 4.

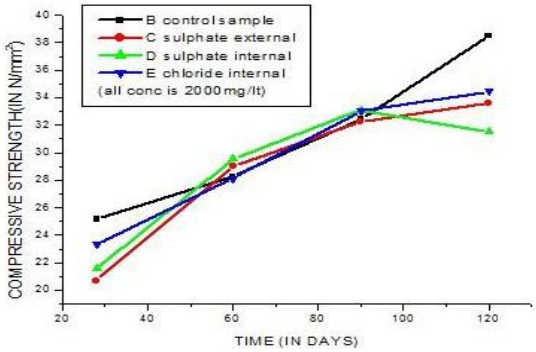


Fig 1 Variation of compressive strength of concrete under internal and external exposure

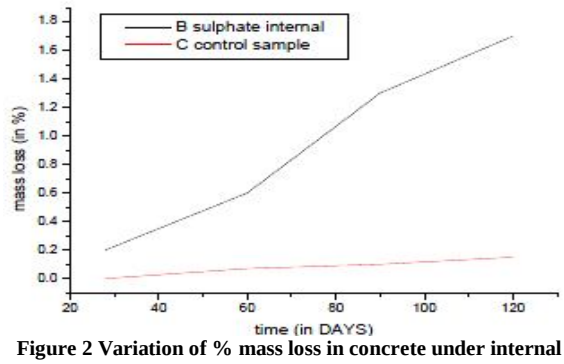


Figure 2 Variation of % mass loss in concrete under internal sulphate attack

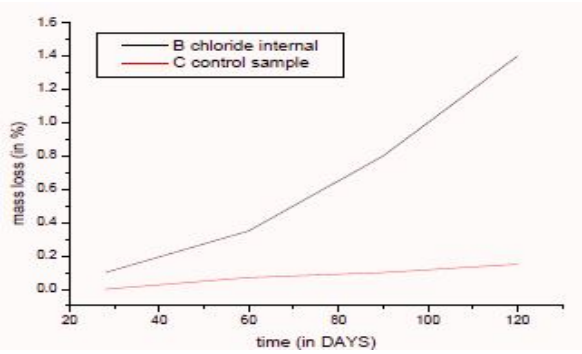


Figure 3 Variation of % mass loss in concrete under internal chloride attack

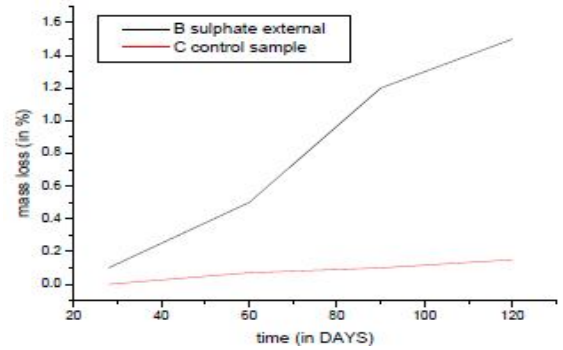


Figure 4 Variation of % mass loss in concrete under external sulphate attack

Petrography tests show that the voids and micro cracks are prominent in samples with sulphate (internal attack) (Fig.6), sulphate (external attack) (Fig.7) and in chloride (internal attack) (Fig.8), being the most prominent in sulphate (internal attack) than in the controlled sample (Fig.5).

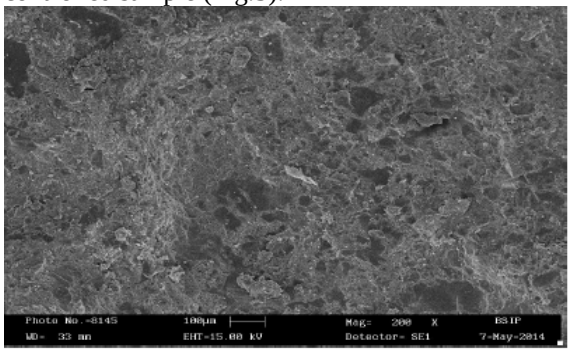


Figure 5 Control Sample (120 Days)

* Red circle shows cracks and voids
* Yellow rectangle shows cohesion less granular mass

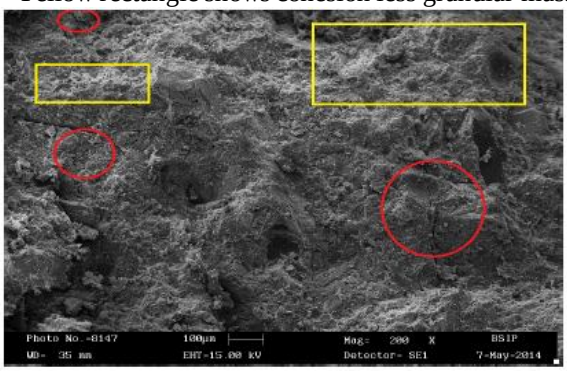


Figure 6 Sulphate internal attacks (120 Days)

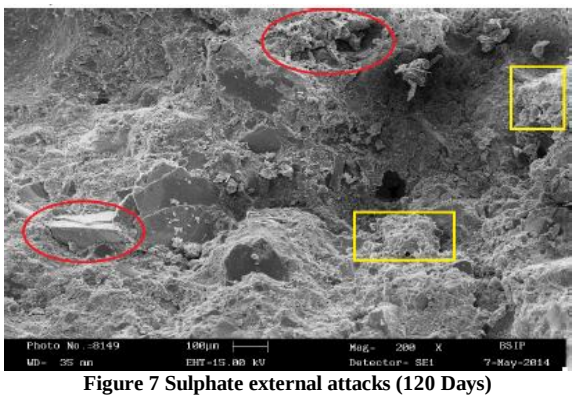


Figure 7 Sulphate external attacks (120 Days)

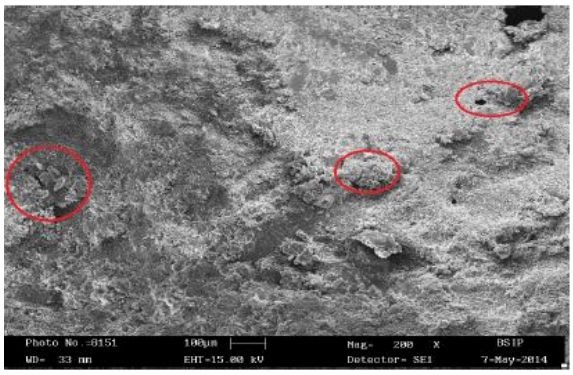


Figure 8 Chloride internal attacks (120 Days)

The cohesion less mass (ettringite) is seen in sample with sulphate (internal), sulphate (external) and in chloride (internal attack), being the most prominent in sulphate (internal attack), in comparison to controlled sample. Above is the main reason for the decrease in the compressive strength of the samples prepared by the addition of the chemicals. The reason why the observed strength deviation is seen in samples prepared with chloride internal is that because chloride do not degrade the composition of concrete (formation of C-S-H gel). It results the corrosion of reinforcement provided in rcc structures thereby leading to deterioration in strength, and not due to deterioration of chemical composition of concrete (much).

CONCLUSION

It can be concluded by the present work that compressive strength of concrete progressively decreases from that of controlled sample with longer curing period under internal and external exposure of water having sulphate and chloride ions. Development of voids and micro crack and cohesion less mass formation are the main reasons for the decrease in the compressive strength of the concrete samples prepared by chemical contaminated water. Water must be without sulphate and chloride while using for preparation of concrete or at the time of curing.

REFERENCES

[1]. Amin, M.M., Jamalidin, S.B., Chuen, K.K. (2007).” Effect of magnesium sulphate attack on Ordinary Portland Cement (OPC) Mortars”.J: Portugaliae Electrochimica Acta, Vol.02., Malaysia
[2]. Bucea, L., Khatri, R., Sirivivatnanon, V (2005).” Chemical and Physical attack of salts on Concrete”. CSIRO Manufacturing and Infrastructure Technology
[3]. Brown, P.W., Doerr, A. (2000). ” Chemical changes in concrete due to the ingress of aggressive species.” J: Cement and Concrete Composites, Vol. 30, USA
[4]. Chan, K.Y. (2007).”Degradation of Abandoned Construction Material”, J: Cement and Concrete Composites, Malaysia
[5]. Dakshina Murthy, N.R., Ramaseshu, D. and Seshagiri Rao, M.V. (2008). ” Studies on Fly AshConcrete under Sulphate attack in ordinary, standard and higher grades at earlier ages”. J: Asian Journal of Civil Engineering
[6]. IS: 456 – 2000, “Code of practice for Plain and Reinforced Concrete”. Bureau of Indian Standards, New Delhi.

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