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Possible Effect of Ground Water on Concrete Structures of Noida and Greater Noida

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Abstract: Noida and Greater Noida are cities in India under the management of the New Okhla Industrial Development Authority and Greater Noida Industrial Development Authority located in the part of National Capital Region of India. Noida is a city that has grown very fast laterally and vertically in an unpredictable manner. Large number of buildings in the form of group housing societies, residential colonies, shopping complexes, hospitals, flyovers, small bridges etc has been constructed or under construction. Majority of these structures are designed for reinforced cement concrete type. Apart from few structures which have been built with pre-cast concrete or ready mix concrete, vast majority of the structures are being constructed in the conventional way. Ground water is the sole source which is being used for mixing and curing purpose. In present study water samples from twenty five locations of the Noida and Greater Noida region were analyzed for their suitability for mixing and curing purpose in concrete as per the provisions of IS 456-2000. Based on the outcome of the study some critical sectors which could experience different types of problem in concrete structures have been identified. The present paper highlights typical concrete durability problems being faced recently in some concrete structures which were constructed just few years ago or the structures upcoming in these sectors. A mapping has been done to assign the problems which may come in each sector.

Index Terms: Ground Water, Corrosion, Concrete, Rebar, Chloride, Sulphate

Introduction

Water is and has been available in abundance in nature. Due to rapid industrialization and uses of pesticides, germicides and fertilizers in the agricultural land, rapid development in transport sector and other technological advances, the available water have become polluted to a considerable extent. Due to industrialization and rapid development in transport sector, not only water, but the atmospheric air has also become polluted, which is an indirect source of water pollution. Acid rain and acid fog have been experienced at many places.

Water contributes an active part in imparting strength and durability to concrete. The role of water is not only important at the mixing stage but also during curing. Impurities in water, which may be either in the dissolved or suspended form, may interfere with the hydration of cement, thus affecting the setting, hardening and strength development. It may also cause efflorescence and leaching effects in set cement mortar/concrete.

Concrete structures such as buildings, bridges, flyovers, power plants and others are ideally required to be built with utmost care to serve its intended purpose without any recurring expenditure on maintenance. However, it is not so in real life scenario and often distress in concrete is notified within few years of construction. The causes of distress can be attributed to many factors, of which the important being the poor quality of construction, improper detailing of reinforcement and not satisfying the requirements as specified in code of practices. The important guidelines for producing durable concrete are:

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- Selection of good quality of materials such as cement, sand, aggregate, water and reinforcing steel
- Tests of materials used in construction
- Providing adequate cover to reinforcement from durability consideration, and environmental conditions at site
- Quality control during manufacture of concrete with particular attention to water - cement ratio, use of chloride free water and suitable admixtures for mix
- Care during transportation and placing the concrete and effecting good compaction to concrete by vibrators
- Adopting good curing methods
- Quality assurance tests on hardened concrete

If these factors are considered and implemented in practice during construction, the resulting structure would provide higher degree of durability, and hence serve full service life. Durability with regard to corrosion has become the key issue and it is recognized that the life cycle cost of buildings and other structures which are corrosion prone has become unmanageable. Having recognized that corrosion in plain carbon steel can only be controlled to a limited extent, an option to use a much nobler material, such as stainless steel seems to make a good sense in spite of high cost. Corrosion of steel in concrete is not an accident that happens all of a sudden, but it needs a platform where series of happenings first occur, before the corrosion takes place.

Quality of ground water in Noida and Greater Noida region is generally not good for the construction at many places and ironically this is being used frequently by the construction agencies without giving much thought. Water acts as a carrier of harmful agents such as chloride ions, sulphate ions which have deleterious effect on concrete. The spalling of concrete, corrosion of reinforcement and cracks in structures are common features in buildings of residential / commercial complexes in Delhi NCR regions (photo-1 & 2). The present paper discusses the ground water quality of Noida and Greater Noida cities with respect to codal provisions for mixing and curing purposes, and is being used in construction of number of buildings.

Photo-1 : Ceiling of a hospital building where plaster has got delaminated from reinforcement due to corrosion of reinforcement

Photo-2 Cracks in Column of school building due to corrosion of reinforcement

Noida And Greater Noida region

Noida is located in Gautam Buddh Nagar district of Uttar Pradesh state India. Noida is about 20 kilometers southeast of New Delhi, 20 kilometers northwest of the district headquarters, Greater Noida and 457 kilometers northwest of the state capital, Lucknow. It is bound on the west and south-west by the Yamuna River, on the north and north-west by the city of Delhi, on the north-east by the cities of Delhi and Ghaziabad, India and on the north-east, east and south-east by the Hindon River. Noida falls under the catchment area of the Yamuna river, and is located on the old river bed. The soil is rich and loamy. The cities are also famous for its wide roads, excellent maintenance and modern lifestyle. The ground water is locally available and directly under the control of user which is mainly the reason for greater dependence on this resource for construction or drinking purpose. In general ground water in Noida and Greater Noida regions at shallow depths is fresh and salinity increases with depths.

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Chemical analysis of ground water from various sectors

Water samples from tube wells collected from various sectors were collected and their location details are given **Table -1**. Samples were analyzed for eight critical parameters mentioned in IS 456: 2000 for Mixing and curing purposes, their limits are given in Table-2. Results of some of the important parameters are tabulated below in **Table - 3.**

Table-1 Sampling Locations

Sl No.	Location	Sample No.	Sl.No.	Location	Sample No.
1	Dankaur	WS-1	14	Sector-35 Morna	WS-14
2	NRI City	WS-2	15	Sector- 37	WS-15
3	Alpha 1	WS-3	16	Sector- 44 Chalera	WS-16
4	Beta 1	WS-4	17	Sector- 62	WS-17
5	Gamma 1	WS-5	18	Sector- 63	WS-18
6	Delta 2	WS-6	19	Sector- 66 Mamora	WS-19
7	Zeta 1	WS-7	20	Sector- 71	WS-20
8	Grand Venice Side II	WS-8	21	Sector- 72	WS-21
9	Kasna	WS-9	22	Sector - 77 Sorkha	WS-22
10	Sector- 2 Harola	WS-10	23	Sector- 102 bhangel	WS-23
11	Sector- 8	WS-11	24	Sector- 108	WS-24
12	Sector- 17A	WS-12	25	Sector- 135	WS-25
13	Sector- 19	WS-13			

Table -2 Limits given in IS : 456 -2000(Clause 5.4)

Sl. No.	Parameter	Tested as per Permissible	Limit
1.	pH	IS 3025 (Part 11): 1983	Not less than 6.0
2.	Inorganic Solids, mg/l	IS 3025 (Part 18): 1984	3000 mg/l
3.	Organic Solids, mg/l	IS 3025 (Part 18): 1988	200 mg/l
4.	Suspended Solids, mg/l	IS 3025 (Part 17): 1984	2000 mg/l
5.	Chlorides, (as Cl) mg/l	IS 3025 (Part 32): 1988	2000 mg/l for concrete not containing embedded steel and 500 mg/l for reinforced concrete work
6.	Sulphates, (as SO_4) mg/l	IS 3025 (Part 24): 1986	400 mg/l
7.	Acidity: ml of 0.02N NaOH required to neutralize 100 ml of water sample	IS 3025 (Part 22: 1986 Reaffirmed 2003	Not more than 5 ml
8.	Alkalinity: ml of 0.02N H_2SO_4 required to neutralize 100 ml of water sample	IS 3025 (Part 23): 1986 Reaffirmed 2003	Not more than 25 ml

INTERPRETATION OF TEST RESULTS AND POSSIBLE ATTACK ON CONCRETE

The quality of the water plays an important role in the preparation of concrete. Impurities in water may interfere with the setting of the cement and may adversely affect the strength of the concrete (Neville, 1970). The chemical constituents present in water may participate in the chemical reactions and thus affect the setting, hardening and strength development of concrete. A popular yard stick to the suitability of water for making concrete is that if it is fit for drinking, it is fit for making concrete, but it is not correct. The mechanism involving the possible chemical reactions are presented in the Table 4.The alkalinity of concrete protects the reinforcement against the corrosion. Even a very dry concrete contains moisture in its capillaries. The calcium hydroxide along with alkali hydroxides which comes from the hydrated cement are filled in the pore water and form a saturated solution having a pH generally greater than 12.5. As long as this pH is maintained for pore water in concrete, the concrete is safe.

Carbonation: Dry concrete is permeable to the ambient air, which contains a minimum of 0.03% of carbon dioxide and this level can be exceeded many times in polluted areas. The CO_2 combines with the soluble calcium product to form an insoluble $CaCO_3$ – a process known as carbonation. Carbonation is very rapid on surface of concrete, but diminishes rapidly with the depth. As a thumb rule one may expect a depth of carbonation of 1 mm in 3 months, 1 cm in 10 years, 2 cm in 30 years in typical concrete. Since Noida and Greater Noida are under development stage, carbonation of concrete is at this juncture is ruled out.

Table-3: Results of Chemical Analysis of Ground Water

Sl No.	Sample No.	pH	Inorganic Solids mg/l	Sulphate mg/l	Chloride mg/l	Acidity: ml of 0.02N NaOH required to neutralize 100ml of water sample	Alkalinity: ml of 0.02N H_2SO_4 required to neutralize 100ml of water sample
1	WS-1	7.4	806	157	85	0.2	23
2	WS-2	7.5	497	130	49	0.2	21
3	WS-3	7.2	601	222	99	0.3	34
4	WS-4	7.1	452	101	74	0.1	16
5	WS-5	7.2	549	208	109	0.3	17
6	WS-6	7.6	611	151	99	0.2	26
7	WS-7	7.2	489	108	85	0.3	19
8	WS-8	7.2	372	112	74	0.4	35
9	WS-9	8.1	608	125	64	0.2	31
10	WS-10	8.2	2148	384	539	0.2	32
11	WS-11	8.1	871	154	191	0.2	23
12	WS-12	7.5	850	272	168	0.3	20
13	WS-13	8.1	871	125	163	0.3	32
14	WS-14	8.2	1277	298	348	0	37
15	WS-15	7.1	2137	1368	869	0.6	46
16	WS-16	8.1	2322	336	780	1.6	23
17	WS-17	7.4	606	123	310	0.2	16
18	WS-18	8.0	991	177	14	0.3	7
19	WS-19	8.2	1149	798	433	0	22
20	WS-20	7.3	971	281	213	0.4	28
21	WS-21	8.0	566	103	2715	0.3	15
22	WS-22	8.2	3136	1179	1255	0	22
23	WS-23	8.2	807	96	191	0.6	31
24	WS-24	7.9	704	38	92	0.3	34
25	WS-25	8.1	646	58	21	0.4	39

Corrosion of Reinforcement: The mechanism of corrosion of reinforcement is essentially due to either in stand alone or in combination of factors such as carbonation of concrete, chloride attack and sulphates diffusing into the body of concrete and subsequently coming into contact with reinforcing steel. Chloride attack on reinforcing steel in concrete has been well documented. Chloride ion in mixing and curing water or water soluble chlorides from the atmosphere or ground water or from concrete ingredients, reaches the reinforcing steel. As the water permeability of concrete varies in a given section, there will always be different ionic concentration at the interface of concrete and the embedded steel. This sets in corrosion cells with anode and cathodes at the higher and relatively lowers chloride ion concentration regions respectively. Formation of corrosion cell results in pitting corrosion. As chloride attack is an electro- chemical process, it changes the chemistry of steel affecting the ductility properties of the bars too. The chloride content in water exceeds the BIS limits for water samples collected from Sector-72, Sector-77. Use of this water for mixing and curing purposes, indicates that there is a possibility of corrosion of reinforcement in near future.

Table 4
CORROSION CAUSING OR ASSISTING CHEMICAL REACTIONS IN CONCRETE

Sl. No.	Reaction causing agents	Reactions	Effects
1.	Oxygen*	Anode: $2Fe(metal) \rightarrow 2Fe^{++} + 4e^-$ $2Fe^{++} + 4OH^- \rightarrow 2Fe(OH)_2$ Cathode: $2H_2O + O_2 - +4e^- \rightarrow 4OH^-$	Corrosion of steel. Formation of protective passive film of nanometer thickness of iron hydroxides/oxides
2.	Chloride*	Without oxygen at anode $Fe + 2Cl^- \rightarrow (Fe^{++} + 2Cl^-) + 2e^-$ $(Fe^{++} + 2Cl^-) + 2H_2O \rightarrow Fe(OH)_2 + 2H^+ + 2Cl^-$ In presence of oxygen at anode $6(Fe^{++} + 2Cl^-) + O_2 + 6H_2O \rightarrow$ $2Fe_3O_4 + 12H^+ + 12\ Cl^-$ Chloride acts as catalyst in corrosion of steel and becomes free to take part in corrosion reaction again. Attack on hydrated paste $Ca(OH)_2 + MgCl_2 \rightarrow CaCl_2 + Mg(OH)_2$ $3CaO.Al_2O_3.6H_2O + CaCl_2.+4H_2O \rightarrow 3CaO.\ Al_2O_3.CaCl_2.10H_2O$ Freidel salt Freidal salt $\rightarrow$ ettringite (in presence of $CaSO_4$) C-S-H + Mg $\rightarrow$ C-M-S-H	Chloride ions break the passivating oxide film formed on steel External penetration causes differential concentration and setup micro-cells. Presence of salt increases its electrical conductivity.
3.	Carbon Dioxide, CO_2	$Ca(OH)_2 + H_2O + CO_2 \rightarrow CaCO_3 + 2H_2O$	Reduces alkalinity or micro Environment, increasing the risk of corrosion. Releases more water
4.	Sulphates*	$SO_4^{--} + Ca^{++} + 2H_2O \rightarrow CaSO_4.2\ H_2O$ $4CaO.Al_2O_3.19H_2O + 3(CaSO_4.2H_2O) + 8H_2O \rightarrow$ $3CaO.Al_2O_3.3CaSO_4.32H_2O + Ca(OH)_2$ Ettringite $3CaO.2SiO_2aq + 3MgSO_4.7H_2O \rightarrow \rightarrow 3CaSO_4.2H_2O + 3\ Mg(OH)_2 + 2\ SiO_2\ aq$ $4\ Mg(OH)_2 + SiO_2.nH_2O \rightarrow 4MgO.SiO_2.8.5H_2O + (n-4.5)H_2O$	Ettringite causes expansion in concrete leading to crack formation. Concrete becomes more susceptible to penetration of external corrosive agents. Reduction in the strength of concrete

*All these agents cause or assist corrosion in presence of water. Hence water should be considered as one of the corrosion causing agent.

Spalling of Concrete/ Mortar: Sulphate reacts with tri calcium aluminate phase of hydrating cement and forms ettringite. Ettringite after absorption of water causes expansion in concrete, leading to crack formation. Finally concrete becomes more susceptible to penetration of external corrosive agents and concrete loses its strength. The sulphate limits prescribed in BIS code are exceeded for water samples from Sector-2, Sector-17, Sector-35, Sector-44, Sector-71. While Sector-37, Sector-66 and Sector- 77 have higher values. The possibility of spalling of concrete and mortar from the plaster from the wall is possible.

CONCLUSION

Based on the above study a overall effect on durability of concrete, a risky zones were identified in the map of Gautam Budh Nagar (Fig. 1). For long term durability of concrete especially w.r.t. to protection of reinforcement, it is recommended that only good quality water conforming to Bureau of Indian Standards codes be employed. Study done by the CSMRS in case of existing structures in other parts of NCR region that poor water quality is the main contributing factor for deterioration of concrete structures within a few years of construction. Simple precautionary measure at the construction stage could go a long way in protecting concrete.

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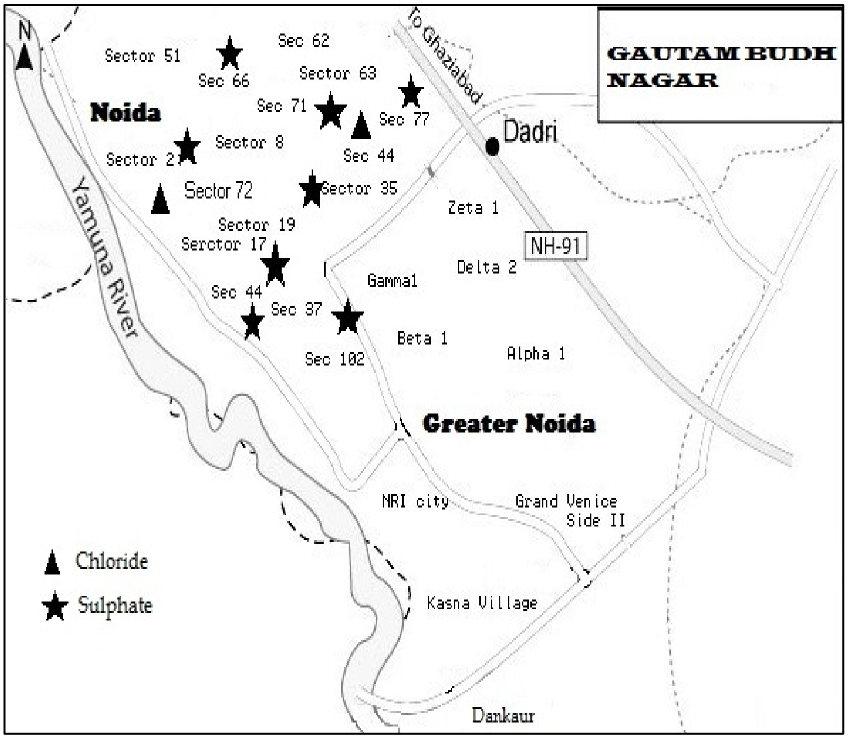

Fig.1 Map of Gautam Budh Nagar showing areas prone to chloride and sulphate attack