PRESENTATION
ON
QUALITY OF WATER-CHALLENGE FOR SUSTAINABLE INFRASTRUCTURE

BY

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CONSTRUCTION

- Civil Engineering structures - designed for a life span varying from 60 to 100 years.
- The characteristic of ground water in several parts of north India is changing fast resulting in a reduced life of Reinforced Concrete structures which may vary from 15 to 30 years depending upon severity of character of ground water.
- Appropriate care in use of water during construction and subsequently protecting the structure from the aggressive environment help in giving a designed life to such like structures.
- Based on these investigations, an appropriate modality need to be defined regarding execution of work.

LIVING BEINGS

50 Ground Water samples tested on 22 km stretch between Pallah & Okhla in Delhi

POLLUTANT	RESULT	MPL*
Nitrate	174 mg/L	100 mg/L
Sulphate	680 mg/L	400 mg/L
Flouride	3.10 mg/L	1.5 mg/L
Mercury	4.60 mg/L	1 mg/L
Arsenic	69.5 mg/L	50 mg/L

*Maximum permissible limit

LIVING BEINGS

- **Excessive dissolved salts -** kidney
- **Nitrates** – Blue baby syndrome in infants
- **Sulphates** – Gastric problems
- **Flourides** - Flourides & Dental Disorders

WATER FOR CONSTRUCTION vis-à-vis DRINKING FOR HUMAN BEINGS CONSUMPTION

- Looking at the complexities so involved following documents define quality of water :-
  - IS 456:2000 – Plain & Reinforced Concrete – Code of practice – Clause 5.4
  - MORT&H SPECIFICATIONS - 2010
  - STATE PWD SPECIFICATIONS

PERMISSIBLE LIMITS (IS 456)

Sl No.		Tested as per	Permissible Limit (Max)
i)	Organic	IS 3025 (Part 18)	200mg/l
ii)	Inorganic	IS 3025 (Part 18)	3000 mg/l
iii)	Sulphates (as SQ)	IS 3025 (Part 24)	400 mg/l
iv)	Chlorides (as Cl)	IS 3025 (Part 32)	2000 mg/l For concrete not containing embedded steel and 500 mg/l for reinforced concrete work
v)	Suspended matter	IS 3025 (Part 17)	2000 mg/l

PERMISSIBLE LIMITS (IS 456)

- To neutralize 100 ml sample of water, using phenolphthalein as an indicator, it should not require more than 5 ml of 0.02 normal NaOH. The details of test are given in 8.1 of IS 3025 (Part 22)
- To neutralize 100 ml sample of water, using mixed indicator, it should not require more than 25 ml of 0.02 normal sulphuric acid. The details of test are given in 8 of IS 3025 (Part 23)
- The *P*H value of water shall be not less than 6

BUILDINGS EFFECTED BY USE OF WRONG WATER
(1980-2000)

- A severe damage to an indoor ward of old Medical College (now Post Graduate Institute) Rohtak
- University Teaching Department building of Maharishi Dayanand University, Rohtak
- Buildings of Govt. Polytechnique Jhajjar
- Various buildings of Moti Lal Nehru Sports School, Rai (Sonepat)
- Signature View Apartments at Mukherjee Nagar, New Delhi
- 100 of such buildings as of now.

GEOLOGICAL CHARACTERISTICS

- Soils on the drier parts of Punjab, Haryana, North Bihar, Uttar Pradesh, and Rajasthan tend to be saline and alkaline efflorescence's.
- Those soil contain many undecomposed rocks and mineral fragments which with weathering liberates sodium, magnesium and calcium salts.
- Such soils are notably impervious and therefore have impeded drainage. Large areas, once fertile, have become impregnated with these salts (reh, kalar) destroying the agriculture value of the ground.
- The salts are normally confined to the top layers of the soil, being transferred from below by capillary action.
- The alkali content in those soils is high and there is a large excess of free salts, combined with poverty in nitrogen and organic plant food material. Such lands pose problems for construction of civil structures which are likely to withstand the attack of salts in soils and ground waters.

SALINITY PROBLEMS

- Effect of pH, Chlorides, Sulphates and Magnesium Ions on the Durability of Concrete.
  - Portland cement on hydration gives rise mainly to calcium silicate to hydrates and some amount is calcium hydroxide.
  - The calcium silicate hydrates is responsible for the strength of concrete and the calcium hydroxide is uniformly distributed in the calcium silicate hydrate matrix.
  - Acidic waters with pH below 6 or so dissolve the calcium hydroxide and also effect the stability of the calcium silicate hydrate matrix both leading to deterioration of concrete.
  - On the other hand alkaline waters with pH in the range 7.5 to 10 or so are harmless to concrete.

SALINITY PROBLEMS

- The sulphates react with calcium hydroxide giving rise to gypsum with a molar volume nearly 2.20 times that of calcium hydroxide. Also the sulphates react with the tricalcium aluminate in Portland cement giving rise to a calcium sulphoaluminate solid solution with a molar volume 2.5 times the original volume. Thus both these reactions lead to severe cracking of concrete structures exposed to sulphatic environments. The cracking also create conditions for the reinforcement corrosion which in turn may lead to spalling of concrete.
- Chlorides such as $MgC1_2$ and $AICI_3$ reacting with lime and forming thereby unstable and water soluble compounds are detrimental to concrete. The chlorides of alkali metals (NaCl, KCl) which do not react with lime or with other components of the hardened concrete are harmless but in concentrated solutions they tend to leach lime from concrete. On the other hand the soluble chlorides may induce corrosion of the steel reinforcement and as such reinforced concretes exposed to chloride environments need to be protected against attack and deterioration.

SALINITY PROBLEMS

- Magnesium ions are introduced into ground water mainly in the form of $MgSo_4$, $MgC1_2$ and $MgHCo_3$. The majority of magnesium ions originate from dolomitic rocks. Surface waters rarely contain more than 25 mg/litre of Mg^{++}ions whereas the ground water may contain as much as 300 mg/litre. As such in water the magnesium ion contents is usually 1.3 g/litre.
- All salts of magnesium with the exception of hydrocarbonate are destructive to concrete and are even more aggressive than $CaSo_4$ and Na_2 SO_4 because in this type of attack the entire calcium content of the binding agent of the concrete may be replaced gradually by magnesium which may lead to the deterioration of concrete.

CASE STUDY : ROHTAK & JHAJJAR DISTRICTS

- The ground water table level varied widely and in the range of 1.2 to 4.7 meters deep.
- The pH of the soil samples of all depths ranging from 7.6 to 9.6 and is slightly in the alkaline range.
- The chloride content in the samples varied from traces to as high as 1.296 percent.
- The sulphate content in the soil samples range from traces to as high as 0.556 percent.
- The sub soil water samples collected at the water table level from 21 bore holes was found to be neutral to slightly alkaline with pH ranging from 6.65 to 8.35. The water samples also contained high concentrations of chlorides and sulphates in general.

CASE STUDY : SONIPAT DISTRICT

- Four ground water samples were also studied in respect of Sonepat District and results showed that vol. of 0.2 N H_2SO_4 required to neutralize 100 ml. of H_2O sample using mixed indicator required 22.1 to 33.57 ml. against I.S. limit of 25 max. which is incorporated in I.S. 456.
- These results indicate that the ground water of Sonepat distt. is not meeting the requirements. This situation is more prevalent with an increase in distance from Yamuna River. But with minor addition of acids of required normality, the water can be brought to meet with the requirements of above specifications of IS:456. 155ml. of HCl of normality N-12 – can be added in 1000 litre of water to bring the water as per specification. Same can vary from area to area.

REPORT IN RESPECT OF WATER SAMPLES COLLECTED

District/ Town	Source of water	PH	Volume of 0.02N NaOH Solution required 100 ml. of sample, ml	Volume of 0.02N H_2SO_4 Solution required 100 ml. of sample, ml	Total Solids, mg/l	Sulphates, mg/l	Chloride, mg/l	Remarks
Rewari	Ground Water	7.52	3.5	15.6	600	60	100	Fit
Rewari	Ground Water	7.55	3.4	15.5	800	70	150	Fit
Jhajjar	Canal Water (through tanker)	7.59	3.4	15.5	800	75	75	Fit
Jhajjar	Canal Water (through tanker)	7.50	3.2	13.3	600	55	80	Fit
Jhajjar	Canal Water	7.49	2.4	10.1	400	45	60	Fit
Jhajjar	Public Health Water Supply	7.51	3.1	13.2	600	50	75	Fit
MAX LIMIT as per IS456		**Not less than 6.0**	**Not more than 5.0**	**Not more than 25.0**	**3200**	**400**	**2000 for PCC 500 for RCC**	

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Jhajjar	Canal Water(through tanker)	7.50	3.1	13.2	600	50	75	Fit
Bahadurgarh	Public Health Water Supply	7.79	10.00	24.00	2700	500	750	Not Fit
Bahadurgarh	Public Health Water Supply	7.45	1.6	8.6	200	40	50	Fit
Faridabad	Ground water	7.75	5.8	18.5	1600	350	300	Not Fit
Faridabad	Ground water	7.65	3.6	11.8	600	105	150	Fit
Palwal	Ground water (PH supply which is a ground water)	7.60	4.10	16.5	1300	250	100	Fit
MAX LIMIT as per IS456		**Not less than 6.0**	**Not more than 5.0**	**Not more than 25.0**	**3200**	**400**	**2000 for PCC 500 for RCC**	

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Nuh	Ground water	7.70	3.4	15.5	1500	400	250	Not Fit
Nuh	Public Health Supply (through tanker)	7.60	3.2	13.4	600	150	200	Fit
Gurgaon	Ground water	7.40	2.9	12.2	500	60	95	Fit
Sonipat	Ground water	8.17	0.2	41.3	568	45.8	36	Not Fit
Sonipat	Ground water	8.1	0.2	30.1	798	146.8	138	Not Fit
Sonipat	Ground water	7.5	1.2	37.6	994	148.9	178	Not Fit
MAX LIMIT as per IS456		**Not less than 6.0**	**Not more than 5.0**	**Not more than 25.0**	**3200**	**400**	**2000 for PCC 500 for RCC**	

REPORT IN RESPECT OF WATER SAMPLES COLLECTED

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Sonipat	Ground water	8.3	-	40.5	915	210.3	110	Not Fit
Sonipat	Ground water	7.3	1.4	37.6	1316	243.6	250	Not Fit
Sonipat	Ground water	7.1	1.7	19.2	1675	504.6	590	Not Fit
Sonipat	Ground water	7.8	3.10	22.50	1200	80	100	Fit
Rohtak	Ground water	9.2	--	98.4	7845	951	3210	Not Fit
Rohtak	Ground water	7.5	2.0	31.0	580	63	61	Not Fit
Rohtak	Ground water	7.6	4.7	38.5	974	187	130	Not Fit
MAX LIMIT as per IS456		**Not less than 6.0**	**Not more than 5.0**	**Not more than 25.0**	**3200**	**400**	**2000 for PCC 500 for RCC**	

BRINGING ALKALINE WATER AS PER IS-456

- Ground water samples - Sonepat District - In Sonepat Distt. – Ground Water samples were not meeting specifications.
- RCC had a life of 25-30 years approximately against design life of 80 years
- Minor addition of acids of required normality, the water can be brought to meet with the requirements of above specifications of IS:456.

BRINGING ALKALINE WATER AS PER IS-456

CALCULATIONS FOR TESTING WATER

HCL Acid of Specific gravity N 1.18-11.6

$N_1 V_1 = N_2 V_2$

Water ***Acid***

$\boldsymbol{N_1 \times 100}$ $\boldsymbol{\underline{N \times 34}}$

50 (0.02N=$\underline{N}$)

50

N_1 (Normality of water) = $\underline{N \times 34}$

50×100

Equivalent Weight = $\underline{\text{Mol. Wt.}}$ = $\underline{100}$ =50

Valency 2

BRINGING ALKALINE WATER AS PER IS-456

CALCULATIONS FOR TESTING WATER

Strength of Alkalinity in term of $CaCo_3$

Equivalent

Alkalinity $= \frac{34 \times 50}{50 \times 100}$ gm/Lit. (Eq. Wt. Of $CaCo_3$) = 340 mg/ltr.

$$\text{Normality} = \frac{\text{Strength (Alkalinity)}}{\text{Equivalent}}$$

340 mg/Lt. – 250 = 90 mg/Lt.

580 mg. of Alkalinity is neutralized with HCl = 1 ml,

90 mg of Alkalinity is neutralized with HCl $= \frac{1 \times 90}{580}$

BRINGING ALKALINE WATER AS PER IS-456

CALCULATIONS FOR TESTING WATER

- For 90 mg of Alkalinity, the requirement of HCl is 0.155 ml.
- 1 litre of water needs 0.155 ml. to neutralize the Alkalinity
- 1000 litres of water need 0.155 ml. to neutralize the
- Alkalinity $0.155 \times 1000 = \underline{155 \text{ ml}}$
- So 155 ml of HCl of Normality N-12 is required to be added to 1000 Litres of water so as to make it safe for use.

MEASURES TO COUNTER SALINTY ATTACK

- Investigations of the soil and ground water of Rohtak and Jhajjar districts shows that the foundation conditions will be aggressive to the usual concrete and brickwork constructions without any special precautions and/or treatments.
- The possible solutions to make durable constructions involve proper choice of materials, adoption of proper construction practices and rigid quality control and use of protective coatings/barriers, wherever necessary.

PROTECTIVE COATINGS

- PCC of 1:2:4 or 1:1.5:3 of minimum 10 cm at bottom.
- Tarfelt with bituminous coating surrounding RCC – 5 Layered
- Cover to steel 1.5 to 2 times more.
- Dense concrete
- Filling salt free sand.

MEASURES TO COUNTER SALINTY ATTACK

❑ Choice of Construction Materials

- ❖ **Cement :** The type, chemical composition and physical characteristics of the cement greatly influence the resistance of plain and reinforced concrete in the presence of sulphates and chlolrides
  - ➢ In so far as the sulphates are calcium aluminate phase of cement are susceptible to sulphate attack of concrete and so such use of sulphate resisting cements is the obvious solution.
  - ➢ From this point of view cements in decreasing order of preference are:
    - High alumina cement
    - Super sulphated cement
    - Sulphate resisting Portland cement.
    - Portland Pozzolana cement or Portland slag cement.
    - Ordinary Portland cement.

MEASURES TO COUNTER SALINTY ATTACK

❑ Choice of Construction Materials

❖ Aggregates

- ➢ Coarse and fine aggregates from natural sources conforming to IS: 383 shall be used in mortars and concretes.
- ➢ The shape, size and grading of aggregates should be as per the relevant standards, codes and practices so as to produce workable concretes which can be placed without segregation and will result in dense and uniform concrete.
- ➢ The aggregates too should not contain any deleterious constituents.

MEASURES TO COUNTER SALINTY ATTACK

❑ Choice of Construction Materials

❖ Water

- Water used for mixing and curing concrete and mortars should not contain harmful amounts of dissolved salts.
- The ground water samples containing large amounts of deleterious salts should not be used.
- Water conforming to requirements of IS: 456 and meeting specifically the limitations of solids content in the water shall only be used.
- Water from the irrigation canal in Rohtak and Jhajjar districts was also tested. The sample tested had pH 7.2 and contained chlorides and sulphates in traces only and was found fit for construction use.

MEASURES TO COUNTER SALINTY ATTACK

❑ Choice of Construction Materials

❖ Bricks

- Properly burnt high strength first class bricks provided that the water absorption less than 10 percent should be used in foundation upto plinth level.
- If first class bricks available do not meet the above mentioned specification on water absorption but otherwise confirm to the PWD specifications (i.e. water absorption limited to 20 percent) the same can be used with additional precautions as detailed below: -
  - Brickwork on plain concrete footing.
  - Reinforced concrete foundations (eg. In RCC framed structures).
  - Reinforced concrete pile foundations.

CONCLUSIONS

- The results of the investigation show that the soil in and near Rohtak & Jhajjar contains sulphates and chlorides. The chloride content ranges from traces to as high as 0.50 percent and the sulphates content ranges from traces to as high as 0.56.
- The ground water in and near Rohtak & Jhajjar also contains sulphates and chlorides, the maximum sulphates and chloride content being 0.49 percent and 1.30 percent respectively. The pH ranges from 6.7 to 8.4.
- The pH ranges from 7.6 to 9.6.
- The water in Sonepat distt. is alkaline and does not meet with requirements of IS code 456.

CONCLUSIONS

- On testing of large number of samples of water, alkaline water was found which needed a treatment of addition of acid of defined normality.
- For Water samples having chlorides and sulphates beyond permissible limits, RO is must.
- Foundations in aggressive water need a multi layered treatment to prevent damage from aggressive salts.
- Desirable to use non-polluted canal water.

Thank You