THOMSON REUTERS ENDNOTE

[Prabhakar*, 5(2): February, 2016] ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

WATER QUALITY IMPACT ON THE DAM CONCRETE FOR UPCOMING PUMPED STORAGE SCHEME IN WEST BENGAL

Kachhal Prabhakar*, RP Pathak, N Sivakumar

Scientist C Central Soil & Materials Research Station, MoWR, RD &GR, Olof Palme Marg, Hauz Khas, New Delhi 110016.

Scientist C Central Soil & Materials Research Station, MoWR, RD &GR, Olof Palme Marg, Hauz Khas, New Delhi 110016,

Scientist E Central Soil & Materials Research Station, MoWR, RD &GR, Olof Palme Marg, Hauz Khas, New Delhi 110016.

ABSTRACT

The construction of large capacity dams on major rivers in the country is required to full fill country's irrigation and power requirements. The long term sustainability of these structures is largely dependent on hydro-environment and the capacity of these structures to resist weathering action, chemical attack, abrasion, or any other process of deterioration. The concrete deterioration is directly influenced by various geographical, climatic and ecological conditions. These are therefore the major factors to be considered during the designing and construction of the upcoming river valley projects. Water plays an important role as the chemical reactions between cement and water enable the setting and hardening of cement, resulting in a binding medium for the aggregates and development of strength. Concrete can be made which will perform satisfactorily when exposed to various atmospheric conditions, to most waters and soils containing chemicals etc. There are, however, certain aggressive conditions under which the useful life of even the best concrete will be short. Understanding these conditions permit measures to be taken to prevent or reduce deterioration. Peculiar problems like deterioration of concrete due to poor water quality, problem of leaching of lime in seepage galleries, high temperature of water springs inside head race tunnels etc. have been encountered during the pre and post construction investigations at various projects. The present paper highlights the pre construction stage water quality studies for three seasons to evaluate its possible effect on concrete along with suggested remedial measures for upcoming Turga Pumped Storage Scheme, West Bengal, India.

KEYWORDS: Soft water attack on concrete, leaching of lime, Seepage, aggressivity of water, Hydro-environment.

INTRODUCTION

During the last fifty years, major developments have taken place in concrete industries both materials and construction practices. The dual focus of these developments has been to achieve strength and durability of concrete. Even with the perfect concrete mix design, it is important that the durability/performance of concrete get adversely affected under certain aggressive site conditions. Many physical and chemical causes such as quality of ingredients & quality control during construction, corrosion of embedded reinforcing or pre stressing steel, chemical attack by the external agents, physical- chemical effects from internal phenomenon and leaching of lime etc. are responsible for deterioration of concrete. The penetrability or water permeability of concrete turns out to be the only property, which can be directly related to long term durability. A number of case histories are there to show that impermeable concrete when exposed to aggressive environment perform much better than the high strength permeable concrete during the intended service life. Durable concrete will retain its original form, quality and serviceability when exposed to aggressive environment over the designed period. Deterioration of concrete is directly related to its durability that depends on the extent of efforts taken to ensure proper design of concrete mix, degree of quality control exercised during construction and guidelines followed to protect the concrete from harmful effects during hardening process. The present study focuses on pre construction stage water quality investigations for pre-monsoon, monsoon & lean seasons and suggesting of concrete mix for Turga Pumped Storage Scheme, West Bengal.

THE PROJECT AT A GLANCE

The Turga Pumped Storage Project on Turga nala is located in Purulia district of West Bengal. This is one of the four Pumped Storage Schemes initially identified by erstwhile WBSEB (now known as WBSEDCL). The Turga Pumped Storage Scheme envisages utilization of the waters of the river Turga in Ayodhya hills for peak power generation on a Pumped storage type development. This mega hydel power project is the fourth of its kind in the world and first in India. It has got the capacity of generating 1000 MW power instantly by discharging stored water from the upper dam to the lower dam through reversible pump turbine. [9]

Major Highlights of the project

- West Bengal State Electricity Board (WBSEB) envisages the construction of 1000MW (4x250 MW) Turga Pumped Storage Scheme situated on the river Turga Nallah – a tributary of Subarnarekha river.
- The project site is about 300km northwest of Calcutta. It involves construction of two rockfill dams with central clay-core for the upper (catchment area 4.2 Km2) and lower reservoirs (catchment area (13.72 Km^3).
- The upper dam – FRL 495m; MDDL 474m & live pondage 14.31 MCM would be 79m high and 796m long, while the lower dam would be 69m high and 502m long.
- The project will have two horizontal intakes with maximum level of 526m and total discharge capacity of $600m^3$/sec. The water-conductor system will comprise two steel-lined headrace tunnels, each 475m long, 7.7m in diameter with a discharge capacity of $300m^3$/sec.
- There will be an underground powerhouse having 200 x 22.5 x 50.3m in size, housing four vertical shaft,
- The project envisages two numbers of circular steel lined Head Race Tunnels having max. dia. Of 7.5m each with the provision of steel liner. D shaped adit to HRT is also provided.
- 580m & 587m long gateless free flow spillways situated at Upper & Lower dam and Two numbers of circular type Tail Race Tunnel of 5.8m dia. also envisaged.
- The maximum turbine and pump discharges will be 150 and $141.2m^3$/sec respectively.

Pumped storage scheme comprises to pump water into the higher reservoir from lower reservoir. When there is higher demand, water is released back into the lower reservoir through a turbine, generating electricity. Reversible turbine/generator assemblies act as pump and turbine (usually a Francis turbine design). Nearly all facilities use the height difference between two natural bodies of water or artificial reservoirs. Pure pumped-storage plants just shift the water between reservoirs, while the "pump-back" approach is a combination of pumped storage and conventional hydroelectric plants that use natural stream-flow.

Table 1: Regional/state wise distribution of potential pumped storage schemes in India

Region/State	Number of schemes identified	Probable Total Installed capacity (MW)
Northern Region		
1. Jammu & Kashmir	1	1650
2. Himachal Pradesh	2	3600
3. Uttar Pradesh	2	4035
4. Rajasthan	2	3780
Sub-total	7	13065
Western Region		

1. Madhya Pradesh	7	11150
2. Maharashtra	18	27070
Sub-total	25	38220
Southern Region		
1. Andhra Pradesh	1	1650
2. Karnataka	4	7900
3. Kerala	2	4400
4. Tamil Nadu	1	2700
Sub-total	8	16650
Eastern Region		
1. Bihar	1	2800
2. Orissa	1	2500
3. West Bengal	4	3785
Sub-total	6	9085
North-Eastern Region		
1. Manipur	2	4350
2. Assam	1	2100
3. Mizoram	7	10450
Sub-total	10	16900
Total All-India	56	93920

Source: West Bengal State Electricity Board

CSMRS WATER QUALITY STUDIES

CSMRS team visited the site in February 2014, August 2014 & June 2015 & recoded water quality data for lean, monsoon & pre-monsoon seasons respectively. Important locations covered are represented in Table 2.

Table 2 : Location of the Sampling Points

Sl. No.	Type of sample	Sampling Location
1.	Water	Proposed Lower Dam of Turga Pumped Storage Project
2.	Water	Irrigation Dam, D/S of PPSP Lower Dam
3.	Water	PPSP Upper Dam
4.	Water	About 700m U/S of Proposed Turga Upper Dam Axis on Turga Nallah
5.	Water	Nallah near Proposed Powerhouse Area
6.	Water	Nallah near Proposed TRT Area
7.	Water	D/S of Upper Dam Axis on Turga Nallah
8.	Water	D/S of V-Notch of Upper Dam Axis on Turga Nallah
9.	Water	Hand Pump water of Ranga Mode Near Turga Upper Dam Area
10.	Water	Hand Pump water of Bandhghutu Village near PPSP Upper Dam Area

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

11.	Water	Hand Pump water of Gosaidih Village Near Lower Dam Area

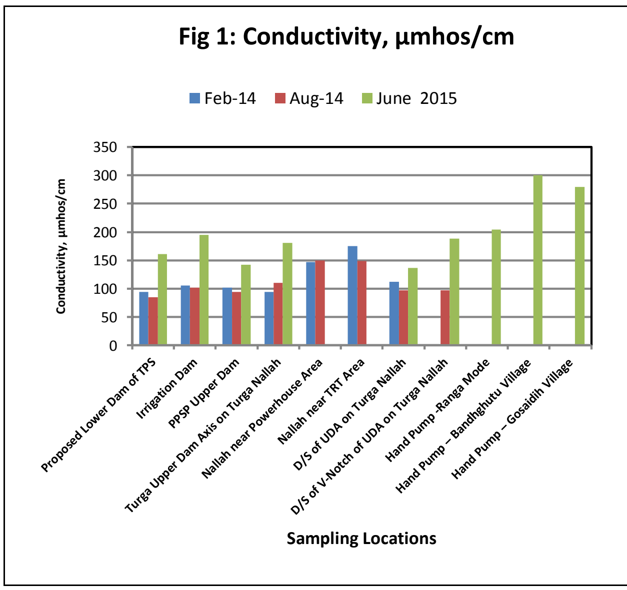
3.1 in situ & laboratory analysis of water samples

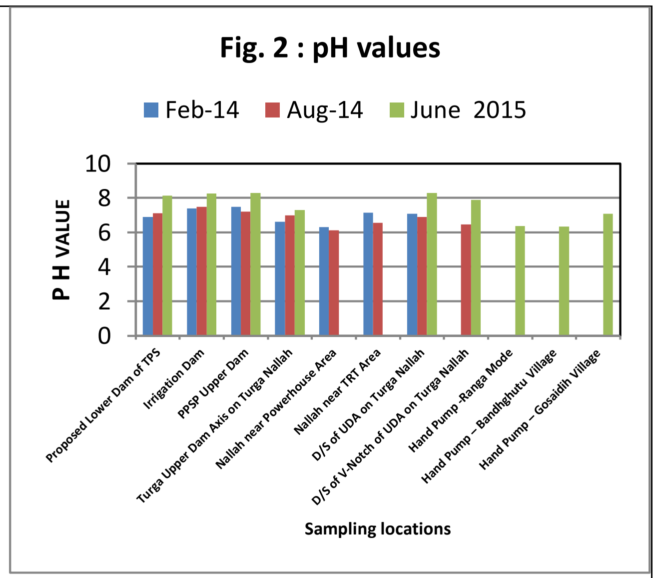
Water samples were analyzed as per analytical procedure laid down in IS 3025-1986 "Methods of Sampling and Test (Physical and Chemical) for Water used in the Industry". Wherever necessary, reference was also made to the procedure laid down in "Standard Methods for the Examination of Water and Waste Water" published by American Public Health Association and Water Pollution Control Federation, USA, 1985. The analysis was carried out at project laboratory using Ion meter and Ion selective electrodes and titration/gravimetric method[2],[3]

3.1.1 In situ water quality data: In-situ parameters viz: temperature, conductivity, pH, $CaCO_3$ saturated pH, ammonium and sulphide of representative water samples were determined at site itself. (Fig. 1 to 4). The pH of water is affected by many factors both natural and man-made. Most natural changes occur due to interactions with surrounding rock (particularly carbonate forms) and other materials. pH can also fluctuate with precipitation (especially acid rain) and wastewater or mining discharges. In addition, CO_2 concentrations can also influence pH of water bodies. Nallh near powerhouse area recorded pH values below 6.50 in lean (6.30) & monsoon season (6.11) observations. For other locations, the pH values recorded in the range 6.46 – 8.29. During the observation period, seasonal variation in temperature noticed & found in the range 19.3ºC – 36.5ºC. Low conductivity values of the water collected from different sites (Table 2) found in the range of 94-194.5 micromhos/cm.

3.1.2 Laboratory Investigations: Lab. parameters like determination of Suspended solids, Total solids, Acidity, Alkalinity, Chloride, Sulphate, Carbonate, Bicarbonate, Calcium, Magnesium, Sodium, Potassium were evaluated in laboratory. Major cations & anions are found in lower side during all seasons observations indicating the water quality is soft in nature. (Fig. 5-14).

GRAPHS ON ANALYTICAL RESULTS OF WATER SAMPLES





ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

Fig. 3: Temperature °C

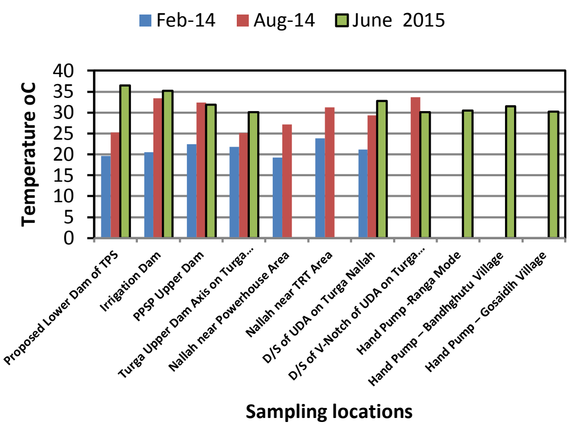


Fig. 4 : $CaCO_3$ Saturated pH values

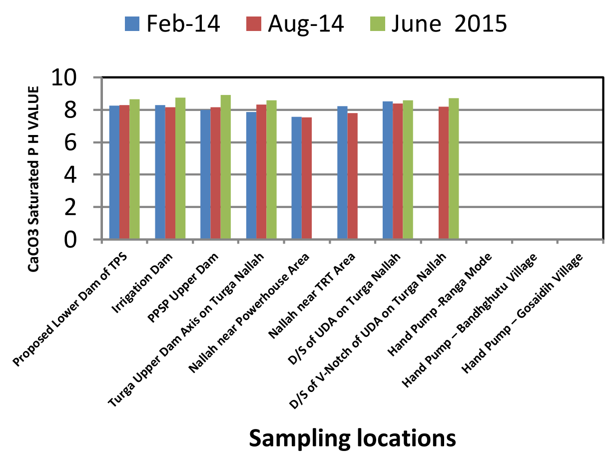


Fig. 5: Calcium

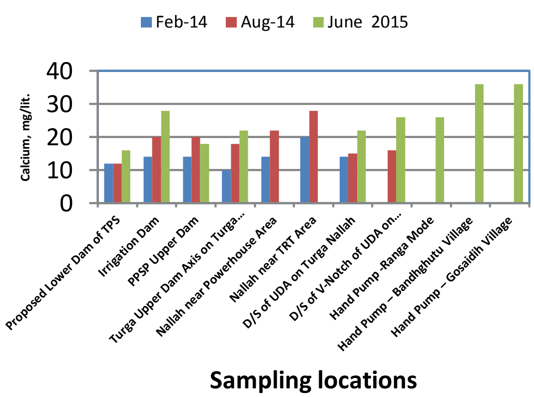
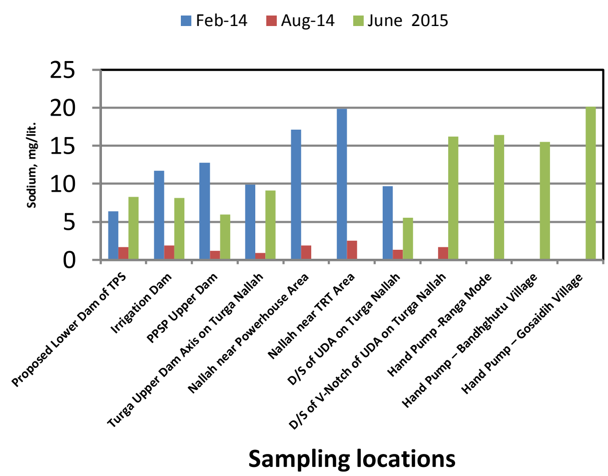


Fig. 6 :Sodium



 ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

Fig. 7 : Magnesium

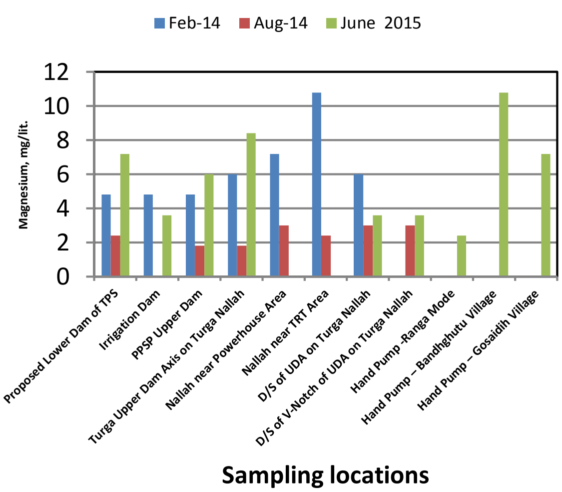


Fig. 8 : Potassium

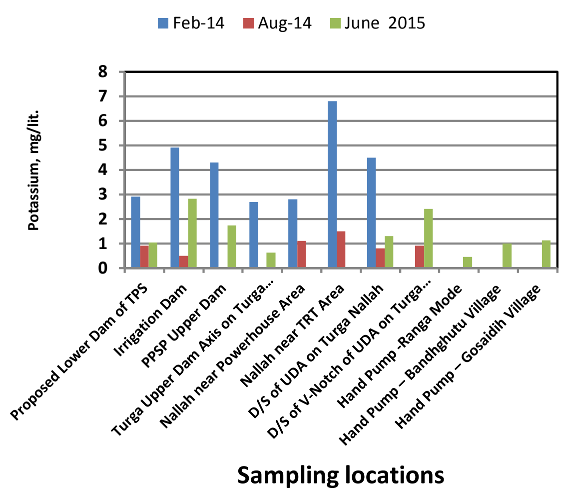


Fig. 9 : Bicarbonate

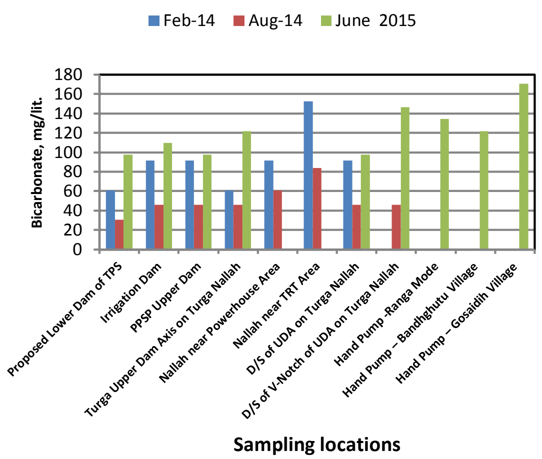
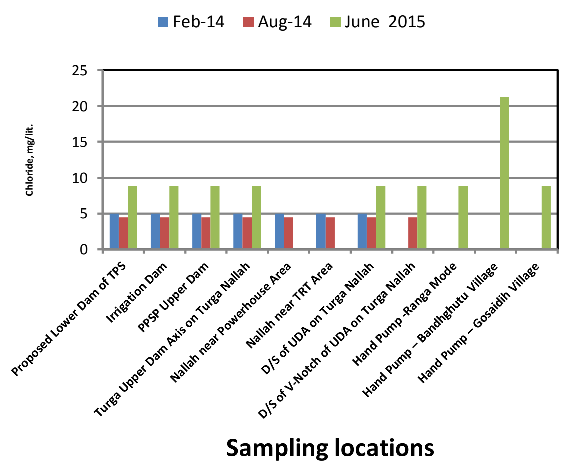


Fig. 10 : Chloride



ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

Fig. 11 : Sulphate

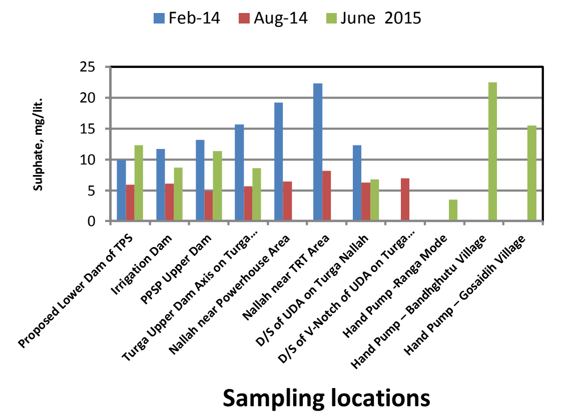


Fig. 12 : Acidity

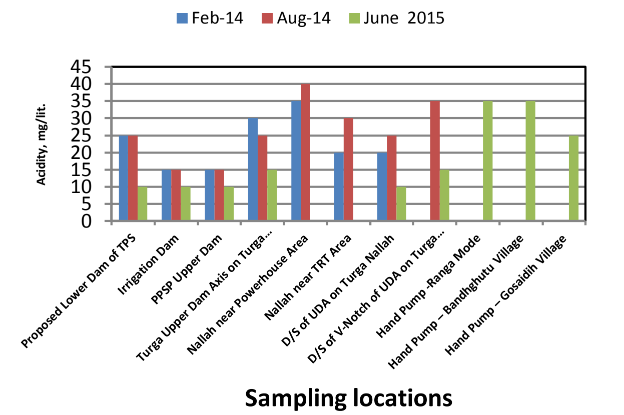


Fig 13 : Alkalinity

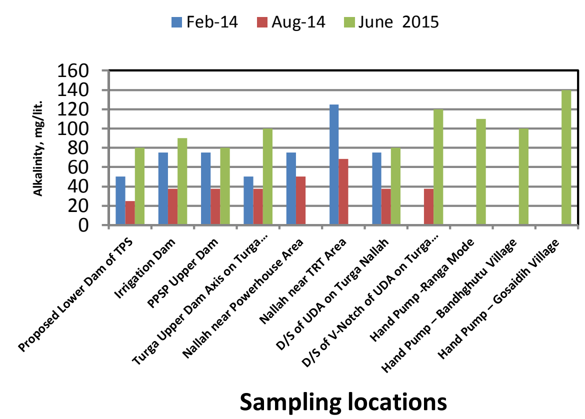
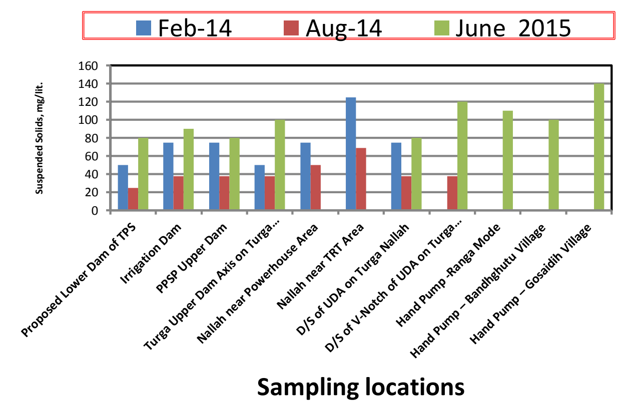


Fig 14 : Suspended Solids



SOFT WATER ATTACK

Soft water is aggressive to concrete structures because of its ability to dissolve substances in it. It is observed worldwide that structures made by taking utmost care and precaution can also be damaged due to soft water attack and consequent leaching. In Himalayan region where the temperature in low and the fresh mountain waters are often relatively free from dissolved ions, leaching and freeze-thaw are the most common degradation problems for concrete. Soft waters are aggressive to concrete structures as they are short of dissolved ions and have a great tendency to dissolve ions from nearby materials. Leaching is the name of the whole process of dissolving and transporting substances out of the concrete. Other degradation mechanisms also become more and more effective in case of leaching of concrete since strength giving calcium is removed from the concrete during the process. Also as the pH value inside the concrete may decrease from 12-13 to 8-9, corrosion of reinforcement may also take place[1]. A number of factors such as permeability of concrete, amount of total Ca and $Ca(OH)_2$ in concrete, carbonation, hardness of water, amount of carbonic acid which is free to attack the concrete etc. may influence the leaching of lime from concrete. [1]

AGGRESSIVITY OF CHEMICAL ENVIRONMENT WITH REFERENCE TO CODES AND PRACTICES

6.1 USBR classification for sulphate aggressivity

The relative degree of sulphate attack may be termed as negligible in all the representative water samples as the values of sulphate (as SO_4 mg/lit.) remain below 150 mg/lit.[5]

6.2 French National Code p 018-1985

pH of all the samples except the water sample drawn from nallah near proposed powerhouse area is more than 6.5. Ammonium ions are absent. The sulphate and magnesium ions are present in very low concentrations. As per the French National Standard, all water samples fall under "non-aggressive" category i.e., A_0 except water sample drawn from Nallah near proposed powerhouse site which fall in A1 category (moderate/slightly aggressive) w.r.t. pH value[6]

6.3 Langelier Index (LI)

International Commission on Large Dams (ICOLD) Bulletin No. 71 has recommended the calculation of Saturation of Langelier Index (LI) as a means of evaluating potential soft water attack. The LI values of other locations are around - 1.0 which indicates that samples are aggressive. Negative values of LI indicate the aggressiveness of water whereas the positive values imply the likelihood of calcium deposition. It is seen from the data that there is possibility of soft water leaching attack since out of 18 water samples 9 water samples have negative values for Langelier Index. In these circumstances there is a possibility of corrosion of concrete. LI values for the samples collected during August 2014 & June, 2015 could not be calculated as the temperature of these water samples exceed 25ºC. The water samples collected from reservoir and TRT have been classified as moderately aggressive and aggressive respectively [7].

RECOMMENDATIONS

As far as corrosion of reinforcement of concrete due to chloride ions is concerned, no such possibility is envisaged. Therefore, minimum concrete cover as per design/codal requirement may be provided. Furthermore, limit of chloride ion within concrete should be restricted to acceptable limit given in IS : 456 – 2000.

Under Para 1.2 (Table 3 of IS: 456-2000) important aspects about environmental conditions of water with respect to its attack on concrete has been dealt with at ordinary temperature only. However, degree of attack gets enhanced at higher temperature. In light of this, if any hot water spring encounters either in river at/or before dam axis or in the HRT region, appropriate remedial measures must be taken. In such situation blended cements should be used in place of OPC.

The overall water quality of the various sites of the project may be classified as "mild" category as far as its attack on concrete is concerned.

CONCLUSION

Water samples are fit for mixing and curing purposes. There is a possibility of soft water attack, which may be enhanced at higher temperature if geothermal springs are countered. IS : 456-2000[4] recommends following mix design formulations under mild and moderate environments. Powerhouse portion the exposure condition may be termed as "moderate". For dam portion, the exposure condition may be termed as "mild". Concrete requirements for various exposure conditions are suggested to the project authorities as follow.[8]

	Plain concrete		Reinforced concrete	
	Mild conditions	Moderate conditions	Mild conditions	Moderate conditions
Minimum cement content, kg/m^3	220	240	300	300
Maximum free water-cement ratio	0.60	0.60	0.55	0.50
Minimum grade of concrete	-	M15	M20	M25

It would be preferable to use blended cement such as Portland blast furnace slag cement, Portland Pozolana cement etc. W/c ratio may be kept low to get a good dense and impermeable concrete. Keeping the cementitious content much above the minimum prescribed value is advisable. However, if potentially reactive aggregates are encountered, optimum cement content may have to be considered. Corrosion of reinforcement may not be a problem provided following conditions are met:

- Adequate concrete cover as per codal/design requirement
- The overall chloride ion content in concrete is within codal limit
- Good dense concrete

ACKNOWLEDGEMENTS

The authors extend their sincere gratitude to the Director, Central Soil and materials Research Station New Delhi for being a constant source of inspiration. Authors acknowledge the logistic & constructive support provided by Mr Manoranjan Mandal, Project Manager, M/s WAPCOS Limited & Shri Anand Swaroop, Senior Consultant, M/s WAPCOS Limited for extending timely help during laboratory and field investigations. We also extend our sincere gratitude to the authors whose publications provided us directional information from time to time.

REFERENCES

[1] Bentur et. Al, "Durability of Concrete and Cement Composites", 1997
[2] "Methods of Sampling and Test (Physical and Chemical) for Water used in the Industry- IS 3025, 1986.
[3] "Standard Methods for the Examination of Water and Waste Water", published by American Public Health Association and Water Pollution Control Federation, USA, 1985.
[4] BIS Code, "IS 456 for sulphate attack and other durability considerations and curing & mixing purposes", 2000.
[5] United States Bureau of Reclamation (USBR) Standard for sulphate Aggressivity.
[6] Classification of Degree of Aggressiveness based on SO_4^-, Mg_2^+, NH_4^+ and pH, French National Code p8-011, May, 1985
[7] International Commission on Large Dams, ICOLD Bulletin No. 71 ―Exposure of Dam Concrete to Special Aggressive Waters – Guidelines and Recommendations for assessing aggressivity of soft water, 1989
[8] CSMRS Report on chemical analysis of water samples of Turga Pumped Storage Scheme, West Bengal, 2015.
[9] Executive Summary for EIA study for Turga Pumped Storage Project, West Bengal, 2000.