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# ADVANTAGES FROM USE OF POZZOLANIC AND POLYMERIC COMPOSITE MATERIALS IN MASS CONCRETING WORK - UNDER AGGRESSIVE ENVIRONMENT

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## ABSTRACT

The long term durability and sustainability of mega engineering structures like concrete and masonry dams are largely dependent on hydro-environment. Poor water quality of reservoir and aggressive chemical environment are detrimental for concrete structures and their propensity put to increase with passage of time. Concrete deterioration starts when it encounters adverse geological, atmospheric, and anthropogenic conditions. Other factors, like temperature variation, increased fluid velocity, poor compaction, consolidation and curing of concrete, alternate wetting and drying etc. are the conditions favorable for enhancement in rate of structural degradation. Hydro-environment is directly influenced by the presence of soluble salts contents, variation in temperature, presence of natural and anthropogenic pollutants in the surroundings of the structure which is a dominant cause for lowering down the pH of water responsible for leaching of lime from concrete.

This paper discusses about the factors having impact on the concrete structures and providing protection to the concrete structures by using polymeric/pozzolanic materials. The field investigations were carried out for evaluation and assessment of structural distress at some important hydro power projects and remedial strengthening measures provided by CSMRS to overcome the problem has also been discussed in this paper.

**KEYWORDS:** Hydro-environment, Water quality, Durability, Polymeric/Pozzolanic materials.

## 1. INTRODUCTION

India is endowed with total hydro-potential of about 2 50 000 MW. However, exploitation of hydro-potential has not been up to the desired level due to various constraints confronting the sector.22% of total electricity produced in India is through hydroelectric power. This creates additional pressure on water resources. In order to exploit hydro power various large and middle scale dam including conventional concrete dam, roller compacted concrete dam, rock fill dam, Concrete Faced Rock fill Dam(CFRD), Earth fill dam, arch dam, barrages etc were constructed on various river valley projects and still work in progress specially in Himanchal Pradesh, Uttrankhand and entire North east.

In order to sustain these large dams structures for years, a good quality control practice is required at the time of construction and thereafter its monitoring . The following safety measures at the time of construction is required to be taken care of

- Quality of construction materials including cement, concrete, steel reinforcement etc..
- Water quality to be used for mixing and curing of concrete.
- Surrounding geology

The actual deterioration of concrete structure starts during its aging process these includes the following reasons:

- Temperatures Variations,
- Increased fluid velocity,
- Poor curing of concrete,

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- Alternate wetting and drying,
- Corrosion of reinforcing steel
- Soft water attack
- Chemical effects on hydrated cement paste from external agents (viz. water containing carbon dioxide, sulphates or chlorides);
- Physical- chemical effects from internal phenomenon, such as alkali-aggregate reaction and salt weathering.
- pH value below 3.5 TO 4.0
- Temporary hardness
- Free lime in the set cement mortar / concrete paste is leached out.

**Aggressive Chemical Exposure:**
Concrete can be made which will perform satisfactorily when exposed to various atmospheric conditions , to most waters and soils containing chemicals, and to many other kinds of chemicals. There are however some chemical environment under which the useful life of even the best concrete will be reduces. Understanding these conditions enables measures to be taken to prevent or reduce deterioration,

Water plays an important role in the production of concrete. 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. Two important requirements of concrete are durability and strength. The durability of cement concrete is its ability to resist weathering action, chemical attack, abrasion or any other process of deterioration. The presence of Soluble sulphates, Chlorides and other salts in concrete pore water results in to severe damage to the concrete structures and causing durability issues. The ingress of acidic water causing corrosion of steel renforcement.Fig.1 -4.Presents the damage to concrete due to aggressive chemical exposure.

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***Figure-1, Lime Leaching in Dam Galleries*** ***Figure-2, Cracks in Concrete***

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*Figure-3, Spalling due to Corrosion*

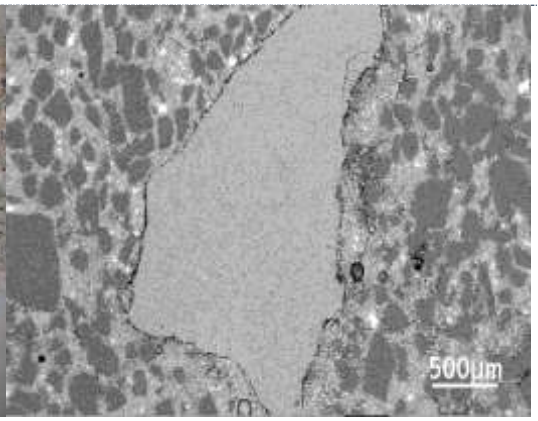


*Figure-4, Concrete Cracks due to Sulphate*

Various kind of polymeric/pozollonic materials used now a days for the purpose of mixing in concrete, repairing and curing purpose.

## 2. MATERIALS AND METHODS

**Pozollanic Materials:**

- Fly ash
- Silica Fumes
- Blast furnace Slag

**Polymer-modified cementitious systems**

- Synthetic rubbers, eg styrene butadiene rubber
- Acrylic and modified acrylic latexes
- Polyvinyl acetate latexes
- Epoxy emulsions

**Fly Ash**

Fly ash is a fine, glass powder recovered from the gases of burning coal during the production of electricity. These micron-sized earth elements consist primarily of silica, alumina and iron. When mixed with lime and water the fly ash forms a cementitious compound with properties very similar to that of Portland cement. Because of this similarity, fly ash can be used to replace a portion of cement in the concrete, providing some distinct quality advantages.

**Use of Polymers And Polymer Composites For Concrete Remediation**

Polymer blended cement concrete and mortar provides a revolutionary alternative solution to the existing problems. These bring some key advantages, particularly in terms of

- Workability
- Abrasion Resistance
- Impact Resitance
- High Strength
- Flexibility

**Case Studies :**

**Nathpa Jhakri Powe Project, Himanchal Pradesh**

The 1500 MW NathpaJhakri power project envisages construction of a 60.5 meter high concrete dam on the river Satluj at Nathpa. For this a 10.15 m dia. And 27.3 km long Head Race Tunnel ( HRT) was constructed.

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During its construction hot water having temperature around 40-650C was foud to seep through the inner face of the tunnel in a stretch of about 2500 m. To undertake concrete lining work under these adverse conditions, further investigation work was refered to CSMRS.for long term effect of hot water on concrete. CSMRS undertook the water quality analysis along the whole length of HRT covering both hot and cold water seepage reaches. The brief observations are presented in Table-1.

***Table 1***

| | |
|---|---|
| Average temperature of hot water | Varies from 26ºC to 58º C |
| Calcium ion content in seepage water | Between 3.5 to 63.2 ppm |
| Average Chloride ion content | Varies between 5 to 25, and exceptionally high for two samples 254 ppm & 1296 ppm |
| Average sulphate content | Varies between 7.3 ppm to 208.06 ppm |

To determine the aggressively of water it involve the derivation of a series of numerical sub indexes related to the aqueous parameters these are Leaching corrosion index ( LCI), Spalling corrosion index ( SCI) and Overall corrosion index ( OCI)

Once the indices have been calculated ,they are used to assess the corrosivity of the water. After identifying the dominant mode of attack ( Leaching or spalling ) recommendation can be suggest on the basis of standard codes and practices in form of either providing concrete of adequate water cement ratio and cement content, and type and if necessary providing further protection in the form of anticorrosive coatings. recommending the type of protective measures.

In case of this project the following recommendations were made by CSMRS

1. 50/50 blend of OPC + Ground Granulated Blast Furnace Slag conforming to IS 455: 1989
2. 70/30 blend of OPC + Fly ash
3. 85/15 blend of OPC + Condensed Silica Fume

The Head Race Tunnel ( HRT) was constructed adopting CSMRS recommendations is presented in figure 5.

***Figure-5 The Head Race Tunnel ( HRT)***

**Myntdu Leshka He Project, Meghalaya**

The MLHEP is located in the Jaintia Hills District of Meghalaya at an altitude of 563.00 above MSL is a concrete gravity dam 59 m high just below the confluence of three rivers (Leshka) viz. Myntdu, Laichiki (Umshariang) and Lamu, with 3667 m long tunnel, penstocks and a power house for installation of 2 X 42 MW

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generating units. The work of assessing the water quality of Myntdu River and its tributaries in catchment area for its long-term effect on durability of concrete was assigned to Central Soil and Materials Research Station (CSMRS) as the pH of water was found to the abnormally low in the range 3.6 to 5.0. In this connection, water samples were collected at regular intervals such as monsoon, pre-monsoon and post – monsoon. The source of the acidic water was identified to be surface runoffs from the surroundings coal mines either sides of the main Myntdu River. The acidic water flowing in Myntdu River is presented in figure 6.

***Figure-6, Acidic nature of Myntdu river and its tributaries***

The river Myntdu originates in Jaintia hills from a place called MihMyntdu at an elevation of 1372 M near Jowai town and flows towards the south. In its course, the river drops by about 847 M in a distance of 38 Kms and meets two tributaries Umsharian from west and Lamu from east to form a trijunction (Leshka). The Myntdu river starts off with a pH value of 6.77 at the source near Jowai. The pH value recorded after the confluence of Umshariang and Lamu with Myntdu is less than 5.0 at the proposed dam site, while before the confluence it has a pH value around 4.20. The immediate tributaries Umshariang and Lamu near the dam axis have pH near a neutral value of 7.0. The major tributaries/ nallah further upstream of the dam axis are Ampliang, Umshanphu, Makjai and Urhali in right bank and Umlatang, Umrylien, Umchong, Umshakhrut and Wapung on the left bank (shown in the sketch, Fig.7). The Makjai river has a pH value more than 6.0 in the right bank while other tributaries Umshanphu and Ampliang have a very low pH (around 2.50); in the left bank all the tributaries/ nallah have very low pH values ranging from 2.75 to 5.0.

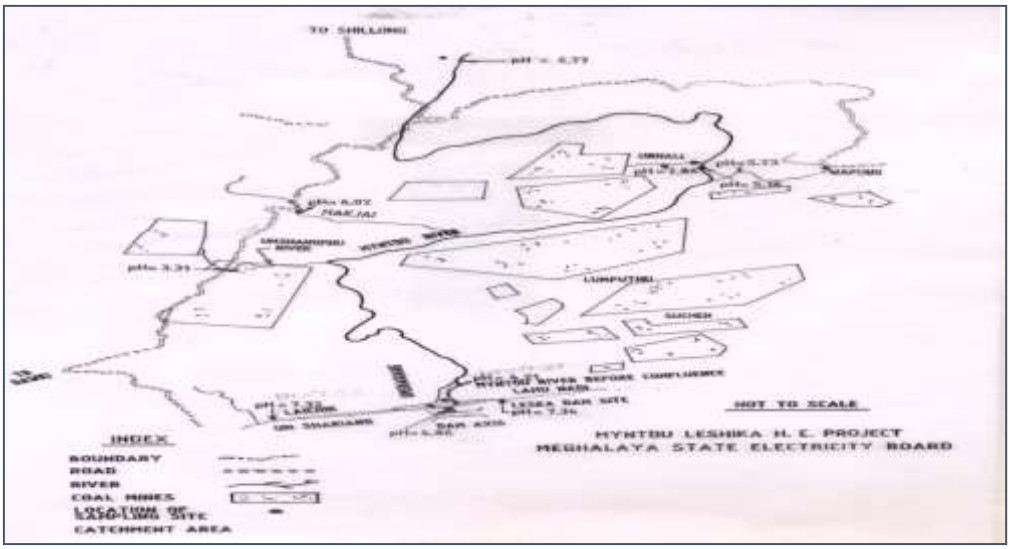


***Figure 7 Sketch Diagram Of Catchment Area***

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## 3. RESULTS AND DISCUSSION

The results of analysis is presented in table-2.

***Table 2***

| Sl No. | Sample Location/ Sample No. | Parameters | | | |
|---|---|---|---|---|---|
| | | **pH** | **Conductivity in µ mhos/cm** | **Chloride mg/l** | **Sulphate, mg/l** |
| **1.** | **Myntdu River,** Dam Axis | 4.86 | 41.6 | 1.4 | 16.1 |
| **2.** | **Lamu River,**beforeconfluence to Myntdu | 7.34 | 62.7 | 1.5 | 7.9 |
| **3.** | **Myntdu River**beforeconfluence to Lamu andLachiki | 4.21 | 49.1 | 1.3 | 8.1 |
| **4.** | **Lachiki (Umarshariang)**beforeconfluence to Myntdu | 7.32 | 51.2 | 1.7 | 8.6 |
| **5.** | **Abandoned Coal Mine** | **2.43** | 563 | 0.8 | 85.3 |
| **6.** | **Urhali**beforeconfluence to Myntdu | **2.86** | 207 | 1.2 | 19.9 |
| **7.** | **Myntdu River**afterconfluence of Urhali | 5.18 | 27 | 2.8 | 6.8 |
| **8.** | **Makjai River** | 6.02 | 21.6 | 1.3 | 0.0 |
| **9.** | **Shangphu Iron Bridge** | 3.31 | 53.5 | 1.1 | 5.1 |
| **10.** | **Bangpung, L/B** | 5.73 | 58.9 | 3.0 | 26.4 |
| **11.** | **Myntdu River at Source** | 6.77 | 35.0 | 0.0 | 0.50 |

After detailed investigation, possibility of following deleterious effects on concrete due to

- Leaching of lime may occur from concrete
- Loss of concrete strength is possible over a period of time
- Possibility of attack on metallic portion e.g. turbine blades, reinforcement etc.

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Series of remedial measures suggested include

- The degree of aggressivity was first defined as "Extreme" through a series of tests.
- W/c ratio less than 0.40
- Good dense & impermeable concrete
- Appropriate grade of concrete; Minimum cement content shall be 280 Kg/$M^3$ for plain concrete and 360 Kg/$M^3$ for reinforced concrete exposed to acidic water.
- Preference to be given to blended cements.
- Adequate protection of reinforcement with good concrete cover
- Non-corrosive steels or coatings or chemical inhibitors or Cathodic protection for protecting the reinforcement.
- Use of good quality turbine blades, which can withstand acidic environments under pressure.

Treatment of catchment area surface runoffs (i.e. Acid mine discharge

## 4. CONCLUSION

Water to be used for curing and construction purposes must be analyzed for the parameters which can deteriorate the concrete structure. In addition to the analysis of water, assessment of setting time and compressive strength may be made mandatory for declaring the suitability of water for concrete making. Application of either suitable pozzolanic /polymeric materials must be practiced after evaluating proper cause of concrete deterioration and lab scale application treatment results.. Experienced professionals are therefore a prerequisite for the successful application of these composites on site.

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