REHABILITATION USING SPECIAL RESIN MORTARS FOR LARGE HYDRAULIC STRUCTURES

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ABSTRACT

Rehabilitation of hydraulic structures is one of the biggest challenges. There are certain elements which have Erosion due to cavitation, abrasion & chemical attack (e.g. sulfate or soft water in granite rock zones); while impact is due to repeated chocs from stones and debris carried out in the discharged water. While majority of the structures are affected due to aging of time and duration. Various systems can be used to mitigate these issues however problem is selection of correct system for such application.

The systems selection should cover both advantages and inconvenient – most of the time, inconvenient taken over the advantages (cost, difficulty in placing, durability, etc.)

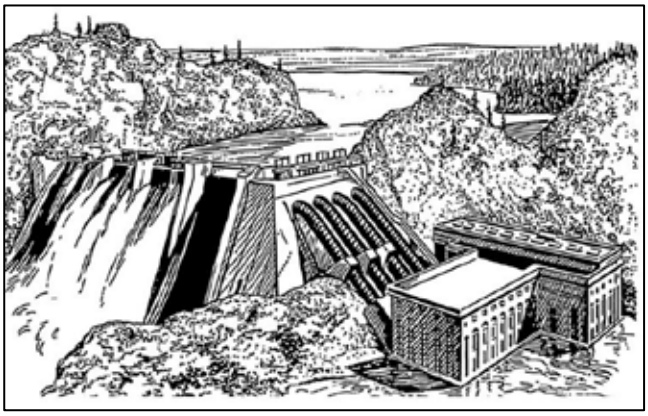
The paper describes a various epoxy system available with Sika for rehabilitation of the hydraulic structure along with highlighting the products specified in Chapter 4 of "Manual for Rehabilitation of Large Dams"

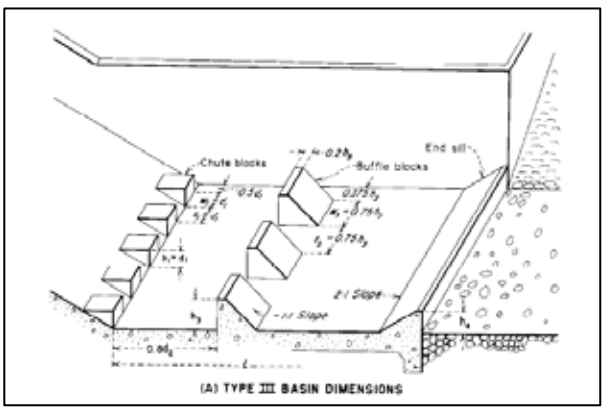
Some references will also be presented from various part of the world & India.

1. HYDRAULIC STRUCTURES

A hydraulic structure is a structure submerged or partially submerged in any body of water, which disrupts the natural flow of water. They can be used to divert, disrupt or completely stop the flow. An example of a hydraulic structure would be a dam, which slows the normal flow rate of the river in order to power turbines. A hydraulic structure can be built in rivers, a sea, or any body of water where there is a need for a change in the natural flow of water.

Hydraulic structures may also be used to measure the flow of water. When used to measure the flow of water, hydraulic structures are defined as a class of specially shaped, static devices over or through which water is directed in such a way that under free-flow conditions at a specified location (point of measurement) a known level to flow relationship exists. Hydraulic structures of this type can generally be divided into two categories: flumes and weirs.





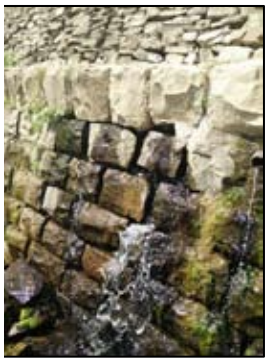
Typical hydraulic structures are dams, spillways, gallery, baffle blocks, weir wall, basin, apron Sluice gates.
(*Source- Wikipedia*)

2. TYPICAL PROBLEMS IN HYDRAULIC STRUCTURES

The typical problems identified in Hydraulic structures are Leakages, Cracking, Disintegration, Distortion& Movement, Spalling, Delamination, Seepage, Joint Sealant Failure & Erosion. Some of the reasons for this damages/ deterioration are due to floods, earthquakes, landslide, ageing etc.

Typical photos of problems in hydraulic structures




CWC guidelines on Manual for rehabilitation of large dams, gives details about causes & symptons of distress in large dams. Below is the table for the same.

Table 4-1: Causes & Symptoms of Distress

Causes	Symptoms							
	Construction Faults	Cracking	Disinte-gration	Distortion/ movement	Erosion	Joint Failure	Seepage	Spalling
Accidental loadings		√						√
Chemical reactions		√	√				√	
Construction er-rors	√	√				√	√	√
Corrosion		√						√
Freezing & Thaw-ing		√	√					√
Settlement & Movement		√		√		√		
Shrinkage	√	√		√				
Temperature Changes		√				√		√
Erosion			√		√			

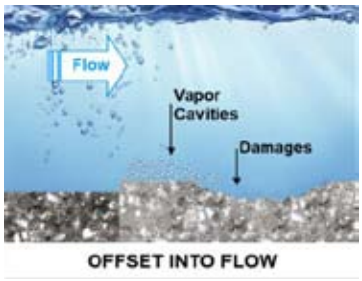
Source Manual for rehabilitation of large dams by CWC

Majority of hydraulic structures are damages due to Erosion. These are caused due to erosion are Cavitation, Abrasion or Chemical Attacks

- **EROSION BY CAVITATION:**

Cavitation is the formation of bubbles or cavities in a liquid. In hydraulic structure, the liquid is water, and the cavities are filled with water vapor and air. The cavities form where the local pressure drops to a value that will cause the water to vaporize at its ambient temperature. Concrete surface irregularities can trigger the formation of these cavities.

Examples of Cavitation damages @ Surface irregularities



OFFSET INTO FLOW

OFFSET AWAY FROM FLOW

PROTRUDING JOINT

- **EROSION BY ABRASION:**

Abrasion erosion damage results from the abrasive effect of waterborne silt, sand, gravel, rocks and other debris being circulated over a concrete surface during operation of a hydraulic structure. Abrasion erosion is readily recognized by the smooth, worn-appearing concrete surface, which can be distinguished from the small holes and pits formed by the cavitation erosion. Spillway, aprons, stilling basins, sluiceways and tunnel linings are particularly susceptible to abrasion erosion.

- **EROSION BY CHEMICAL ATTACK:**

Acidic environments result in deterioration of exposed concrete surfaces. The acidic environment can range from low acid concentration found in many river to high acid concentrations found in many processing plant. The compounds present in hardened Portland cement are attacked by soft water and many salt and acid solution. Soft water leach out the mineral compounds from the cement matrix and damages the structure.

3. MATERIALS FOR REPAIR OF HYDRAULIC STRUCTURES

Selection of repair material is always a biggest challenge. Internationally there are various methodology and system available as per BIS Codes, ASTM, ACI, European Codes, ICOLD etc, however it is recommended to plan repair work using repair material and methodology based on the experience with suggested system. Manual for rehabilitation of large dams by Central Water Commission (CWC) has recommended in section 4.4 various suitability of material. We will only elaborate on epoxy-based material and it tests. Section 4.4.6 recommends usage of epoxy compounds for repair of damage concrete & as bonding agent for old to new concrete. The performance of epoxy base product shall be as per ASTM C 881- Standard Specification for Epoxy-Resin-Base Bonding System for Concrete

3.1. Epoxy Compounds

The CWC manual recommends using epoxy compounds for

- Grouting in cracks, foundations & anchors
- Binder in epoxy mortar
- Bonding agent between hardened concrete to fresh concrete

The compounds should comply to ASTM C881. CWC manual has given restriction for the use of all seven types, in fact it has suggested to used only three types & instead of all six classes, it has suggested to use only three classes. All this has been identified in table 4-6 & 4-7 of the manual respectively. The performance of mechanical properties of epoxy compound is classified in table 4.8. All are listed below from extract of the manual.

Table 4-6: Three Types of Epoxy and their application

Type I	**For use in non-load bearing application for bonding hardened concrete to hardened concrete and other materials, and as a binder in epoxy mortars or epoxy concretes.**
Type II	For use in non-load bearing applications for bonding freshly mixed concrete to hardened concrete.
Type IV	For use in load bearing applications for bonding hardened concrete to hardened concrete and other materials and as a binder for epoxy mortars and concretes.

Source Manual for rehabilitation of large dams by CWC

Table 4-7 Classes of epoxy and their use as per range of temperature

Class A	For use below 4 °C, the lowest allowable temperature to be defined by the manufacturer of the product.
Class B	For use between 4 °C and 15 °C.
Class C	For use above 15 °C, the highest allowable temperature to be defined by the manufacturer of the product

Source Manual for rehabilitation of large dams by CWC

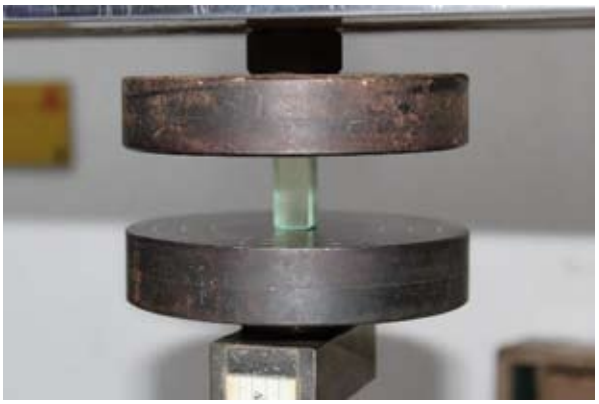
Table 4-8: Mechanical properties of epoxy resin bonding system

Sl. No.	Performance Characteristic	Test Method	Requirement
1.	Viscosity of Neat Resin System	ASTM D 1084	< 20 Poise (2.0 Pa.s)
2.	Compressive strength (7days)	ASTM D695	≥70 MPa
3	Tensile strength (7days)	ASTM D638	≥50 MPa
4.	Bond strength (14days)	ASTM C882	≥10 MPa

Source Manual for rehabilitation of large dams by CWC

3.2. Test Specimens as per ASTM standards

3.2.1 *Compressive strengthen as per ASTM D695*



3.2.2 *Tensile Strength as per ASTM D638*

3.3 Epoxy Compounds available in market

3.3.1 *Bonding Primer*

Sikadur® 32 LP. It is an epoxy based bonding agent for new & old concrete and it comply with ASTM C-881 Type-II, Grade-2, Class B+C.

3.3.2 *Injection Grout*

Sikadur®-52 (IN) SLV is a 2-component, 100% solids, moisture-tolerant, super low viscosity, high-strength, multipurpose, epoxy resin adhesive. It conforms to the current ASTM C-881, Types I and IV, Grade-1, Class C specifications

3.3.3 *Epoxy Mortar*

Sikadur®-52 (IN) SLV – Mortar is 3-component thixotropic mortar based on a combination of epoxy resin and selected quartz aggregates. After mixing it becomes an easy to use multipurpose repair and adhesive mortar confirming to ASTM C881 Type-IV Class C.

3.3.4 *Moisture intensive Epoxy*

Sikadur®-53 (UF) is a two-component solvent free moisture intensive liquid based on epoxy resin.

4. PROJECT REFERENCES

4.1. Sala Hydro Electric Project, Reasi, Jammu &Kashmir.

Repair of Spillways using Sikadur®-52 (IN) SLV – Mortar, 2018 & 2019

4.2. Karcham Wangtoo hydroelectric plant. Kinnaru, Himachal Pradesh

Repair`s using Sikadur®-53 (UF), Since 2016

4.3. Tankapur Hydro Electric Project, Banbasa, Distt Champawat Uttarakhand 2020

Repair`s using Sikadur®-52 (IN) SLV – Mortar, 2020

4.4. Parbati Hydro Electric Project, Kulu, Himachal Pradesh, 2018

Injection using Sikadur®-52 (IN) SLV

4.5. Baira Suli Hydro Electric Project, Chamba, Himachal Pradesh,

Injection using Sikadur®-52 (IN) SLV, 2019

5. REFERENCES / ACKNOWLEDGEMENT

- Manual for Rehabilitation of Large Dams– CWC
- ASTM C 881 -99, Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete
- EN-1504, Repair of Concrete Structures.
- National Institute of Technical Teachers Training & Research, Chandigarh