REPAIR OF DAMAGES IN DISTRESSED MASONRY DAMS - A CASE STUDY

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Repair, Restoration & Strengthening

Repair- To provide protection and making up the deficiencies.

Restoration - To restore the distressed structures to normal serviceability levels.

Strengthening - To improve the load carrying capacity as a whole or part thereof to its original level that had been lost.
Basic Requirement of Repair

1. To arrest the deterioration by establishing a barrier of repair materials. (Oxygen, water, ions etc).

2. Structural integrity by using material having properties similar to those of substrate concrete.

3. Provide an esthetically acceptable finish.
Requirements of Repair Materials

• Wide variety of repair material with a range of physical and mechanical properties.

• Repair materials range from polymer based to inorganic cementitious materials.

• To achieve lasting repair, it is essential that property of substrate and Repair material should match properly to withstand the stresses resulting from volume changes and load without experiencing distress and deterioration.
Cementitious Repair Mortars

- Cement, sand or graded aggregate
- Thermal and chemical compatibility
- Low cost

Polymer-modified Cementitious Mortars

- Cement, sand or graded aggregates
- SBR, acrylic and modified acrylic latexes
- Thermal and chemical compatibility
- Flexible (Use of Polymer - Reduces water/permeability/curing period & improve workability/bond/abrasion/strength)
Resin-Based Repair Mortars

- Polyester resins
- Acrylic resins
- Epoxy resins
  - Resin
  - Diluents or modifiers
  - Hardener/admixtures
  - Fillers/aggregates

Advantages of Resin-based Repair Mortars

- Good adhesion to most building materials
- High mechanical strength – tensile and flexure
- Excellent abrasion, chemical, impact, fatigue resistance
- Very low shrinkage during and after cure
Bond Coat Materials

- Cement slurry
- Polymer emulsions - Polyvinyl acetate (PVAC), Styrene butadiene rubber (SBR), Acrylic emulsions
- Polymer emulsion slurries
- Epoxies - High cost, Precise mixing, Clean up operations

Requirements of Bond Coat

- Compatibility with concrete
- Adequate bond
- Workable life
- Tolerance to wet conditions, Tolerance to misuse, Ease of use
MASONRY DAM

Masonry dams are dams made out of masonry – mainly stone joined with mortar.

Rehabilitation of Masonry Dams

Remove the weak zones and replace them or repair them with stronger materials so that transfer of stresses is by monolithic action.
Remedial Measures In Masonry Dams

**Grouting** - filling of the cavities/ fissures with cement/ epoxy/ polymer grouts material to impart impermeability

- **Steel/concrete Jacketing**- emergent remedial measures for arresting entry of water
  - (Concrete membrane should not get separated due to different properties of the masonry and cover concrete and also due to their behavior under stress)

- **Cable Anchoring**- to reduces overturning moment and imparts greater frictional resistance against sliding.
Remedial Measures For Seepage In Masonry Dams

- **Geo-membrane**- jacketed with geo-membrane

- **Guniting**- flowable concrete is pressed on u/s surface. Guniting appears to have an edge over pointing, as work is quicker and management of quality control is better. But guniting shall not be considered as a preventive measure and can be considered as a remedial measure since it acts as an additional line of defense.

- **Raking and Pointing** - In pointing process, voids in between the stones are first filled with stone chips by placing cement mortar as binding material; the joints are filled with mortar extending on both sides of joint. Damaged/deteriorated pointing should be repaired with modified repair mortars like epoxy mortar, polymer modified mortar etc.
Approach to Rehabilitation Problem

1. Identification of cause of damage/distress

2. Estimation of short and long term effect of the distress on the structural safety.

3. Planning of rehabilitation program to ensure the continued project benefits.

4. Pre application studies in laboratory for selection of suitable material.

5. Carrying out the actual rehabilitation work.
REHABILITATION OF MASONRY DAMS
ANJUNEM DAM, GOA

- **Salient features**: 
  - **Location**: Kerim, Sattari, Goa
  - **River**: Costi river
  - **Length**: 176 m
  - **Height**: 42.80 m
  - **Capacity**: 4483 Ha. m.
  - **Dam type**: Gravity Masonry
STUDIES ENTRUSTED

1. Identification of suitable repair material for sealing seepage points
2. Devising repair methodology.
3. Providing guidance during repair work.
4. Quality control of repair work by extracting cores.

Problem:
Delamination of gunitting, debonding of pointing material and formation of cavities inside masonry thus giving way for water inside dam body
DAMAGES

DELABIATION OF GUNI TETING
CRACKS IN GUNITING
DEEP CAVITIES IN MASONRY
FOUNDATION GALLERY FLOODED WITH SEEPAGE WATER
LOSS OF POINTING MATERIAL
LABORATORY TESTS

TENSILE STRENGTH

- Test performed as per IS 9162-1979 on standard size briquette specimens
- Tested in an Universal testing machine

ABRASION RESISTANCE

- Test conducted using Dory’s abrasion testing machine
- 5 cm x 5 cm x 5 cm samples subjected to abrasion (about 800-1000 revolutions). Standard sand used as abrasive charge.
- Loss in weight compared with weight of similar size concrete specimen under identical test conditions.
LABORATORY TESTS

SLANT CONE TEST

- Test prescribed in ASTM C 882
- Two equal sections of a 75 by 150 mm cylinder made of concrete and repair mortar bonded using primer at an angle of 30 deg.
- Average bonding area is 9116 sq mm. The specimens are cured and tested under compression.
LABORATORY TESTS

BOND STRENGTH WITH ROCK

- Mortar compacted in between two rock specimens by applying primer on bonding surfaces.

Specimens thus prepared were cured and then capped in steel caps.

The assembly was tested in an universal testing machine to determine bond strength.
<table>
<thead>
<tr>
<th></th>
<th>System No. 1</th>
<th>System No. 2</th>
<th>System No. 3</th>
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</thead>
<tbody>
<tr>
<td><strong>Density of mortar (gm/cc)</strong></td>
<td>2.28 - 2.32</td>
<td>2.24 - 2.32</td>
<td>2.26 - 2.31</td>
</tr>
<tr>
<td><strong>Compressive strength of mortar (Kg/cm²)</strong></td>
<td>800 - 900</td>
<td>100 - 150</td>
<td>300 - 348</td>
</tr>
<tr>
<td><strong>Tensile strength of mortar (Briquette test) (Kg/cm²)</strong></td>
<td>150 - 180</td>
<td>9 - 16</td>
<td>34 - 40</td>
</tr>
<tr>
<td><strong>Abrasion resist. expressed as loss in weight in gm/sq.cm.</strong></td>
<td>Mortar system: 0.20 - 0.22</td>
<td>More than concrete</td>
<td>Concrete: 0.44 to 0.54</td>
</tr>
<tr>
<td><strong>Pot life of primer (minutes)</strong></td>
<td>40</td>
<td>30 - 60</td>
<td>30 - 60</td>
</tr>
<tr>
<td><strong>Bond strength with in direct tension (Kg/cm²)</strong></td>
<td>90 - 100</td>
<td>6 - 10</td>
<td>*9 - 15</td>
</tr>
<tr>
<td><strong>Bond strength with Concrete – slant shear test (Kg/cm²)</strong></td>
<td>160</td>
<td>20</td>
<td>23</td>
</tr>
<tr>
<td><strong>Double shear strength with Concrete (Kg/cm²)</strong></td>
<td>51</td>
<td>5</td>
<td>5</td>
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REPAIR METHODOLOGY

1. Surface Preparation:
(Removal of loose/damaged/deteriorated Gunited surface, cleaning of joints, Clean the surface by water jet & Chemical to remove algae fungi, loose particles etc.)

2. Primer application

3. Raking and pointing of joints (T Joint)

4. Seal coat .
REHABILITATION OF ANJUNEM DAM

Anjunem Irrigation Project
Kerim - Sattari
Goa
PERFORMANCE

- Total area of Upstream Face – 5400 m²
- Area repaired – 623 m²
- Reduction is seepage about 25%
HIRAKUD DAM

SALIENT FEATURES

Location - Burla, Orissa.
River - Mahanadi river.
Purpose - Irrigation, Hydro Power & Flood control.
Dam type - Composite (Concrete, Earthen & Masonry)

DAMAGES

Under water cracks - hairline to 12 mm on the upstream face having cumulative length of about 22.8 Km due to alkali aggregate reaction and thermal effect.

REMEDIAL MEASURES

The cracks - grouted with underwater epoxy systems having low viscosity of 150 cps and bond strength of more than 24 kg/sq. cm and 16 kg/sq.cm in direct tension and shear mode.

MERITS OF REPAIRS

The epoxy treatment restored the structural integrity of the dam as confirmed by post application studies.
CONCLUSIONS

• Proper diagnosis, selection of appropriate repair material, adopting proper methodology and ascertaining efficacy of the treatment are the key points for successful restoration or strengthening of the damaged hydraulic structures.

• The seepage flow in a concrete/masonry dam occurs through the material, through joints and the cracks developed due to any cause. Best possible way to arrest seepage is to treat the upstream face to prevent ingress of water, saving complete cross section of dam.

• The remedial measures like grouting and guniting appears to be palliative nature and if adopted as an urgent action, they have to be replaced by permanent measures.
Thank You