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Experimental Investigations on Properties of Special Repair Mortar for Stone Masonry Dam

U.S. Vidyarthi[1], Nisheeth Agnihotri[2], Ravi Agarwal[3]

[1]*Scientist 'E' Central Soil and Materials Research Station, New Delhi*
[2] *Scientist 'B' Central Soil and Materials Research Station, New Delhi*
[3]*Scientist 'C' Central Soil and Materials Research Station, New Delhi*

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Abstract - *Repair is termed as "to replace or correct deteriorated, damaged or faulty materials, components or elements of a structure" Mortar is considered a mix of cement, sand, and water; in few cases, additives such as chemical admixtures may also be used. The application of mortars is primarily in masonry, plaster, and repair works. Special Repair Mortars are engineered material, or one can say readymade mortar with constituents proportioned in a manner to obtain desired physical and chemical properties. Special repair mortars may be utilized in spalling of concrete, repair of concrete surfaces due to honeycomb cum segregation, concrete affected by the ingress of aggressive substances, and rehabilitation of stone masonry dams and other site-specific requirements. The paper envisages the experimental investigation on the physical properties of special repair mortar and detailed application procedure adopted in the rehabilitation process of one of the stone masonry dams.*

I. INTRODUCTION

Civil structures comprising concrete, brick masonry, and stone masonry, etc., are designed for the service life. The service life of a structure largely depends upon its upkeep and maintenance. Concrete structures are vulnerable mainly because of their low ductility, low strength to density ratio, the porous structure allows deleterious materials to pass, type of exposure conditions during the service life, susceptible to chemical attack (i.e., acids, AAR, etc.), corrosion of reinforcement (i.e., chloride ion ingress, carbonation).

In hydraulic structures such as stone masonry, dam wear or erosion in mortar is observed due to prolonged exposure in sunlight, alternate drying and wetting cycles, abrasion, and drying shrinkage. Consequently, it results in the removal of mortar between the stone blocks, and seepage from the dam body may observe. Thus, timely maintenance with suitable repair material is of the uttermost importance to save guard the dam structure.

The selection of repair material should be based on project requirements and to identify the properties of repair material with respect to the project requirement. Secondly, the selection of such material should be an optimum balance of performance, risk, and cost factors. Other than repair, mortar materials such as epoxy resins, polyurethanes, acrylates, polymer dispersions, and cement polymer compounds are commonly utilized for crack and surface repairs.

Worldwide infrastructure rehabilitation costs are staggering. The patch repair method is widely used to restore the original conditions of the concrete structures. Most patch repair mortars fall into two categories: mortars based on organic binders (epoxy resin or polyester) or those based on inorganic binders, like Portland cement (PC). The former is associated with toxic side effects (Pacheco-Torgal et al., 2012b), while the latter are known for their high embodied carbon (Pacheco-Torgal et al., 2013).[1]

II. EXPERIMENTAL PROGRAM

In terms of the technology, the repair mortars may be termed as crystalline-based and densification-based. The crystalline type (CT) of material is hydrophilic in nature, catalytic, having in-depth penetration, having no silicate, improves with age, and does not react with free lime. Contrary to crystalline-based materials, the densification technology-based materials are hydrophobic, reactive, deteriorate with age; initial surface penetration only reacts with the free lime and having no self-healing capabilities.[2]

Testing of mortar is undertaken for a variety of reasons which include the evaluation of conformity to a specification or standard, to control and monitor the consistency of a product or process, to examine performance against project-specific requirements, and as part of an investigation into a specific issue or to understand a defect.[3]

In the present study, the laboratory investigations for performance testing were carried out. The tests conducted are to evaluate the physical properties of Crystalline Technology-based special repair mortar, which is used in the rehabilitation of one aging stone masonry dam. The CT-based repair mortar should consist of properties such as UV resistant, non-shrink, abrasion-resistant, and high strength.

The rehabilitation scheme of the stone masonry dam consists of seepage control works through the dam body. In this scheme, for reaches having heavy seepage, pointing of upstream side of the dam has been carried out with special

CT based repair mortar balance portion of upstream and downstream where minor seepages or damages in pointing are observed, were carried out with normal cement mortar. For heavy reaches, drilling and grouting through the dam body have also been conducted.

Following laboratory investigations were conducted at CSMRS laboratory to evaluate the hardened properties of CT based special repair mortar:

A. Compressive Strength

Compressive strength is a test routinely used to measure the end performance of hardened mortar. It is applicable for production control, performance, and compliance testing. With regards to analytical investigation and the assessment of in situ mortar,

Fig.2 Compressive Strength Test

compressive strength cannot be determined due to the insufficient specimen size of the placed mortar. The mortar was prepared as per the mix proportions prescribed, and cube molds of size 70.6 mm were cast using the mortar. Curing and Compressive Strength testing of cubes were carried out as per IS 4031: Part 6.

B. Bond Strength (Slant Shear Test):

A Slant Shear test with primer at the interface was conducted to find the shear strength of CT-based mortar. It is determined by using the epoxy system to bond together two equal sections of a 3 by 6-in. [75 by

Fig.1 Slant Shear test samples

150-mm] Portland-cement mortar/concrete cylinder, each section of which has a diagonally cast bonding area at a 30° angle from vertical. After suitable curing of the bonding agent, the test is performed by determining the compressive strength of the composite cylinder. This test was carried out as per ASTM C 882.

***C. Split Tensile Strength*:**

This test was conducted in accordance with ASTM C496, and three test specimens were examined by diametric compressive load along their length. Due

Fig.3 Split Tensile Strength Test Assembly

to the loading, tensile stresses were induced on the plane containing the applied load. The area under load is in a state of triaxle compression, and by this way, much higher compressive stresses than uniaxial compressive tests have resulted.

D. Rapid Chloride Permeability Test:

The RCPT was conducted to evaluate the chloride ion ingress through the mortar. Cylindrical specimens were cast of size 100 mm dia and 50 mm thickness and cured for 28 days. After Conditioning

Fig.4 Rapid Chloride Permeability Test

These specimens were tested in a test setup that consists of a NaCl reservoir, NaOH reservoir, and microprocessor unit. The charge passed through each specimen has been measured in coulombs. This test was conducted in accordance with ASTM C 1202.

E. Under Water Abrasion:

This test method is intended to qualitatively simulate the behavior of swirling water containing suspended and transported solid objects that produce abrasion of concrete/mortar surface and cause

Fig.5 Under Water Abrasion Test

Potholes and related effects. It also provides a relative evaluation of the resistance of concrete/mortar to such action. Tests were conducted as per ASTM C 1138, and cylindrical specimens (Plain 300 mm φ x 100 mm) were cast and cured for 28 days. This procedure stimulates the abrasive action of waterborne particles (silt, sand, gravel, and other solids

III. APPLICATION PROCEDURE

The application procedure of CT based special repair mortar utilized for rehabilitation of damaged pointing between stone blocks of masonry dam involves the following steps:

i. Surface Preparation

- Remove existing loose, delaminated, or unsound material by high-pressure water blast or chipping, etc.
- Remove dust, micro fractured particles, and foreign material from the masonry grove by pressure washing or other suitable means necessary to clean the surface.
- A roughened surface texture is typically required to achieve an adequate bond.
- Maintain surface in saturated surface dry (SSD) condition for the application of CT base repair material.

ii. Mixing and Application

- Best results may be obtained by using a mechanical mortar mixer and paddle with a capacity for low-speed continuous blending. For small quantities of material, a paddle mixer can be substituted.
- Mix typically requires 3.45 to 3.55 liters of water per 25 kg of CT material. Add approximately 90 % of water to the mixer and mix briefly and further add 10% of water to achieve a mix of medium to stiff mortar consistency. Mixing of 3 to 5 min may result in a uniform consistency mortar.
- When the primer applied surface seems sticky, the groove shall be densely filled and up to the top by cementitious repair mortar.
- Repair mortar should be fully consolidated by a trowel, and bonding with primer and substrate should also be ensured.
- Complete the finishing operations as quickly as possible. Repair mortar can be finished to varying surface textures, including a rough finish to semi-smooth using a rubber float or steel trowel.
- Curing is also proposed with a continuous source of moisture by suitable means for at least 28 days.

IV. RESULTS AND DISCUSSION

Based on the laboratory investigation, results obtained for CT-based mortar are presented in Table 1. The results are indicative of high compressive strength, and lower abrasion depth. Moreover, the chloride ion permeability results are also indicative that the mortar is capable enough to control the ingress of chloride ions and other harmful substances. The bond strength test of repair mortar is of paramount importance due to the fact that by using priming agent resulting in good bond strength may result in lesser chances of peeling of pointing material. In the present study, a two-component priming agent was used to apply a priming coat. Due to the exposure condition, the mortar should be sufficient enough to bear the tensile stresses developed resultantly. Therefore, the split tensile test or direct tensile test of the material may carry out. The test

Table 1: Results of Laboratory investigations conducted at CSMRS

Laboratory Investigations	Results
Compressive Strength 28 days (N/mm^2)	69.35
Bond Strength as per Slant Shear Test ASTM C882 (N/mm^2)	11.70
Split Tensile Strength (N/mm^2) as per ASTM C496	5.77
RCPT (Coulombs) as per ASTM C1202	381
Abrasion Depth (mm) as per ASTM C1138	1.29

results in case of performance testing of the material may be checked in line with the manufacturer test certificate.

V. CONCLUSION

Referring to the laboratory investigations, it can be concluded that the special repair mortar considered in the present study exhibits, higher compressive strength and tensile strength, very low or negligible chloride ion permeation, and adequate resistance to abrasion in underwater service conditions. However, all the test results are relative and may also be checked in conformity with the batchwise laboratory reports generated by the manufacturer. The usage of special repair mortar is generally considered very obvious, but prior to selecting any repair mortar, its applications and performances with respect to project requirements should be evaluated. In general, at the site, due to limitations in testing, facility test for hardened applied mortar may be a hard-hitting task. The factors involved may be lesser crack depth, unavailability of adequate material, etc., but the laboratory investigations for hardened properties and fresh properties may be conducted well before its usage at the project site. The localized repair with sample may also be opted to observe the performance with respect to the requirement.

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