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Health Assessment and Rehabilitation of an Existing Stone Masonry Dam - A Case Study

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Abstract: ***Repair and Rehabilitation is an important activity linked to the durability requirement of civil structures. The hydraulic structures face severe service environment such as sulphate attack, chloride attack, freezing thawing cycles, temperature gradients, static and dynamic forces and Alkali Aggregate Reactivity. The rehabilitation schemes have been developed and are implemented in concrete hydraulic structures based on Field Quality Assurance Plan (FQAP) covering the detailed rehabilitation measures. However, India is having more than five thousand number of old dams including stone masonry dams and most of the aging stone masonry dams are necessitating repair and rehabilitation. This paper illustrates the challenges faced during the comprehensive repair and rehabilitation of more than 100 years old stone masonry dam under Dam Rehabilitation and Implementation Scheme (DRIP-I). The present study systematically describes about the rehabilitation scheme and the measures specially the execution of crystalline repair mortar, dam body grouting and water permeability test (WPT) implemented to reinstate the structure.***

Keywords: Rehabilitation, Stone Masonry, CT based repair mortar, grouting, WPT.

I. INTRODUCTION

Majority of the old dams constructed in Indian subcontinent are earthen dams or stone masonry dams. In addition, most of the existing stone masonry dams in India, were constructed around ten decades back and the water retaining structures like stone masonry dams, weirs, barrages were constructed using lime, surkhi mortar blended with ashes. The fact that apart from static and dynamic forces, these structures are also exposed to wetting and drying cycles, UV radiations, chloride and sulphate attack which make them more vulnerable. The construction and maintenance of stone masonry dams are challenging considering the fact that each joint should be properly filled and packed with waterproof mortar [1].

The present study inculcates the rehabilitation work carried out for Chandpatha Dam, Shivpuri district (M.P.). The Chandpatha dam was constructed on river Barai in between 1915-1918. The project is situated near Shivpuri town in Madhav National Park about 100 km from Gwalior. Madhav Lake is about 3 km at downstream side of this dam from where drinking water is supplied to Shivpuri. Chandpatha Dam is 2164m long stone masonry dam with catchment area 72.52 km^2 and submergence 213ha. It has two under sluices to provide water into Madhav Lake from where drinking and irrigation water is supplied to Shivpuri district. The total length and maximum height of stone masonry dam is 2164m and is 13.87m respectively.

Fig.1 Chandpatha Dam

The rehabilitation was done under Dam Rehabilitation and Implementation Project (DRIP-I) funded by the World Bank, as the dam was facing several issues which could result into safety hazards. The major distress in dam was observed in terms of seepage/ leakage from downstream of dam body, which was critical in few reaches. In addition, to blocked/non-functional sluice gates, revised maximum flood and provision of automated gates at left bank and provision of handrails at dam top are also considered as part of comprehensive rehabilitation scheme.

The paper provides a way forward in rehabilitation of aging stone masonry dams and focuses primarily on the measures adopted to arrest the seepage from dam body, through procedures adopted such as application and investigations of special repair mortar, dam body grouting, efficacy of dam body grouting thought water penetration test.

II. METHODOLOGY

The seepage from dam body was observed in many reaches, mainly due to the erosion of mortar from the joints, however at few reaches the seepage was intense and critical. The present condition of stones in masonry work may be summarized as good, in general the basalt rock was utilized for stone masonry work. The following methodology has been adopted to arrest the seepage from dam:

1) Visual inspection of dam upstream (u/s), dam downstream (d/s) and dam top.
2) Identify and document the reaches of heavy, moderate and low seepage and elevation approximation.
3) Pointing with normal repair mortar for reaches having mortar erosion or low seepage.
4) Application of crystalline repair mortar with two component epoxy bonding agent for pointing at moderate to high seepage areas.
5) Grouting with cementitious grout from dam top and horizontal grouting with low viscous PU based grout from dam u/s and dam d/s in critical reaches.

(a) Construction of Gabion wall 2a

(b) Surface preparation at dam u/s 2b

(c) Horizontal grouting from dam d/s 2c

(d) Pointing with crytalline mortar at dam u/s 2d

Fig.2 Rehabilitation activities performed at Chandpatha Dam

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III. REHABILITATION PROGRAM

A. Materials

1) Crystalline high strength special repair mortar

It is a high-strength concrete replacement mortar that uses crystalline waterproofing technology and impermeable to pressurized water and is used to repair damaged concrete, cracks, joints, tie holes, and honeycombed areas. The repair mortar (MasterEmaco S 580) was utilized for flush pointing at moderate to high seepage areas of dam. Except few reaches, the repair work was carried out at low water levels of reservoir.

(a) Dry crytalline mortar

(b)paddle mixer

(c)preparation of mortar cube at site

(d) pointing with CT based high strenath mortar

Fig.3 Application process of high strength mortar)

2) Two Component Bonding Agent

The bonding agent was used to ensure the proper bond strength of rock and mortar interface. To ensure the durability of pointing works a solvent free two component based epoxy bonding agent namely MasterBrace 1414 Part A and MasterBrace 1414 Part B of BASF was utilized. The grey colour mixed viscous liquid can be applied to both damp as well as dry surfaces. Prior to the application of bonding agent surface preparations i.e. removal of dust, debris, eroded mortar, oil grease etc. was carried out followed by light hydro jetting and the narrow joints were cleaned using steel wire brushes. In general, the mortar coating applied within 30 minutes and ensure that the epoxy coat is still tacky.

3) Polymeric Grouting Material

A low viscous, expanding, high resilient adhesive solid in density and strength was used for critical reaches and high seepage zones. The polymerization took place when grout comes into the contact with water and in the process expands and fill all the cavities, voids etc. in the nearby area. For the present rehabilitation scheme a polyurethane(PU) based CICO Polygrout is utilized, it creates a flexible water barrier and the liquid retains its initial low viscosity upon contacting water allowing it to flow without dilution. The specific gravity of grout material in present case varies in range 1.05-1.08. Due to the low viscosity and expansion during reaction even the smallest cracks, fissures and pores can be impregnated.

IV. PROCEDURES AND INVESTIGATION

The procedure adopted for different rehabilitation activities can be sub-divided into pointing of u/s and d/s face, horizontal grouting of critical reaches and grouting from dam top. Pointing with high strength crystalline mortar was carried out from the u/s face of dam.

The pointing work incorporates surface preparation, application of anti-fungal agent, two component epoxy bonding agent and top layer of crystalline repair mortar.

Surface Preparation activity at site was performed with necessary care so that the stone masonry joints having good appearance remain unaffected during the process, the masonry joints of reaches having seepage, were cleaned using surface grinder and all loose eroded mortar, fungus, algae, oil etc. were removed followed by flush jetting at low pressures.

Fig.3 Different stages of surface preparation

On completion of cleaning process, the anti-fungal chemical agent consist of poly halogenated phenol which prevents the bacterial growth in concrete and mortar was brush applied to the cleaned surface. Once the surface turned into saturated surface dry condition the two component bonding agent was applied on prepared joint grooves, and within 30-45 min. after application of epoxy bonding agent the crystalline mortar mix has been filled inside the grooves with proper compaction to ensure no air voids remain trap inside the groove. The joints were neatly finished and all the excess mortar has been removed. Proper curing of all repaired surfaces was executed for at least 14 days after execution of the work.

V. INVESTIGATIONS

The investigations were performed to determine the physical, mechanical and durability parameters of mortar mixes, aggregates, cement and efficacy of grouting work performed at site. The investigations performed to determine the properties of crystalline repair mortar are Slant Shear Test, Rapid Chloride Permeability, under water abrasion resistance, compressive strength and tensile strength. Investigation procedure followed are described in brief as many of the test protocols are not specially designed for repair mortars.

A. Slant Shear Test

The test specimens were prepared in accordance with ASTM C 882M-05. The cylindrical test specimen (150mmx75mm) consists of one hardened half cylindrical portion of concrete and another half potion was prepared by pouring the fresh mortar upon the top of hardened specimen. The bottom portion was cut at an angle of 30 degrees, resultantly formed an elliptical shaped joint having bonded surface area approximately 9116 mm^2. The schematic diagram and representative specimen are demonstrated as Fig.4. The values of X, Y and Z are 140mm, 75mm and 10mm with slant slope height 150mm [2].

(a) Schematic diagram of bottom half (b) Half cut specimens (c) bond strength testing in CTM

Fig.4 Slant Shear Test Setup

The bottom half cut piece was placed inside the mold having almost similar dimensions. The two component epoxy bonding agent 2mm in thickness applied upon elliptical surface of hardened bottom cylindrical portion and subsequently fresh mortar mix was poured in three equal layers ensuring proper compaction of each layer and the extra mortar from the top surface strike off. After demolding, the specimen was cured for 28 days as per the test protocol. Immediately after removal from the curing arrangements the capping of specimen was performed and the specimen was tested for bond strength under controlled loading in compressive strength testing machine. The bond strength of epoxy bonding system was determined by dividing the load carried by the specimen at failure by the area of the bonded surface.

1) Under Water Abrasion Resistance

The underwater abrasion resistance test was conducted on mortar specimen to determine the abrasion resistance of repair mortar as the dam upstream surface experience abrasion an effect of swirling action of water with boulders, gravels, silt, hard substances like glass bottles and wooden logs.

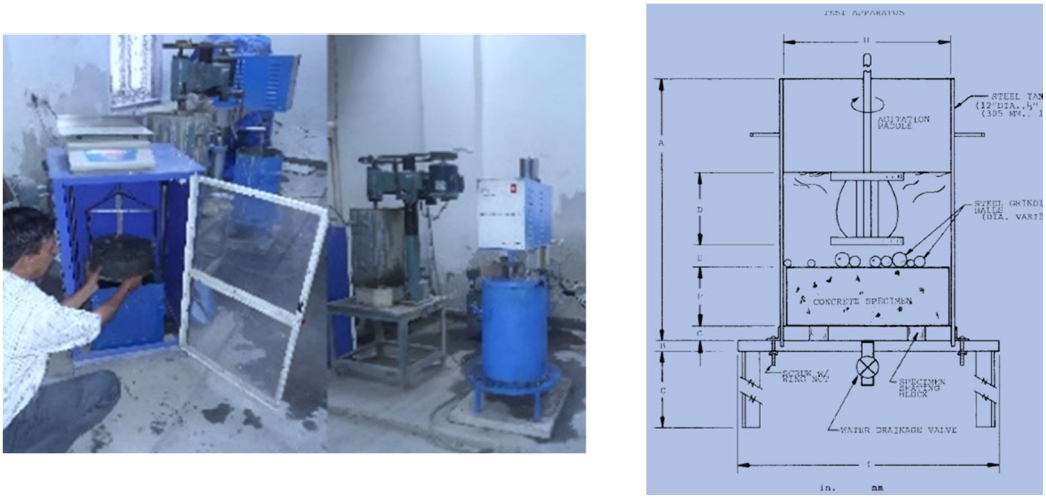


Fig.5 Under Water Abrasion Resistance test setup (ASTM C 1138)

The test was performed on cylindrical specimen having diameter 300mm and height 100mm. The seventy numbers abrasive charges i.e. 1000 grade chrome steel balls diameter ranging between 12mm-25mm were kept on the specimen.

(a) Casting of Test Specimen (b) During Test (c) Abrasion at the top of the specimen

Fig.6 Different stages of under water abrasion investigation

The test specimen was removed from the test container at the end of every 24 hours of operation. Flush off the abraded material was flushed off and the mass of the specimen in air and in water was determined. The abrasion depth has been determined based on the readings recorded at the end of 72 hours. As recommended a test conducted for 24 hours produces sufficient abrasion in most of the concrete surfaces [3].

2) Rapid Chloride Permeability

To examine the resistance against the chloride ion ingress the rapid chloride permeability test (RCPT) was performed in accordance with ASTM C 1202. The mortar cylinders of size 100mm dia and 50mm thickness were extracted by rig based core drilling machine from mortar cubes size 150mm.

The cube specimens were cured for 28days in standard curing conditions. The cylindrical specimen embedded between NaCL and NaOH reservoir were exposed to 60VA current for 6 hours. Based on the charge passed in coulomb the chloride ion permeability of the mortar test specimen was examined for varying water content [4].

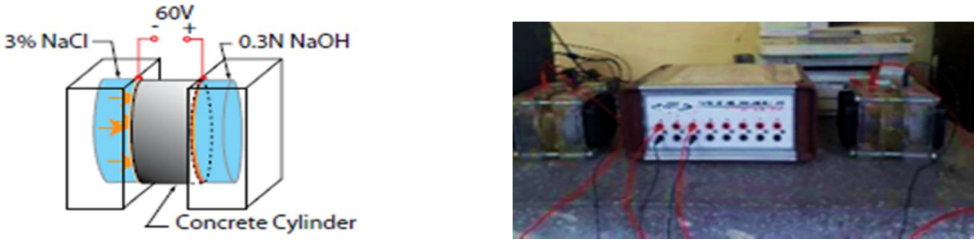


Fig.7 Specimen Assembly in RCPT with NaCL and NaOH reservior

3) Split Tensile Strength

The split tensile strength was investigated on moulded cylindrical specimen of crystalline mortar of size75mmx 150mm and three numbers of specimen were tested in accordance with ATSM C 496.

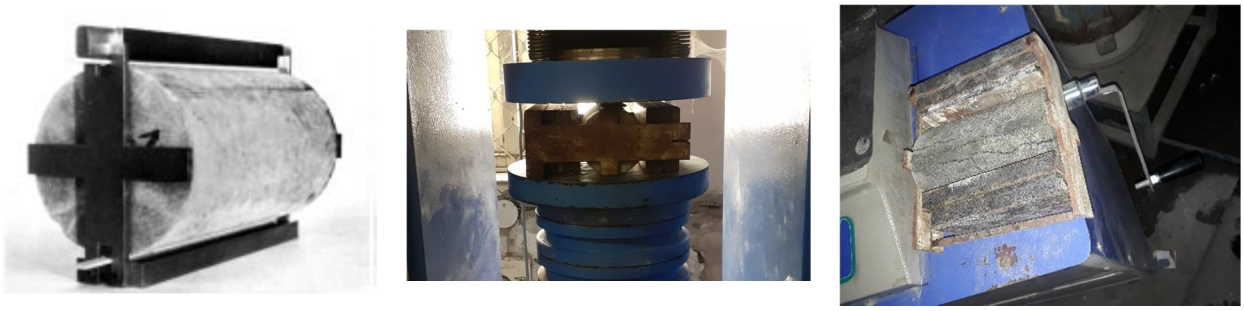


Fig.8 Test setup and tested specimen - split tensile strength

The test assembly consists of steel frame to place the specimen along the length and diametric compressive load applied along the length. The loading induces rather strong compressive stresses in the region immediately surrounding the applied load as well as tensile stresses on the plane containing the applied load. Because the areas of load application are in a triaxial compression state and can resist far higher compressive stresses than would be suggested by the results of a uniaxial compressive strength test, thus tensile failure rather than compressive failure occurs [5].

B. In-Situ Water Permeability Test (WPT)

The water permeability test was carried out to check the efficacy of grouting in dam body vertical grouting. In critical reaches the primary holes were drilled from dam top at an interval of 6 meter and in between one secondary hole was drilled to perform the WPT. The hole diameter was 46 mm and depth varies from 3 meter to 12 meter, The water permeability test was performed at pre-grouting and post grouting stage as per IS 5529 Part-2. The double packer method was used to perform the WPT. The procedure utilized to conduct the water percolation experiments utilizing a double packer in a portion of the drill hole is depicted in Fig. 9. The purpose of dam body grouting was to arrest the seepage traces in critical reaches as well as to arrest the seepages observed from foundation level.

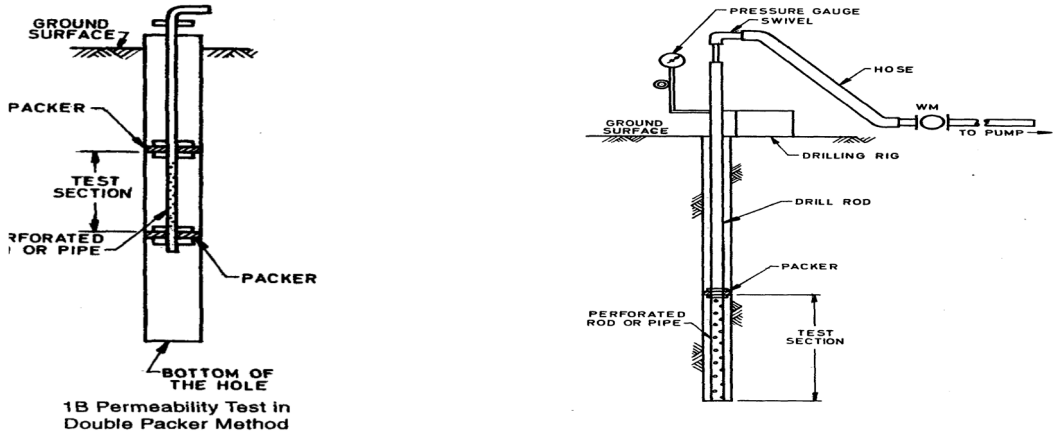


Fig.9 Sketch showing Double Packer method and equipment layout

Using this technique, the hole were drilled to the appropriate end depth and then cleansed with water until clear water appears. The drill hole were secured using two packers attached to the ends of a perforated drill rod that is the same length as the test section. Before doing the double packer tests, the bottom of the perforated rod should be plugged. Either the top down or the bottom up approach can be used to perform the test. However, it is more practical and cost-effective to begin the tests at the bottom of the hole and come upward [6,7].

VI. RESULTS AND DISCUSSION

The work under this rehabilitation scheme includes QA/QC at site, laboratory and in-situ investigations as per the testing frequency of Field Quality Assurance Plan (FQAP). The study comprehends the laboratory investigations of special repair mortar, two component epoxy bonding agent, Portland cement, coarse and fine aggregate and in-situ water permeability test. The laboratory investigations for special repair mortar provide a way forward for physical and mechanical properties such as bulk density, specific gravity, compressive strength and spilt tensile strength. In addition, the durability properties i.e. water permeability, under water abrasion resistance, resistance towards chloride ingress may define the long term behaviour under adverse service and atmospheric conditions. The laboratory investigations carried out for epoxy bonding agent are split tensile strength, bond strength, compressive strength and tensile strength at a large.

The test results for crystalline repair mortar and epoxy bonding agent are presented in table 1 and table 2 respectively. The test results were analysed in line with the manufacturer test certificates (MTC) of corresponding batches and it is observed that the observations are complying the MTC requirements.

Table-1: Physical properties of special repair mortar

Description	Bulk Density kg/m^3	Compressive Strength, MPa [28d]	Tensile Strength, MPa [28d]	RCPT Value as per ASTM C 1202, Coulomb	Under Water Abrasion depth(mm)
MasterEmaco S580	2245	69.35	4.27	377.00	2.50

Table-2: Properties of mixed epoxy bonding agent

Description	Slant Shear Strength MPa	Compressive Strength as per IS 4031 MPa [28d]	Tensile Strength as per IS 516, MPa [28d]	Setting Time(min)	Bond Strength (MPa)
MasterBrace 1414	13	71	27	161	3.1

The water permeability test (WPT) was performed for critical reaches where dam body grouting was executed. The pre-grout and post grout WPT results in Lugeon were determined and analysed for individual test holes. The pre-grout Lugeon value ranged between 3.26 and 7.1. However, post grout for all test holes results were observed under 3.0 as recommended in IS 6066. The pre and post grout water permeability test results in accordance with test holes for vertical dam body grouting are presented in Fig.10.

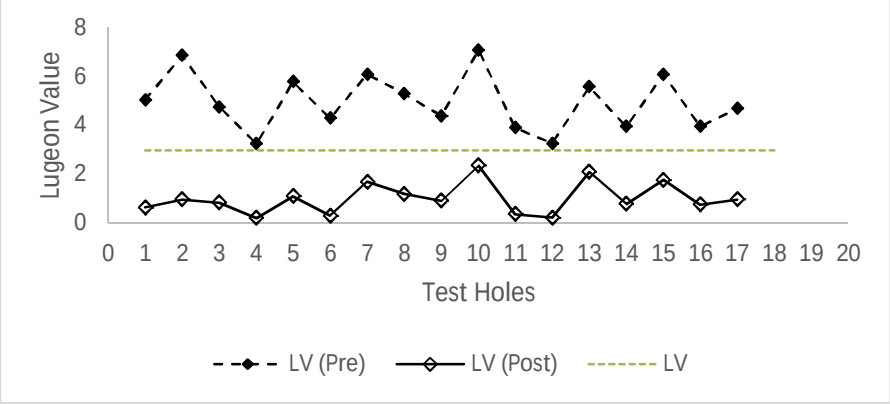


Fig.10 WPT results comparison of pre-grout and post-grout stages in dam body grouting

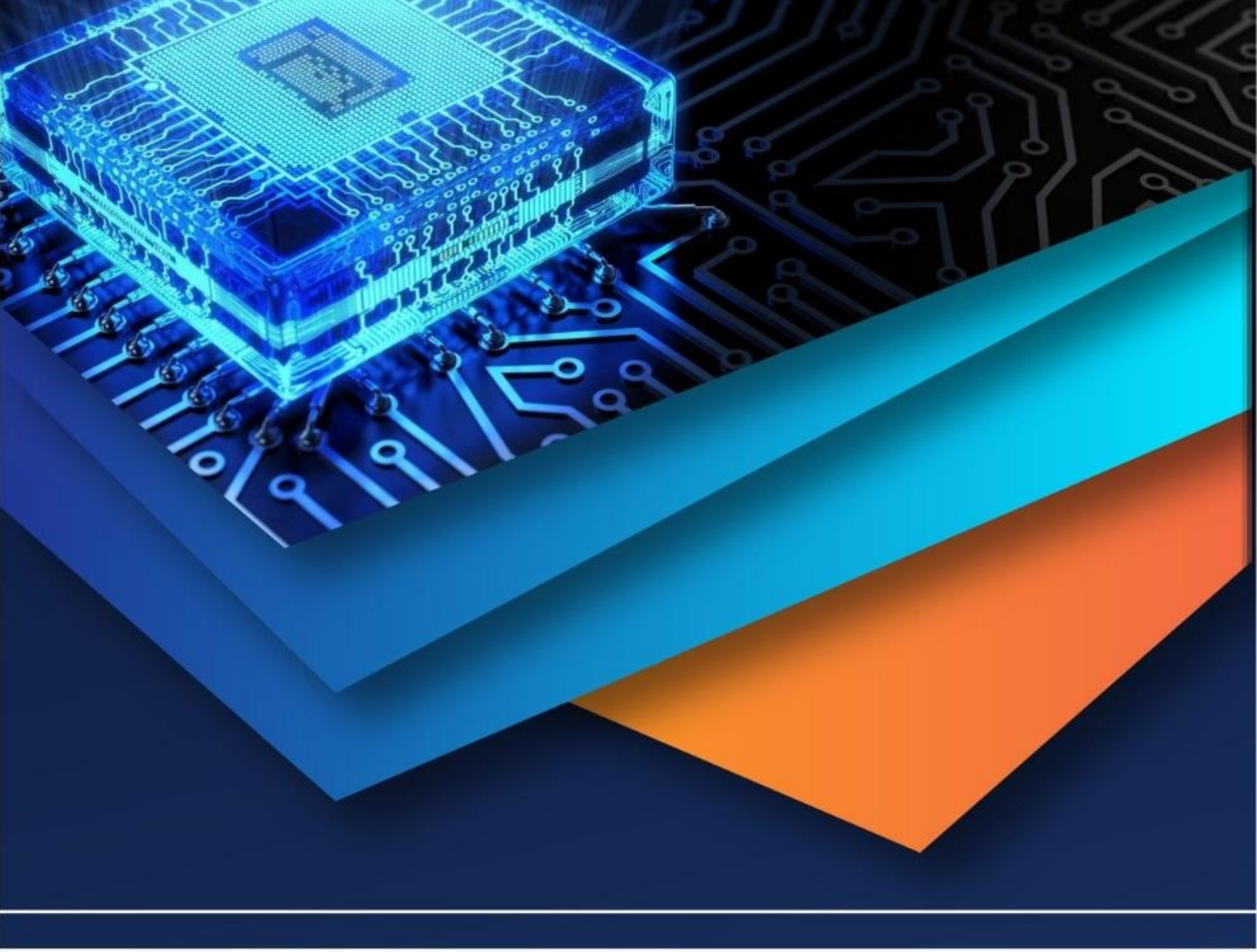
VII. CONCLUSION

The present study demonstrates the rehabilitation process adopted for aging stone masonry dam. The methodology and material properties are also discussed based on in-situ and laboratory investigations. The major challenges in case of stone masonry dams are to endure the earlier construction i.e. old masonry joints while performing the rehabilitation activities. The activities such as pressure grouting were performed on suitable pressure which plugs the existing voids and cavities and in addition does not cause any damage to the joints having adequate performance. It is pertinent that with the present rehabilitation scheme the water seepage from dam body in all reaches has brought down to safer limits as per the technical specifications. Moreover, the cutting of grooves for repair are performed with utmost precautions to avoid the damages in nearby zones. The critical reaches having higher rate of seepages were repaired by horizontal pressure grouting using Poly Urethane (PU) based grouting material which expands when comes in contact with water.

This rehabilitation scheme also provides a way forward to the future rehabilitation works for stone masonry dams. It is also important to consider the fact that not much non-destructive technique is found seemly to gauge the defects in masonry dams as most of the methods are either having depth or thickness constraints or suitable for materials like concrete. In addition, considering the restraint such as non-availability of design drawings and QC documentation, the visual inspection methods like physical inspection can be proven, moreover instruments like borescope and video scope can also be utilized for in depth monitoring of narrow cavities, joints and cracks.

REFERENCES

[1] Malcolm J. Brandt, K. Michael Johnson, Andrew J. Elphinston, Don D. Ratnayaka., Dams and Reservoirs, Chapter 5, (2017) Elseveir.
[2] ASTM C 882M-05, “Standard Test Method for Bond Strength of Epoxy-Resin Systems Used with Concrete By Slant Shear”, American Society for Testing and Materials Standard(ASTM), Pennsylvania (PA), USA.
[3] ASTM C 1138, “Standard Test Method for Abrasion Resistance of Concrete (Underwater Method)”, American Society for Testing and Materials Standard(ASTM), Pennsylvania (PA), USA.
[4] ASTM C 1202-10, “Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration”, American Society for Testing and Materials Standard(ASTM), Pennsylvania (PA), USA.
[5] ASTM C 496, “Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens”, American Society for Testing and Materials Standard(ASTM), Pennsylvania (PA), USA.
[6] IS 5529 Part-2 (2006), “In-situ Permeability test in besd rock”, Indian Standard (IS), Bureau of Indian Standards (BIS), New- Delhi, India.
[7] IS 6066 (1994), “Pressure Grouting Of Rock Foundations In.River Valley Projects – Recommendations”, Indian Standard (IS), Bureau of Indian Standards (BIS), New- Delhi, India.
[8] IS 1489 Part-1 (1991) “Specification for Portland Pozzolana cement (fly ash based)”, Indian Standard (IS), Bureau of Indian Standards (BIS), New- Delhi, India.
[9] Abdallah I. Husein Malkawi, Mohanned Al-Sheriadeh, “Evaluation and rehabilitation of dam seepage problems, A case study: Kafrein dam”, Elseveir Engineering Geology 56 (2000) 335–345.
[10] “Field Report on Quality Control & Assurance checks including testing of materials at CSMRS laboratory for undertaking Rehabilitation work of Chandpatha dam, M.P. under DRIP”. (No. 54/CSM/CD/2058/10/1306)



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