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STRUCTURAL CONSERVATION OF HISTORICAL PALACE USING REFOR_TEC AND SOCKFIX TECHNIQUE

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Abstract - A Heritage Structure in any country is one of the silent testimonials of its sublime past. A large number of historical structures in India are facing extinction and along with them, diminishes remainders of pro existing cultures. The necessity of proactive and reactive maintenance of historic buildings to preserve their integrity cannot be overstressed.

This paper focused on few strengthening techniques and proposals that are taken into consideration for preserving the cultural, historical and architectural values of the palace. Excessive load onto the lower floor of the palace due to repetitive rise in floors with time by the forthcoming rulers lead to situations of overloads. Such overloads started resulting into generation of minor and major cracks into the surrounding walls. As a remedial solution of this problem, the ruling king started constructing extra limestone walls so that the excess load coming right from the top levels may get easily distributed through these newly constructed walls and then get transferred to the foundation below. However, this construction of limestone walls further raised a problematic situation in present days. Due to construction of these walls, the circulation areas of all the interconnected rooms as well as around the passage got minimized. To overcome this issue, certain modern techniques have been established so as to remove these walls and provide required openings resulting into a provision of more circulation area than earlier.

***Key Words*: Structural Conservation, Heritage structure, REFOR-tec, Sock Fix, Structural Strengthening.**

1. INTRODUCTION

India is a country with a rich historical background sounding to be an evident starting from various buildings, temples, forts and other creatures considering heritage structures for a well-known historical era [1]. Many of these were constructed long time ago when the Indian Civilization was at its top. Their planning, architecture, design and construction during the period when computers, code of practice, design guidelines, research centres and latest construction techniques were absent gives the wisdom and expertise of our ancestors. These constructions have somehow managed to survive for several years whereas most of the modern constructions requires repair after a certain period of time of service [1]. Such works are often performed to reverse the decay or modifications made in the building after its initial construction. Repair and Rehabilitation is an Art which enables to extend the service life of a heritage structure [2].

Heritage constructions in a country are mute testaments of its divine past. Historic environments are also the venues that enable the social and cultural connectivity. The in depth detail of socio-economic life of the past civilizations are carried through generation by these historic environments [4]. The obligations to conserve and preserve the architectural heritage of our local communities are mandatory as our duty to conserve the significant built heritage and its values of previous era. However, architectural heritage these days is at risk everywhere in the form of lack of experience and care. Few have already been lost and more are in danger. It is a living heritage and it is necessary to understand, define, interpret and manage it for the upcoming generation [3].

A royal Palace after years loses its glimpse of glory with respect to the architectural as well as structural point of view under various ways. In such cases, timely conservation of this royal beauty (Tourist attraction) becomes mandatory. Preservation can be done in many alternative ways say its repair or rehabilitation in one way or the other. Also, there are chances of renovating and rejuvenating in major or minor ways [3].

2. Aim

The main aim of the current work is, to preserve a historical palace by using modern conserving approaches such as REFOR-tec and Sock-Fix techniques along with the removal of the existing stone walls to yield a better circulation area.

3. LITERATURE REVIEW:

N. Rajesh (June 2017) gave his review on 'Conservation Of Heritage Structure Of Danish Fort At Tranquebar Village', Tamilnadu, and brings out the brief history of the structure and the conservation efforts made in the past and recommend further research required to extend the life of the structure and further transfer knowledge of lessons learnt to conserve similar buildings [5]. **Maurizio Berti**

(November 2015), gave his review on 'Conservation of Coral Stone Architectural Heritage on the Coast of East Africa', and concluded that Knowledge and mastery of the physical and chemical phenomena in coral stone buildings are the basis of the preservation process. But the techniques of the past, when known to the restorer, can suggest the best way for the restoration and maintenance practices [6]. **Arun Menon** (October 2014) states that 'Heritage Conservation In India', and Conservation of heritage structures is an interdisciplinary effort, wherein traditional knowledge on building materials, techniques and specifications are brought to the realm of current practitioners of conservation engineering, with the intent of merging them with modern tools and practices. Capacity building in structural safety-centric conservation engineering is a major challenge for India, with an urgent need to identify the existing diffused expertise in relevant sub-areas within conservation and forming a consortium for a holistic approach to the national grand challenge of protecting heritage structures. [7]. **Enea Mustafaraj** (May 2014) concluded that 'Repair and Strengthening of Historical Structures: Naziresha's Mosque in Elbasan', from the assessment results, it was seen that the mosque exhibits structural deficiencies. Some of the most common problems are: deterioration of surface plaster, loss of masonry units, structural and non-structural cracks throughout the mosques, damaged roofing and drainage systems, sanding and suffusion phenomena etc.

Some of the suggested measures to be taken in order to preserve the mosque for the future are: filling the voids by injection, application of local reconstruction, application of CFRP and longitudinal FRP bars etc. [8]. **Soheir M. Hegazy** (March 2014), gave his review on 'Conservation of Historical Buildings', and says that a real experience of some critical criteria of the conservation process, some of which were mentioned such as: An integrated team of highly qualified professionals have to be involved in re-qualifying historic buildings. The major professions involved in the aforesaid process are: architects, archeologists, building economists, structural, mechanical, electrical engineers, art historians, material scientists, crafts persons for each material, building contractors, surveyors, town planners, conservators, environmental, historical garden engineers and curators. [9].

S.Saileysh Sivarajaa, et.al (2013), gave their review on 'Preservation Of Historical Monumental Structures Using Fibre Reinforced Polymer', and concluded that FRP as strengthening and retrofitting material has several advantages over conventional materials. Its thickness is small and hence its application does not add weight to existing structures. It helps to preserve the cultural heritage of monumental structures. It is not corrodible. [10]. **Brit AnakKayan**, et.al (2013), gave their review on 'Conservation Plan for Historic Buildings from Building Control Administration Perspective' and says that Promotion of conservation plan has attracted more attention to the maintenance of historic buildings. However, conservation plan for historic buildings has diverse array of the major issues, particularly from building control administration perspective. [11]. **O.A. Kamal**, et.al(November 2013), gave their review on 'Nonlinear Analysis Of Historic And Contemporary Vaulted Masonry Assemblages', and This paper incorporates both analytical and experimental investigations of the nonlinear behavior of unreinforced masonry assemblages, especially curved elements such as arches, vaults and domes. [12]. **Neha Jain** (December 2012), gave her review on 'Conservation Practices In India – A Case Study of Jaisalmer Fort', and This research aims to find out through case study analysis of projects at the Jaisalmer fort, the strengths and weaknesses of ASI and INTACH.

The research aims to find how efficient these agencies are in their efforts to save monuments.

Current conditions require ASI to draft another amendment, which is much more considerate about the present heritage of the country and considers enforcement more seriously. [13].**Yasser Korany** (2011), gave his review on 'Effective Techniques for Restoration of Heritage Masonry', and states that the selected technique must be consistent with aesthetics, function, and the requirements of strength, ductility, and stiffness and provides an overview of the traditional and recent techniques proven to be effective in restoring heritage masonry structures. [14].

4. OBJECTIVES:

- To study the aspects and prospects of Heritage Conservation.
- To overcome the issue of structural overloads generated due to periodic modification.
- To introduce modern techniques for the removal of later added walls.
- To provide better circulation area for the visitors of the palace.

5. MATERIALS AND METHODOLOGY

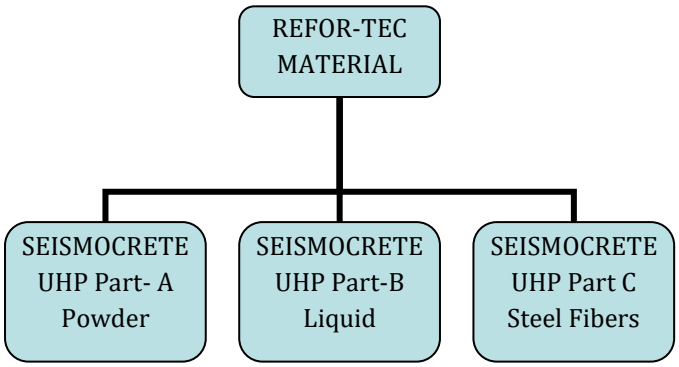
5.1 MATERIALS

The materials used for the conservation work is:

5.1.1 Refor-tec:

Refor-tec, a "High-Performance Fibre Reinforced Micro Concrete" is peculiarly developed cement based material, fibered in forced with FIB-energy, enriched with activated micro-silica with very high pozzolanic action, three-component of REFOR-Tec® ambit. It combines the auto-leveling rheology together with special physical-mechanical values and ductility properties.

The Refor-tec compiles three ingredients; SEISMOCRETE UHP parts: powder, liquid and fibres.



It is used in Different types of Engineering Shapes, Special Structures, and Construction & Strengthening - Very High Durability & Sustainability - LEED® Credits.

Also for strengthening and Exactitude Anchoring of Massive and Highly Stressed Machineries like: Wind Turbines, Precision Machineries, etc.

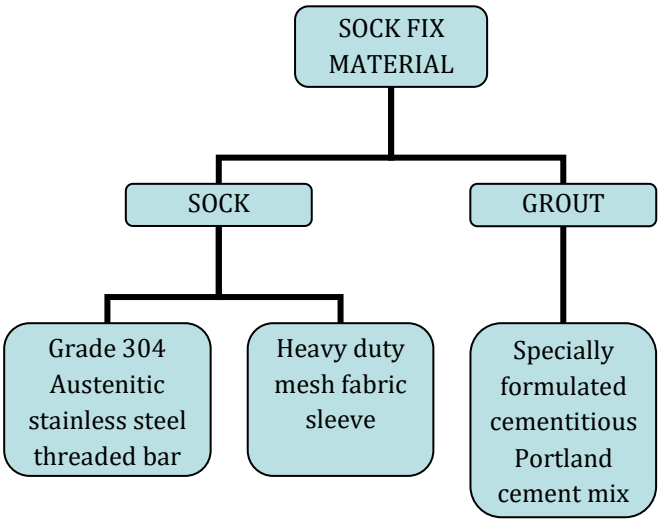
It provides resistance from fire to pillars and beams and also use in Manufacture of lightweight and thin section structural elements.

Table -1: Technical Characteristics of Refor-Tec

Temperature of application	+5°C - +35°C
Workability time	≥ 1 h
Density	2.450 Kg/m3
Shear strength	16 MPa
Compressive strength after 1 day	48 MPa
Compressive strength after 28 days	130 MPa
Tensile strength after 28 days	8.5 MPa
Flexural strength after 28 days	32 MPa
Specific heat	= 2700 K Joule / (m^3 x K)
Depth of carbonation	0

5.1.2 Sock fix:

It is a Mechanical grouted sock anchor system used for stabilising distressed masonry. This technique contains a grout-filled sock that compounds with a threaded bar in a complex action which spreads out to build a strong chemical/mechanical bond with the substrate.



The Sock Fix technique is used in industrial and heavy load applications such as stabilization of rubble-filled walls, for stitching cracked solid and multi-leaf walls, for securing external walls to hollow concrete floor slabs, for stitching cracked solid and multi-leaf walls and for securing unstable parapet walls and arches and also Used where high levels of performance are required in bending and Used where drilling lengths in excess of 1m are required.

It is a Fast, efficient, verified installation technique and useful in Restores structural unity and Stabilises masonry and also Gives permanent, non-disruptive, fully concealed repairs by Installing in the fabric of the structure.

Table -2: Technical Characteristics of sock fix

Compressive strength after 1 day	18 N/mm^2
Compressive strength after 3 days	40 N/mm^2
Compressive strength after 7 days	55 N/mm^2
Compressive strength after 28 days	65 N/mm^2
Ultimate tensile stress of Bar	750N/mm^2

5.2 METHODOLOGY ADOPTED

The Conservation work was done in a historical palace in stages starting from the wall removal work followed by the strengthening of its stone masonry using advance materials and Techniques, Refor-tec and Sock fix.

5.2.1 Wall Strengthening through Refor-tec:

The walls were made up of stone, lime and red mud. The wall was supporting a horizontal stone beam beneath the stone slab. To remove this stone wall, it was necessary to provide a fix support to the stone beam.
The Height of wall was around 3.420 m and the stone beam was resting on to it with the wall length along with the stone being around 2.260 m.

To provide a firm support to the stone beam, two types of steel sections (200mc and 100mc) were used which were then welded with steel plated box. After supporting the wall with the steel frame sections, all the supporting steel sections were filled with the Refor-tec material.

Refor-tec is a high performance reinforced micro concrete material with added fibres into it. It was mixed in one time by mixing component A Powder of 25kg bag, component B Liquid of 3.125 kg in 1 can and component C Fibre Fib-Energy ST/HS of 1.15 kg thoroughly into a container with the help of a mechanical mixing paddle.

The mixed material was then filled into the all supporting steel sections.

After hardening of Refor-tec material, the finishing work was done by welding and grinding the section surfaces to provide smooth finishing.

Fig -1: On Site Structural strengthening and circulation provision before and after.

5.2.2 Sock-Fix Technique:

There was a requirement of pathway for the visiting tourists which resulted into the provision of opening of gates by cutting the existing stone walls.

The over loads coming straight from the upper stone masonry imparted heavy load on to these walls. Thus, this wall removal process may result into Buckling of those walls. To overcome this problem of Buckling, a brand new technique was introduced for the first time in our country named as "Sock-fix".

Gate opening is done right after the application of sock-fix material into the wall. It was around 2133mm height and 1370mm width. Holes of 32mm dia. were drilled at various locations away from the gate opening throughout the wall. After that the sock-fix installation work was done. In ancient masonry works, the Sock Fix technique was used for stabilising purpose. This project commenced with marking of position on exterior face of the masonry wall for making holes followed by the Core drill at correct inclination and direction with a prescribed core diameter and depth. The Set-up was then pre-arranged so as to carry out pressure potting followed by the compressor installation. Later on, pressure pot was purged and the components were colligated with clean water. Each Sock Fix was moistened and the injection tube was left for priming with the help of clean water anterior to the installation. Sock Fix Grout was then mixed by a power mixer at least for 3 minutes or until a smooth fluid material is obtained followed by its pouring using a sieve into the pressure pot container.

Sock Fix was then inserted into the drilled hole and it was ascertain that the sock has uniformly distributed along its full length. It was to bring into notice to do not force or twist it as tears in the sock if found may lead to premature grout leakage. If the assemblance length gets beyond 1000 mm, then Sock Fix supposed to be wetted again once inserted.
Sock Fix valve was then connected with pressure pot and Sock Fix sleeve was amplified with Sock Fix Grout from pressure pot with a maximum pressure of 3 bar. It was to be noted that injection should be done under reduced pressure so as to avoid damage in masonry under low strength masonry.

As soon as Sock Fix sleeve gets amplified, it was gradually rotated into the hole so as to aid the flow of grout and also to ensure that the bar gets centralized on closure. The pressure was kept constant until the sock gets completely amplified in the drilled hole and all the grout gets expelled out. The shut off valve was then shut and separated from the pressure pot. In the end, grout tube end that was below the masonry surface was cut off when it got confirmed that the grout has cured sufficiently to restrict further residual pressure.
Later with time, the gate opening was done there right after the hardening of Refor tec material.

Fig -2: On Site gate opening and circulation provision before and after.

6. RESULT

6.1 STRUCTURAL STRENGTHENING USING REFOR-TEC MATERIAL

The application of Refor-tec as a "High-Performance Fibre Reinforced Micro Concrete" resulted into: high progressive hardening with zero cracking, storming durability with resistance to wear, frost/thaw actions and sulphate attacks and utter waterproofing.

Since the material was having sound bonding properties, it made strong bond with the added steel sections which in turn resulted into high load bearing capacity.

Its adequate thickness of application ensured more strength as well as manufacturing of light weight and thin elemental sections when compared to other traditional reinforced concrete practice.

The practice reduced walls size to provide better circulation area.

6.2 STRUCTURAL STRENGTHENING USING SOCK FIX

The application of Sock-fix technique as a mechanical grout sock anchor system was intended to stabilize distressed masonry by building a strong chemical/mechanical bond with the structure.

It secured the unstable Palace walls by increasing their strength through crack filling.

7. CONCLUSION

The conservational work discussed for a Palace involved some unique materials and techniques as, Refor-tec and Sock-fix technique. It was found that the application of these materials and techniques has successfully provided the required strength to the Palace. Retrofitting materials and methods used here were proved out to be more advantageous over regularly used conventional materials and methods. The application of these materials reduced the wall thickness of the Palace. This reduced thickness helped the structure to lessen the additional weight acquired by the existing thick walls of the Palace which in turn helped out to preserve its cultural heritage.

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