Challenges in Conservation of Heritage Structures

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Abstract- **Rajasthan is the most beautiful and vibrant state of India. The unique characteristic of its architecture is very popular in the whole world. The Rajasthan architecture is significantly depend on Rajput architecture school which was mixture of mughal and Hindu structural design. Grand havelis, astonishing forts and elaborately carved temples are the vital portion of architectural heritage of Rajasthan. Few of most striking and splendid forts along with palaces with parched Aravali land clearly depicts history of Rajasthan's celebrated heritage. Almost every city of the spectacular desert land Rajasthan is lined with fabulous forts and palaces built by various rulers and architects. These forts and palaces were generally built outside the walled city over the high hills to protect the city**

The state of Rajasthan hosts few of splendid palaces and forts of the whole world. Ornamented havelis, elaborately carved temples and also magnificent forts are section of the Rajasthan's architectural heritage. The artistic builders designed major architectural styles which are located in cities like Jaisalmer, Udaipur, Jaipur and Jodhpur. The most significant architectural designs in Rajasthan include Jantar Mantar, Dilwara Temples, Lake Palace Hotel, and City Palaces, Chittorgarh Fort, Deeg palace and Jaisalmer Havelis.

The glory is well conserved in the Rajasthan and in the majestic forts and palaces. Enduring the unmerciful desert winds and oppressing heat of the scorching sun, they have stood unshakable against many-a-sieges and have provided protection to the rulers in their time of conflict. Now, they have been opened to the tourists who come here to see a wonderful presentation of their rich heritage and splendid artistic architecture. Many of these forts and palaces retain their old allure and ritual. Some of the royal residences have been now turned into heritage hotels, where the visitors can still experience the magic of India's imperial past. Important Artifacts of Rajasthan Architecture are: Havelis, Chhatris, Jharokhas, and Stepwells.

Keywords- **Heritage Architecture, forts, havelis, Chhatris, Jharokhas.**

I. BASIC NEED OF HERITAGE CONSERVATION

Heritage links us to history, the beautiful past we inherited to preserve and transfer to our next generations Heritage generally gives us a sense of our past and of our cultural identity. Some researchers predicted very alarming data regarding the survival of old heritage buildings. Load bearing behavior of the Historic structures is very complex due to continuous intrusion between various elements. The main load is the dead load with wind and earthquake. The behavior of these structures change with decay of material and the cracks developed may even alter load path. Here a brief scenario of heritage buildings and their structural aspects are discussed including technical research activity, survey of structures, structural behavior, and decay problems in materials, safety evolution and structural damages.

After the Second World War the problem of rebuilding and reconstructing the demolished Historic buildings appeared worldwide. The complex load carrying behavior is due to massive and continuous interaction between various structural elements e.g. domes, vaults, arches and pillars. The structural resistance depends preliminarily on two factors: the geometric features of the structures and characteristic strengths of the materials used.

II. EXPERIMENTAL RESEARCH FOR CONSERVATION

The study of structure begins by mapping visible damage. Survey drawings should map different kinds of materials, noting any decay and any structural irregularities and damage, paying particular attention to crack patterns and crushing phenomena. Geometric irregularities can be the result of previous deformations, which can indicate the junction between different building phases or alterations to the fabric. It is important to discover how the environment may be damaging a building, since this can be exacerbated by poor original design and/or workmanship (e.g. lack of drainage, raising dampness, and vegetation), the use of unsuitable materials and/or by poor subsequent maintenance. Observation of areas where damage is concentrated as a result of high compression (zones of crushing) or high tensions (zones of cracking or the separation of elements) and the direction of the cracks, together with an investigation of soil conditions, may indicate the causes of damage.

The general laydown of technical activities for conservation of such heritage structure includes, Identification of historic materials (masonry-binding brick and fieldstone, plaster, paint receiving layer, painted layer, and protective layer etc), Identification of historic techniques, Damages, deterioration or alteration of historic materials, Substantiation and selection of conservation materials and methods, Recommendations for the conservation-restoration works, Inspection of the quality of conservation works.

Different methods of research on conservation of heritage structure are: chemical analysis, Petro graphical -

Mineralogical, X-ray diffraction, spectral, chromatographically, micro-chemical analysis, analysis of pigments and organic bindings, artificial aging; biological mycological research; physical research of building materials; monitoring of microclimate regime of some historic buildings. The practice is based on the composition of historic materials, the existing physical condition or the character of destruction, and on the principle of reversibility. These were clubbed together with the technologists of restoration when applying all the new methods.

The schedule of tests should be based on preliminary phenomena views which are important to understand. Tests usually aim to identify the mechanical (strength, deformability etc.), physical (e.g. porosity) and chemical (e.g. composition) characteristics of the materials, stresses / deformations of the structure and the presence of any discontinuities within the structure. As a rule, the schedule of tests should be divided into stages, starting with the acquisition of basic data, followed by a more detailed examination with tests based upon an assessment of the implications of the initial data. Non-destructive tests should be preferred to destructive testing that involve any alterations to a structure. If NDTs are not sufficient then it is necessary to assess by opening up the structure in terms of reduced structural intervention against the loss of culturally significant material. Tests should always be carried out by experts to gauge their reliability correctly and the assess implication of test data carefully. If possible different NDT methods should be used and the results should be compared.

III. STRUCTURAL BEHAVIOR

The behavior of any structure is influenced by three main factors: the shape & the connections of the structure, the construction materials and the forces, accelerations and deformation, but before going to these details we have to understand the mechanism of Decay first.

Restorers and art historians who were working with architectural monuments in the 1960ies observed that many historic monuments seemingly deteriorated at a much higher Rate than it should have been expected only by natural ageing. This effect could be visualized impressively in comparative studies of documents that showed the preservation state of some monuments at the beginning of the 20th century and approx. 60 years later It was concluded that if there will not take place dramatic changes to the quality of the Atmospheric environment - which were supposed to be the main cause of the observed Changes - we will lose by the end of the century a substantial part of our cultural heritage. In 1975 Feilden estimated that by the end of the century only 10% of the architectural heritage will “survive”, 1989 he gave a more “optimistic” estimation, saying that hopefully it will be more than 20%. To a similar conclusion came Winkler 1973, who included results of many different studies on stone deterioration (time lapse) and concluded that most of the stone surfaces should be strongly deteriorated by the end of the 20th century.

It was well understood, that scientific research is necessary to understand the processes of deterioration of materials and also to develop methods for rehabilitation and conservation of the endangered heritage. Measures initiated on pure empirical knowledge are certainly a good prevention, but they do not guarantee success. On the other hand pure scientific research gives clear results, however often fails, when applied in practice. The main achievement of the years lying now behind us, was the creation of an interdisciplinary cooperation of all persons and bodies that integrated both – scientific and practical experience. For the first time many different disciplines from science, humanities, architecture, engineering and others came together and tried to find solutions for problems that in the past were thought to be problems only of one of these groups respectively. This cooperation needed several years of intensive exchange and discussions and it seems that it started to work now. It is not possible to give here an overview of all activities and achievements that have been done in Germany for the protection of historic monuments and the specific research for a better understanding of their decay processes. Evidently the whole variety of historic building structures and other monuments consisting out of a variety of stone material, metals, brick structures and many other different cultural materials do behave in their environment differently in detail

IV. DIAGNOSIS & SAFETY EVOLUTION

Diagnosis and safety evaluation of the structure are two consecutive and related stages on the basis of which the effective need for and extent of treatment measures are determined. Evaluation of the safety of the building should be based on both qualitative (as documentation, observation etc.) and quantitative (as experimental, mathematical etc.) methods that take into account the effect of the phenomena on structural behavior. Any assessment of safety is seriously affected by two types of problem, the uncertainty attached to data (actions, resistance, deformations, etc.), laws, models, assumptions, etc. used in the research; the difficulty of representing real phenomena in a precise way. It therefore seems reasonable to try different approaches, each giving a separate contribution, but which when combined produce the best possible ‘verdict’ based on the data at our disposal.

The diagnosis is to identify the causes of damage and decay, on the basis of the acquired data. Which cover the historical analysis, qualitative analysis and quantitative analysis, which includes both mathematical modeling and testing.

However, safety evaluation is also a difficult task because methods of structural analysis used for new construction may be neither accurate nor reliable for historic structures and may result in inappropriate decisions. This is due to such factors as

the difficulty in fully understanding the complexity of an ancient building or monument, uncertainties regarding material characteristics, the unknown influence of previous phenomena (for example soil settlements), and imperfect knowledge of alterations and repairs carried out in the past. Therefore, a quantitative approach based on mathematical models cannot be the only procedure to be followed. As with the diagnosis, qualitative approaches based on historical research and on observation of the structure should also be used. A fourth approach based on specific tests may also be useful in some situations.

V. NON STRUCTURAL ELEMENT EXPERIMENTAL STUDY

Photo-1 shows the marvelous work of Ekthamba Mahal in Mandore garden Jodhpur. It is a three story structure with octagonal plan. Decorative arches packed with stone Jalies make it airy. Jalies are damaged but the quantum of damage varies 1% to 5%. These jalies are very old and has cracks in its thickness.

Replacement of complete jalies is neither cost effective nor follows the conservation ethic, the part replacement is difficult as there is progressive failure in fitting parts.

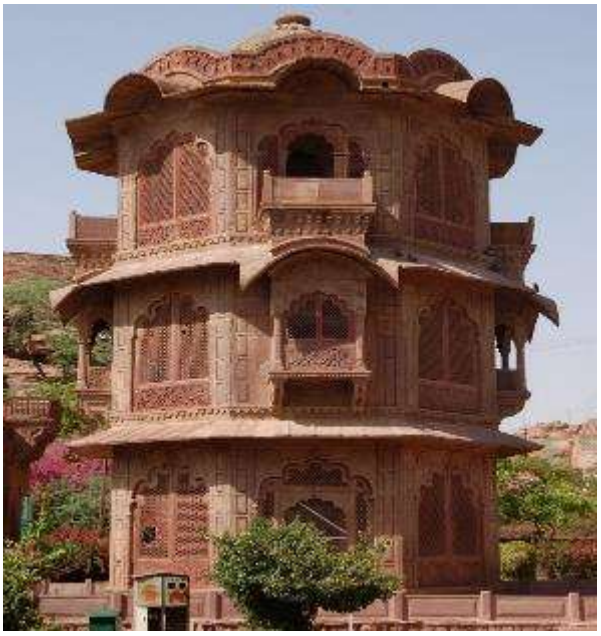

PHOTO-1 Ekthamba Mahal

Requirements of Traditional Mortar

Repair mortars are needed for replacing mortar in damaged or severely weathered masonry mortar joints, for reconstruction of deteriorated masonry, and for renewal of rendering. The main components in a mortar mix are sand, binder and water. Additional material may be added to modify the properties or appearance of the mortar.

Repair mortars should be durable, practical in application, and without negative effect on the durability of the existing masonry heritage structure. Mortar should be considered 'sacrificial' since it is easier to repair mortar joints than replace masonry units. Photo-2 shows conservation work with traditional practice.

PHOTO-2 Conservation Work on Fort Wall

Durability is not only dependent on the mortar mix but also on how it is installed and cured, on the compatibility between the masonry unit and the mortar, and on the severity of the environmental exposure, which in turn depends on weather, design details, construction practice, operation, and maintenance. The general principle "the stronger the better"can lead damage to the masonry or shortened mortar service life in heritage structures. Photo-3 of famous Salem Sing Ki Haveli Jaisalmer where for repair cement mortar was applied as against the traditional mortar which was stronger than required and caused failure due to its incompatibility in fabric & strength. The typical performance requirements are:

- Mortar should be no stronger than needed for the structural and durability requirements of the masonry. The long-term compressive strength should be lower than that of the existing masonry units and similar or lower in strength than the existing bedding mortar. Unfortunately although the mortar itself may become more durable it can have a negative effect on the performance of the masonry as a whole.
- Water absorption and vapor transmission rates should be similar to or greater than those of the existing mortar and masonry units.
- Full contact between repair mortar and masonry units should be well ensured.
- A lower strength mortar will also tend to be "soft" or more flexible, a property that permits the mortar to respond to small differential movement without cracking.
- Cracks allow water ingress into the assembly which can lead to freeze-thaw damage in cold weather. In the spirit of sustainability and reversibility, low strength mortars will also be easier to remove in future maintenance and repairs.

PHOTO-3 Salem Sing Ki Haveli

Challenges in Mortar Selection-

- Original mortar materials are no longer available. And difficult to determine the exact composition and properties of the existing mortar.
- Issues of historic authenticity. The repair mortar should correspond to the original one.
- Many of the materials and techniques for producing and applying traditional mortars were lost and substitutes may have to be found and techniques learned again.
- Traditional mortars, usually of much lower strength than modern mortars.
- Appropriate laboratory and site test procedures are needed for the evaluation of repair mortars.

Lime Dhar for Parkota wall of Sojat fort (Photo-7) being done in traditional way where low strength mortar being used. The process include reducing alkalinity of hydraulic lime by changing water from slaking tank. Mixing in mill with surkhi and old dismantled mortar from the same old work with brick bats. In addition organic additives Gur & Gugal with Belgiri are incorporated.

PHOTO-4 Lime Dhar

VI. STRUCTURAL ELEMENT EXPERIMENTAL STUDY

The transformation of the massive stonework of Romanesque architecture into the delicate tracery of the Gothic presents clear evidence of the powerful logic of the trial and error methods employed by the medieval builders. Without mathematical theories or predictive methods, but with great geometrical skill, Gothic builders learned to fashion stone - a material limited to receiving compressive forces and requiring careful fitting - into ribs and vaults that display some understanding of the actions of forces within the structure. The inside of celling of Ajeet Singh Deval (Photo-5) at Mandore. The structure consisting mainly, the skeleton of piers, buttresses, arches and ribbed vaulting can be considered the splendor of the art of cutting stone that looks fragile for its size and heavy enough to doubt for the structural stability.

PHOTO-5 Ajeet Singh Deval

At the present stage of knowledge, numerical simulations are fundamental to provide insight into the structural behavior and to assess/retrofit existing masonry structures. Nevertheless, the step towards the development of reliable and accurate numerical models cannot be performed without a thorough material description and a proper validation by comparison with a significant number of experimental results. This means that carefully, deformation controlled experiments in large-scale masonry tests, small masonry samples and masonry components are necessary. So for accurate structural analysis material properties of the existing structure are required without hurting the monument. The nondestructive methods of UPV are being applied in Gadisar Prol Jaisalmer (Photo-6) & Terrace at (Photo-7) third floor in Patvon Ki Haveli where wooden roofing has been sandwiched between lime Dhar & stucco work evaluate to engineering properties of these monuments which is virtually absent in the masonry literature.

PHOTO-6 Gadisar Prol Jaisalmer

PHOTO-7 Gadisar Prol Terrace

Challenges in Analysis of Heritage Structures

The problems related to the analysis of ancient constructions are: sometimes the geometry is usually missing, as shown in Photo-8 of Rani Mahal in Sojat fort Pali where the constitution of the inner core of the structural elements is unknown, a complete mechanical characterization of the materials utilized is hardly possible, the sequence of construction is not documented and the building processes vary substantially from one period to another as well as from one site to another. Nevertheless, it is believed that sophisticated numerical tools are of much importance for the process of building knowledge about the structural behavior of the constructions and for sensitivity studies about material parameters.

PHOTO 8 Rani Mahal Sojat

The durability of structure is affected by environmental factors such as wind, frost, rain, heat, storm, vapor & moisture. In the case of this monument situated inside Gadisar lake Jaisalmer where all the factor enhancing to detoriate the structure at a faster rate (Photo-9).

PHOTO-9 Gadisar lake Jaisalmer

All buildings deteriorate with time. The factors deciding the rate of deterioration include initial status (design assumptions, materials used and workmanship), age, quality of use, environment, ground movement and quality of upkeep. At a given time, depending on the above and other factors a structure is in a state of deterioration. Under more severe state, deterioration may turn into structural damages. The decay are more prone to corners & discontinuities as chances of physical intervention are augmented (Photo-19).

There may be damages irrespective of the state of deterioration. Such causes are attributed to effects of earthquake, flood, cyclone, fire, weapons effect of destruction etc. The state of deterioration, indeed, contributes to these short duration effects.

When one intervenes towards restoration it is a primary need to examine the premises on which the initial design, material selection and construction were based. It is necessary to ascertain whether assumptions of load, environmental exposure, soil bearing capacity etc. are still valid.

The scaling is formed in the inner side of the dome (Photo-10) which has beautiful aries work, due to seepage from top, but could not be scaled off as it will spoil the beautiful design of aries work.Venice Charter and Burra Charter for guidance, provisions are to be read, understood and applied in entirety.

Only such materials that are consistent with existing material systems should be adopted. Only in very special/critical situations a different/modified material may be used in a way that it can be withdrawn without damaging the original system (fabric). Interventions, particularly structural interventions, and replacements should be explicit so that any viewer would be able to discern between the original and the subsequent.

For example, use of cement is discouraged in restoration /conservation of ancient monuments. In a stone wall containing decorative panel while being restored would accept only stones without motif.

In Kiradu Barmer (Photo-11) for groups of temples conservation could not be carried out as the original quarries are in Sindh Pakistan. And stone with similar fabric is not available. Neither there are such distinctions like explicit or implicit interventions as long as functional requirements are not disturbed. And yet, there is to be caution about using new material that cannot be withdrawn later

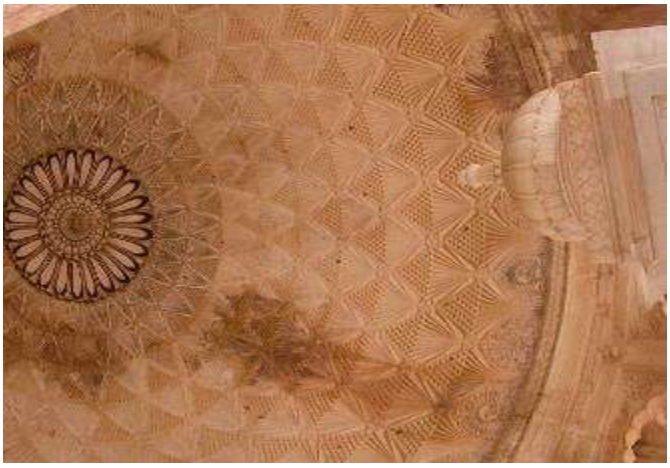

PHOTO-10 Top Dome

PHOTO-21 Kiradu Barmer

Earthquakes

Most of the heritage structures are unreinforced masonry structures. Stone masonry construction generally shows very poor seismic performance. Poor quality of mortar is the main reason for the low tensile strength of rubble stone masonry. Timber floor and roof structures are usually not heavy and therefore do not induce large seismic forces. However, typical timber floor structures are made of timber joists that are not properly connected to structural walls. These structures are rather flexible and are not able to act as rigid diaphragms. Due to their large thickness, stone masonry walls are rather heavy and induce significant seismic forces. This bhuj of Sonar fort collapsed on 9.4.09 due to earthquake of very moderate intensity of 5.3.This has been due to the fact that the structure is free lump mass with almost no cohesion between masonry blocks and being asymmetric on one axis as being semicircle.

Dynamic parameters of ancient structures are generally not favorable from the viewpoint of the aseismic design. For example the fundamental period of such type of structures ranges between 0.10 – 0.30 s, i.e. they are very rigid. The consequence is that such structures are much sensitive to pulse type of loading. Stone and brick masonry both have large specific mass.

VII. DISCUSSION

Very recently the scientific community has begun to show interest in advanced testing (under displacement control) and advanced tools of analysis for historical constructions.

The lack of experience in this field is alarming in comparison with more advanced research fields like concrete, soil, rock or composite mechanics. It is also advocated that sophisticated and robust models for masonry structures are currently available and can be successfully used for the analysis of historical constructions.

Conservation of heritage structures is multi-disciplined work involving knowledge of structural engineering in depth with latest available technology in the industry, but this tool has its dependence on material property like the property of stone available in the concerned region and the mortar. The property of stone as well as mortar changes with passing of time and more important is that the masonry work in heritage structures was traditional lime sand surki mortar with organic additives like gur, gugal, methi, hemp and coconut etc in combination of one or more with varying percentage.

The property of stone & mortar changes with time and their today's value is very difficult to ascertain. To reach at scientific values of their property & engineering characters NDT and Ultra sound techniques are of importance.

Beside that the problem of Heritage structures their accessibility becomes problem. When masonry structure is subjected to lateral inertial loads during an earthquake, the walls develop shear and flexural stresses. The strength of masonry under these conditions often depends on the bond between element and mortar which is quite poor in heritage structures as lime mortars or mud mortars are used. A masonry wall can also undergo in-plane shear stresses if the inertial forces are in the plane of the wall, Shear failure in the form of diagonal cracks is observed due to this. However,

catastrophic collapse takes place when the wall is subjected to out-of-plane flexure.

In an ideal world, restoration strategies should be designed to include the least intrusive methods and they should be reversible. Wherever possible, they should also attempt to use traditional materials that are similar to those used for the original construction – and compatible with the masonry in terms of movement accommodation etc.

VIII. CONCLUSION

Conservation of Heritage buildings is quite different from new construction. Conservation needs preliminary study of existing structure in detail and the stages it has passed in past. Performing experiments can be highly sensitive. The burning demand of today's societies is to carry out Restoration & Conservation of these mighty structures. For that identifying the damage, progress of damage, any immediate risk needing attention and environmental effect is necessary. Modern science has opened up scope by latest tools. Today strong need is to have a compromise between Quantitative, Qualitative and Historical analysis for restoration of historic building and a model spectrum is required to be developed giving due weightage to all variables for the value of individual structure. Data collection has vital role to play for conservation and requires very precise and scientific involvement. Existing fabric has to be restored; new one should be compatible and in resemblance with minimum intervention to the old one. Heritage has always attracted tourism nationally as well as internationally strengthening local and national economy. Heritage may be categorized as Monuments, Sites, Buildings, Artifacts, Cultural Landscape and Intangible Heritage .Religious, Art History and Architecture, Scientific and Technical, Nationalist, Domestic, Economic and Development, Re-creational and Humanistic are its paradigms.

Various international agencies independently, under UN cover and national agencies, regional authorities and NGOS are working in this field. There is need of active coordination of all these administrative and executive agencies so that uniformity in policy of conservation is formed. Under the same cover techniques should be idealised for utilities on regional bases and by facility to be provided to all concern interested in matter via information-technology.

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