SPECIFICATIONS FOR
BUILT HERITAGE CONSERVATION

2021

TATA TRUSTS

AGA KHAN TRUST FOR CULTURE

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BUILT HERITAGE CONSERVATION

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Review Workshop (September, 2021)

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TATA TRUSTS

FOREWORD

The Tata Trusts, having worked for decades on preserving monuments in public spaces, initiated an exercise to prepare this document whose urgency lay in the lack of a Specifications Manual and Rates specific for conservation works in built heritage. In a country blessed with a built heritage that spans both time and styles of architecture, conserving this built environment is paramount: it defines the diversity that makes India, the differences that influence and enrich our culture and an understanding of how we live together.

Conservation of monuments in public spaces revitalises communities and usage of the commons. Conservation of heritage buildings and their continued or adaptive re-use is as vital in preserving an architectural style as it is in preserving environmental costs; and as climate change endangers buildings further, strengthening our built heritage to withstand these increased threats is becoming urgent.

While the Central Public Works Department (CPWD) publishes a specifications manual, with regular updates, related to modern construction works, the field of built heritage conservation does not have any benchmarked specifications or rates to serve as a guide for undertaking projects.

As projects in built heritage are on the increase around the country, the Trusts commissioned experts from the sector in partnership with the Aga Khan Trust for Culture, to prepare this document, that collates specifications of materials commonly used in conservation projects and lays down procedures for their correct usage keeping in mind traditional building materials, along with an analysis of rates. The manual focusses on materials such as Lime, Stone, Brick, Timber etc. and processes such as Flooring, Roofing and Landscaping.

The first of its kind in the field, we hope that this document will support future conservation projects and enable decision makers – officials, donors, corporates, contractors, as well as younger conservation architects entering the field, and government agencies embarking on projects – and serve as the starting point for establishing standards in built heritage conservation. India is a land with two millennia worth of processes and materials, and we hope the document will grow in the future with contributions from practitioners in the conservation of built heritage.

Ratan N. Tata
Chairman, Tata Trusts

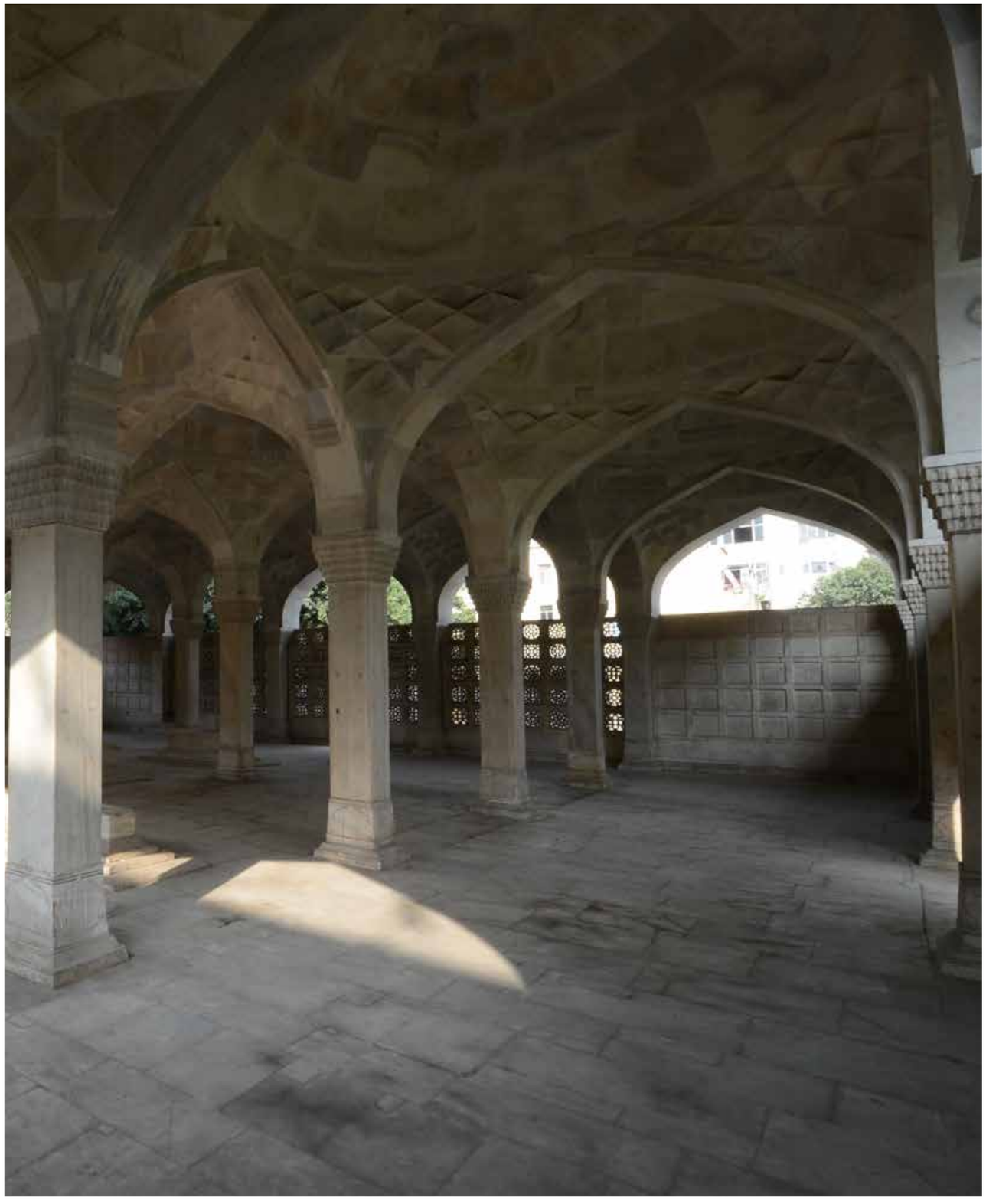
EXECUTIVE SUMMARY

India boasts of an ancient civilization and though less than 10000 historic buildings are protected across the country, it can be estimated that over a million historic structures still stand across the country. By comparison over 650,000 heritage buildings are protected in the UK and an estimated 30,000 in New York city alone.

The Archaeological Survey of India protects 3675 monuments to be of national importance while a similar number are estimated to be protected by the State Governments across the nation. A few thousand structures are also 'listed' by urban municipalities such as in Delhi, Mumbai, Hyderabad, amongst others. Several thousand heritage buildings, though not protected for their heritage value are in the care of government agencies such as the Central Public Works Department, most are thus in private ownership – where there is little advice and no incentives to retain their historic architecture and character.

Traditionally, our built heritage was cared for by a team of craftspeople under the leadership of a master craftsmen, who were well versed in the use traditional tools, techniques and materials. However, from the 20th century these roles were replaced by supervising engineers, archaeologists and architects, often unfamiliar with traditional building materials and techniques and thus using inappropriate practices or materials in the conservation process. In recent decades, with the lack of opportunities and respect, the availability of skilled craftspeople has further declined, posing a significant challenge to built heritage conservation.

In 2007, following the successful completion of the Garden Restoration of Humayun's Tomb, the Archaeological Survey of India requested the Aga Khan Trust for Culture to undertake the conservation of the Humayun's Tomb as well as several monuments standing within the larger Humayun's Tomb – Sunder Nursery – Nizamuddin Basti area. Soon thereafter, the Tata Trusts agreed to support the conservation effort at the Humayun's Tomb. In 2013, on the completion of the conservation effort at Humayun's Tomb, the Tata Trust lent support to AKTC's conservation effort at the Qutb Shahi Heritage Park, Golconda, Hyderabad. 50 years after independence, conservation of India's built heritage had become a national priority and over the past 25 years, conservation effort nationwide have been supported by government, corporates, national and international trusts, private philanthropists, amongst others. Yet, the costs, impact and quality of works have varied and on occasion well intentioned efforts have compromised the significance of historic buildings. The Tata Trusts have supported a wide range of conservation projects and have often been approached for guidance on costs, quality, process to be followed – by officials and corporates.
In 2014, the Archaeological Survey of India notified the new National Policy for Conservation, laying emphasis on the continuation of building craft traditions in India and aligning conservation practice to the Indian context while respecting established international principles. While this policy is definitely a bold new step, the lack of an established standard for conservation has led to varying approaches in conservation, with well-meaning efforts often leading to further damage and deterioration. Even within ASI



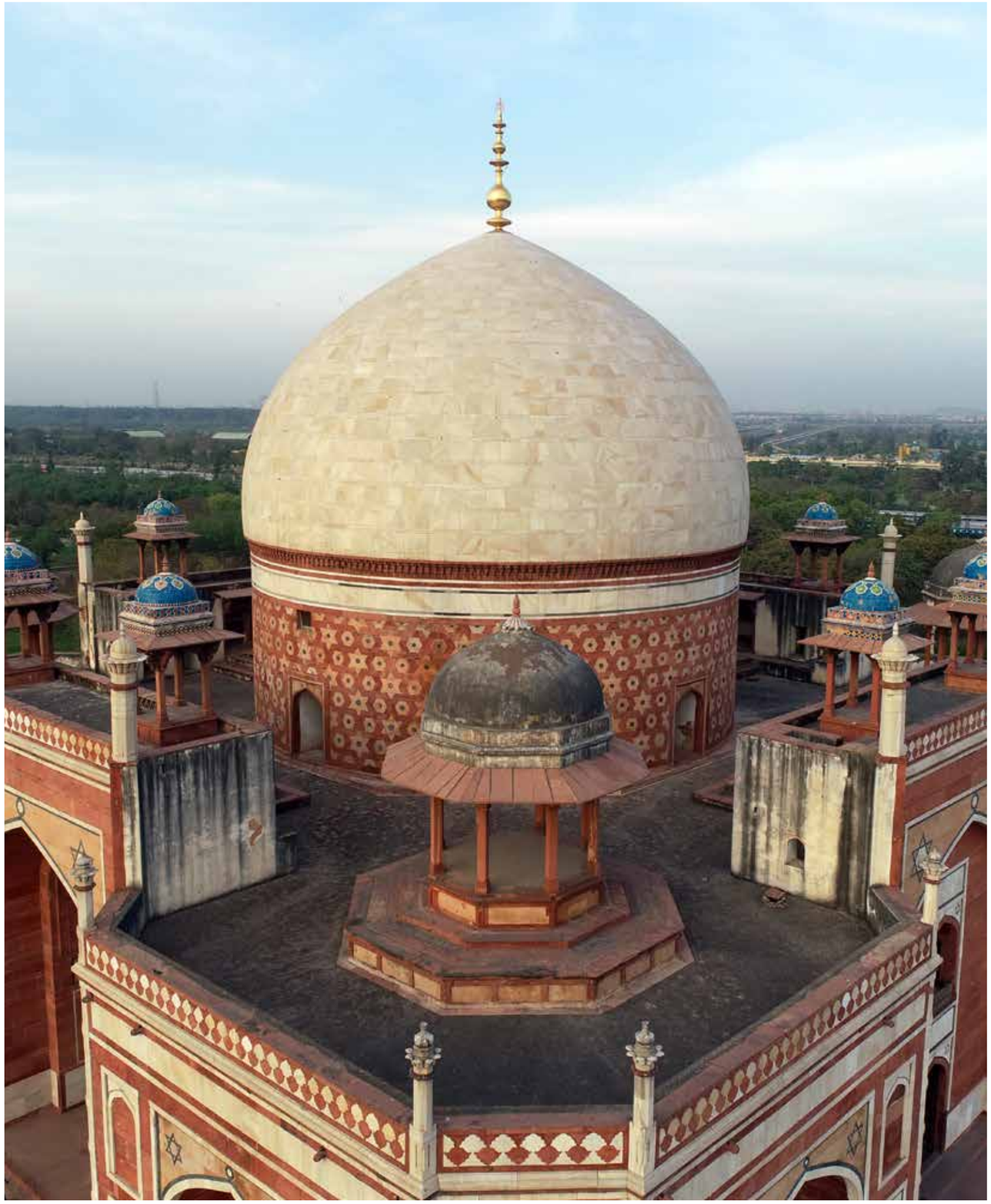
conservation works undertaken in different circles have varied considerably in use of material and costs. To facilitate conservation effort and provide a template for officials, donors, contractors, conservators, an effort to write a sequel to the CPWD Schedule of Rates was required. This manual includes detailed Technical Specifications, associated Schedule of Rates and also the Analysis of Rates to enable a systematic approach to conservation; just as the existing specifications of the Central Public Works Department do for modern construction. To ease understanding of this manual, it includes several case studies that serve as examples of the conservation works undertaken by the Aga Khan Trust for Culture in Delhi and Nizamuddin as well as those provided by independent conservation practitioners who advised on this effort.

The specifications build's upon data collected across geographical areas from the Archaeological Survey of India, State departments of Archaeology, the Indian National Trust for Art and Cultural Heritage and several independent practitioners. Prepared by an inter-disciplinary team including engineers, conservation architects, conservators, craftsmen, architects, conservators, archaeologists, amongst others established at the Aga Khan Trust for Culture's Delhi office

Over the past year, specifications, rates were sought and independent experts, officials from ASI, State Departments of Archaeology and CPWD reviewed the documentation at regular intervals. A review workshop held mid-way through the exercise allowed practical challenges, aspirations of conservation professionals and responsible officials and institutional preferences to be incorporated in the effort.
While this will be of much use in a large part of the country, envisioned as a dynamic document, the manual as yet does not address the needs of heritage buildings in areas of the country with unique building traditions such as with mud, wood or bamboo, amongst others. It is hoped that the Central Public Works Department will incorporate this within their own Schedule of Rates and thus build upon this exercise and update it at periodic intervals, incorporating additional specifications, analysis of rates, case studies and guidelines for conservation. In any case for many heritage buildings this manual will need to be read in conjunction with the existing CPWD DSR as for heritage buildings in use, modern additions and infrastructure is also required to be provided.

This manual is meant for the use of conservation professionals, who can include site specific redressal of problems as will be required, for many items of work of similar nature. They will be able to use sound practices based on standard specifications that will be crucial to maintaining quality of works.
It is hoped that the compilation of these standards and practices will enable an enhanced level of implementation of conservation works in the country, empowering both public and private owners of heritage buildings in conservation decision making, and widening available expertise in the conservation effort. It is estimated that in the UK, 55% of the construction industry budgets are utilized on conservation of their 650,000 protected heritage buildings in turn meeting several of the Sustainable Development Goals and reducing carbon emissions and environmental impact of building anew.

Ashok Khurana, Director General, Central Public Works Department (Retired)
Rajpal Singh, Chief Engineer, Aga Khan Trust for Culture



TATA TRUSTS

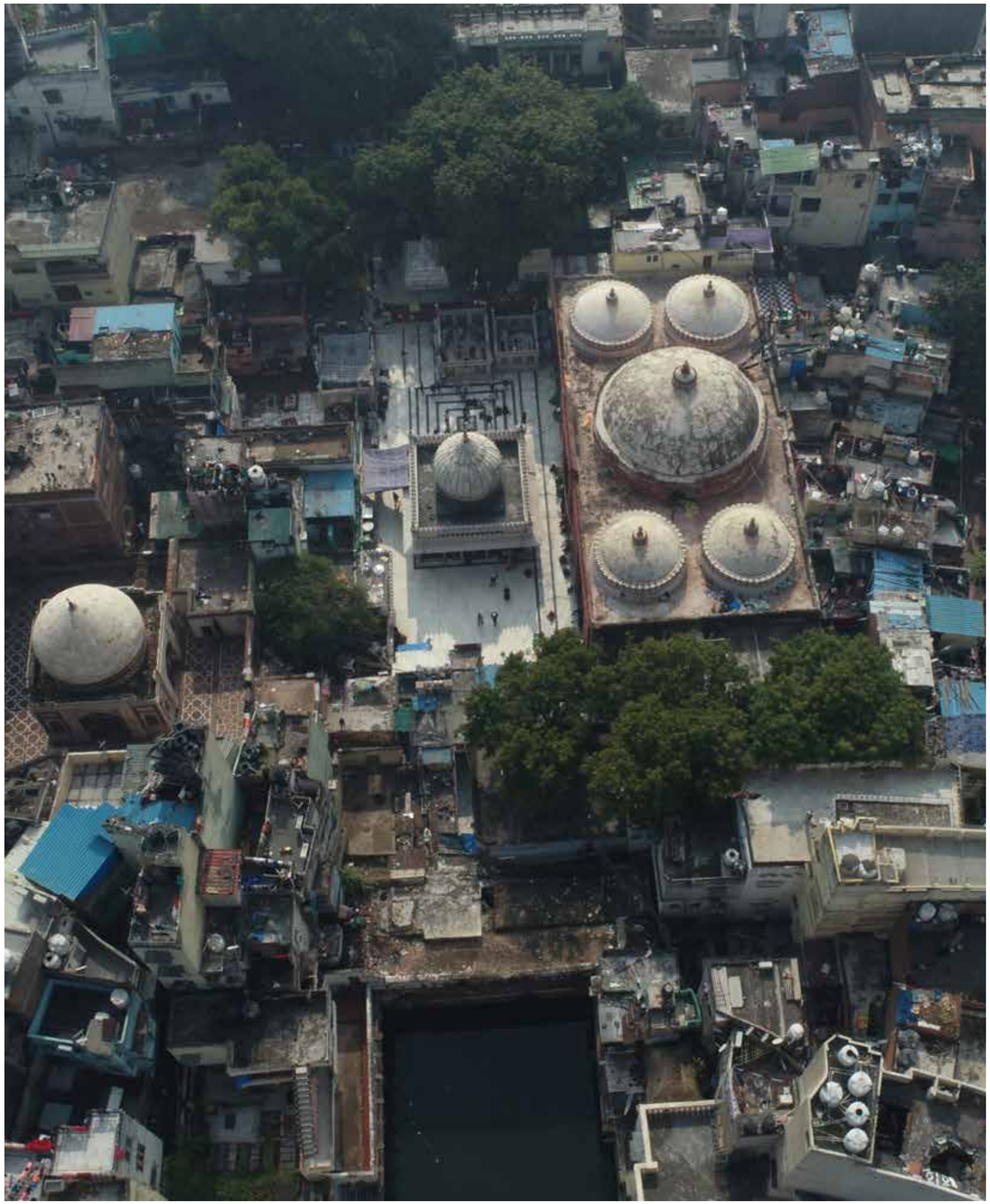
ACKNOWLEDGEMENTS

To produce a document such this, involving material specifications and standardisation of rates, was to embark into as yet, unrecorded terrain in the field of built heritage. While it was apparent to us this was necessary as we examined proposals and projects with no benchmark to refer to for guidance, we could not have taken this up without the support and understanding of both the Trustees at Tata Trusts and the team of experts who agreed to take this on. One understood the need, the other enabled the technical thoroughness needed.

We hope this manual will be taken up by a government body and be annually updated, so as to catalyse the field of built heritage - an enabling document for several agencies to use in conserving our country's vast and myriad built heritage. It is not a final say on the subject; as the years go by we hope it will be added to, further strengthening the document by recording materials and processes that vary from region to region, many particular to our country. This initial step has been taken; the path ahead, hopefully cleared, using the guidelines and standards, for re-opening many more mindfully conserved heritage sites for public usage.

I would like to extend my thanks to the Trustees at Tata Trusts and to Mr. Ashok Khurana (former Director General Central Public Works Department) for leading the project; Dr. R.C. Agrawal (former Joint Director General ASI; and the team at Aga Khan Trust for Culture (AKTC) - especially Mr. Ratish Nanda, CEO who anchored all, Mr. Rajpal Singh, Chief Engineer AKTC, Mr. K R Bhandaria, Engineer – in – Charge, AKTC and Ujwala Menon, Senior Program Manager AKTC - who through difficult times, illness and several lockdowns, persevered in collating data, rigorously documenting and checking all collected and conducted peer reviews to record this manual. To all the architects, engineers, designers and photographers who worked on this together, co-ordinating site visits and meetings through the pandemic restrictions, our gratitude. I would like to thank my colleague Paroma Sadhana, Programme Officer, Arts and Culture, Tata Trusts, who shared in the enthusiasm in bringing this to fruition, and was especially diligent in keeping all on track.

Deepika Sorabjee
Head – Arts and Culture
Tata Trusts



Aga Khan Trust for Culture

ACKNOWLEDGEMENTS

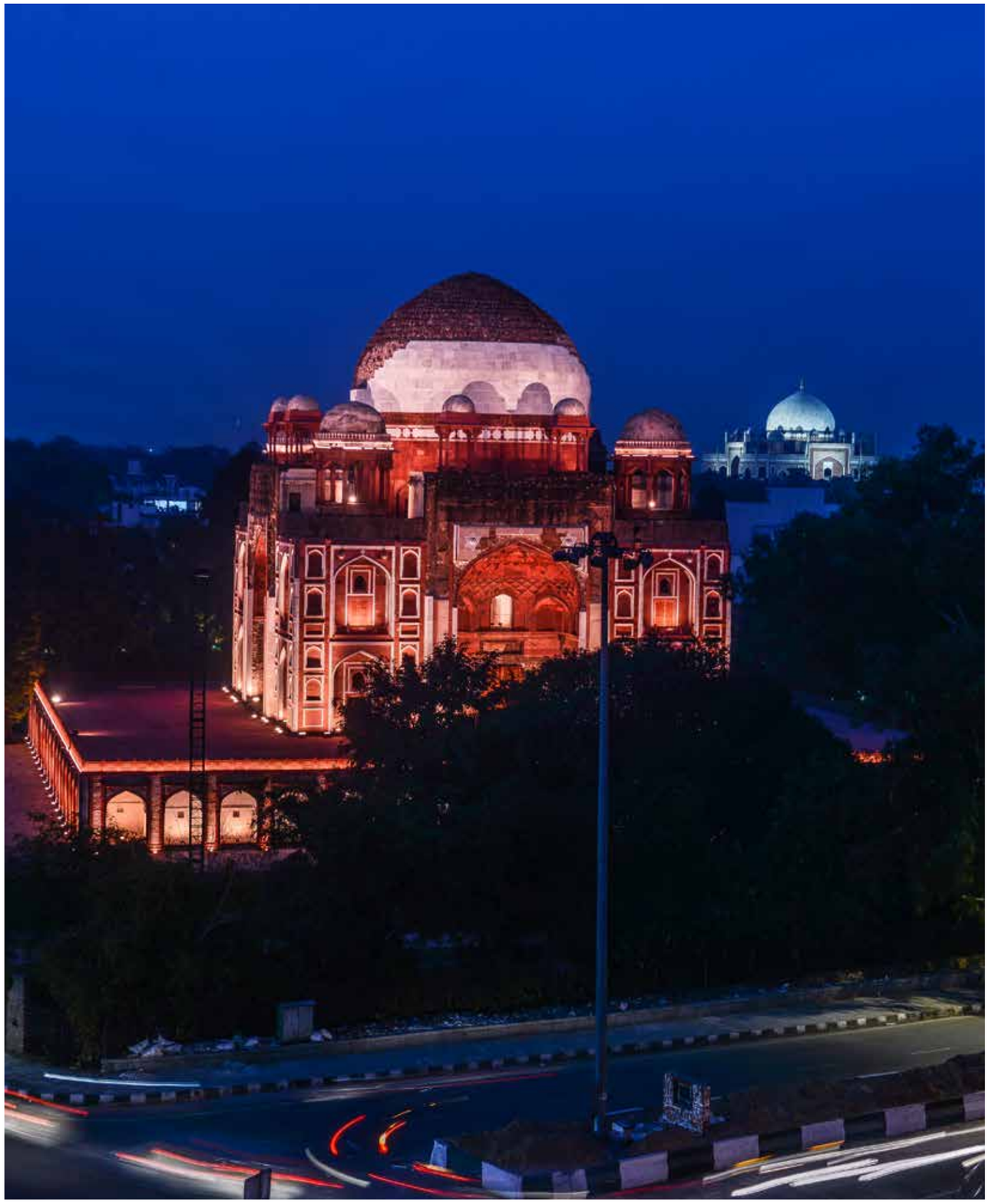
At the end of 25 years of conservation effort at Humayun's Tomb – Nizamuddin Basti – Sunder Nursery area of Delhi and a decade long effort at the Qutb Shahi Heritage Park, Golconda, Hyderabad – both undertaken by the Aga Khan Trust for Culture with the support of the Tata Trusts - this manual attempts to benchmark traditional material preparation and costs of undertaking conservation works in an effort to aid, facilitate and encourage similar conservation effort at countrywide heritage sites.

For a mammoth effort such as this, acknowledgments are due to several individuals, not all of whom can be named. This is especially true as this effort builds upon over 25 years of implementing conservation effort at the Aga Khan Trust for Culture in partnership with the Archaeological Survey of India as well as with the Department of Heritage at the Government of Telangana and has thus been indirectly informed by several officials and former colleagues.

We are grateful that the CAG audit of the Archaeological Survey of India in 2013, the Parliamentary Committee on Tourism & Culture in its report of July 2021 as well as the PMO appointed committee on 'Improving Heritage Management in India' in May 2020 Chaired by Shri Amitabh Kant, CEO, NITI Aayog, all noted the variation in the quality of conservation works being undertaken in India and emphasised the urgent need to prepare detailed specifications for conservation works along with analysis of rates.

First and foremost, I am grateful that Mr Ashok Khurana understood and envisaged the need to prepare specifications, analysis of rates, guidelines for conservation and pursued this with officials of the Ministry of Housing & Urban Affairs as well as Ministry of Culture, Central Public Works Department and the Archaeological Survey of India. He consistently provided leadership and guidance for this effort.

Mrs Usha Sharma, IAS, former Director General, ASI; Mrs V. Vidyavathi, IAS, Director General, ASI; Mr Janhwij Sharma, Additional Director General, ASI; Dr M Nambirajan, Joint Director General; Mr N K Pathak, Director (Monuments), ASI as well as Superintending Archaeologists of several ASI circles from countrywide locations have been generous in their support and making ASI material available for incorporation in these specifications. At the ASI special thanks are due to Mr. R S Jamwal, Former Director (Conservation) who has independently reviewed the specifications



and provided valuable insight into conservation practices followed by the Archaeological Survey of India across its many sites. Also to Mr Sunder Paul, Superintending Archaeological Engineer, ASI who actively participated in the review workshops and provided valuable guidance.

At the Ministry of Housing & Urban Affairs, Mr Kamran Rizvi, IAS, Additional Secretary (Works) and Mr. Ved Prakash, IRSE, Joint Secretary (Works), enthusiastically supported the effort and enabled active involvement of CPWD officials in the periodic review of this manual. Mr Vinayak Rai, Chief Engineer, CSQ (Civil), CPWD deputed Mr D S Adhikari, AE, CPWD, to inform and periodically review the work and his inputs helped align this effort with the CPWD DSR.

At the Delhi Government, Mrs Swati Sharma, IAS, Secretary, Art, Culture & Language and Mr. Mohammed Ahsan Abid, Special Secretary, Government of National Capital Territory of Delhi both saw value in the exercise and in addition to their involvement ensured engineers and finance officers responsible for the Department of Archaeology were both involved in discussions.

At the outset of this exercise, several independent Conservation Architects generously shared specifications, case studies and schedule of rates they have prepared and used for undertaking conservation projects across the country. We gratefully received valuable material from INTACH and I am grateful to Mr Divay Gupta, Director, Architectural Heritage Division for his additional inputs. Mr. Benny Kuriakose, Ms. Poonam Mascarenhas, Mr. Manish Chakraborti, Mr. Munish Pandit and Ms. Urvashi Srivastava, amongst others both generously shared original material and actively participated in an intense review workshop in September. Similarly, Mr Yogesh Kapoor, Landscape Architect provided the valuable inputs on behalf of Shaheer Associates from garden restoration projects they have been involved with including at Humayun's Tomb, Baghe Babur, Qutb Shahi Heritage Park, amongst others.

I am indebted to Mr. Benny Kuriakose, who, following the review workshop continued to guide and advice the team. His invaluable knowledge and guidance was instrumental in making this manual relevant to conservation practice in the Indian context.

At the Aga Khan Trust for Culture I have been privileged to work alongside an inter-disciplinary team. To undertake our projects, seek funds from donors such as the Tata Trusts, for 25 years we have had to prepare specifications and rates analysis. This enabled us to undertake this mammoth effort on the request of the Tata Trusts. Since the beginning of our involvement in India, Mr Rajpal Singh, AKTC Chief Engineer has personally prepared these and has made exemplary effort for the present effort. He has been ably supported by Mr K R Bhandaria, Project Engineer, who joined the effort on his retirement from CPWD.

Aga Khan Trust for Culture

On behalf of AKTC, Ms Ujwala Menon, Senior Project Manager, AKTC ably led the team and coordinated the effort; she was assisted by Ms Nishtha Goel, Architect. I am grateful that Conservation Architect, Ms Bhawna Dandona joined the effort and focussed on preparing the technical specifications; she was assisted by architects Ms Prashansa Sachdeva, Ms Mrinalini Singh. This work has been possible with the sincere efforts of Mr Rajpal Singh, Mr K R Bhandaria, Ms Ujwala Menon and Ms Bhawna Dandona.

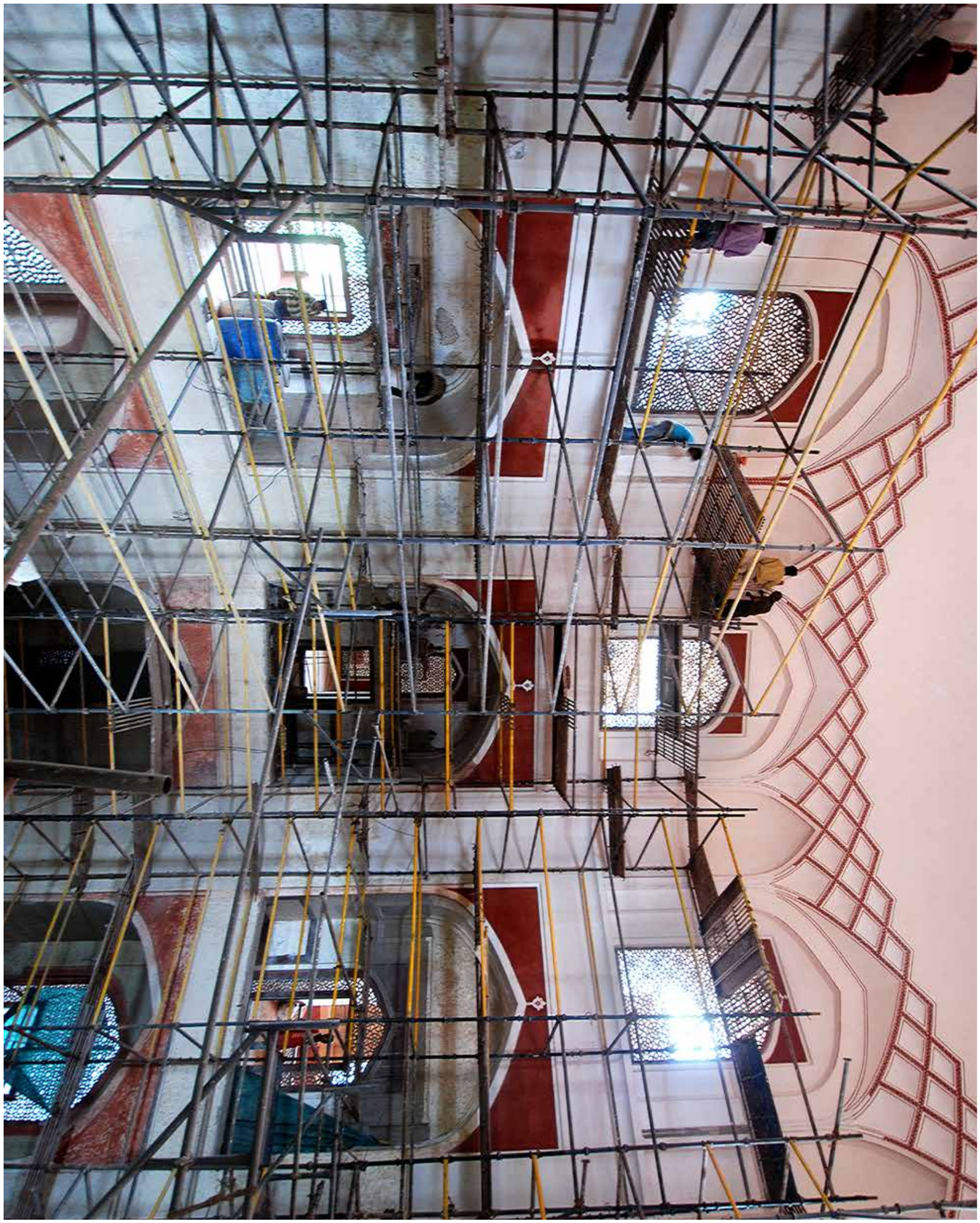
Significant inputs were provided by Dr R C Agrawal, Former Joint Director General, ASI, Mr N C Thapliyal, also formerly at ASI. At AKTC Conservation Architects Prashant Banerjee, Neetipal Brar, Aishwarya Das, Maanvi Chawla and engineers Mr M P Mishra, Mr Nikul Kumar, amongst others also contributed to the effort. Photograph and layout was carried out by Mr Narendra Swain and Mr Rinkesh Rana respectively.

Finally, this effort would not have seen the light of day without the deep understanding of the need in India for a material specifications and standardisation of rates for conservation by Ms Deepika Sorabjee, Head, Arts & Culture, Tata Trusts. Deepika has been keen on art and heritage conservation and actively involved in this effort over the past three years, just as she has done so for the effort at the Qutb Shahi Heritage Park. Also at Tata Trusts, I thank Ms. Paroma Sadhana for her actively and patiently facilitating this mammoth project.

I would also like to take this opportunity to thank conservation professionals in advance for their future inputs to further develop this manual. This effort will only be valuable if it is incorporated into individual and institutional efforts and it is hoped the Departments of Archaeology across India, the Archaeological Survey of India and the Central Public Works Department will find this of value.

In Gratitude,

Ratish Nanda, CEO & Conservation Architect, Aga Khan Trust for Culture



INTRODUCTION

Introduction

This document aims to guide responsible conservation practices in a standardized manner In India. Suitable and appropriate treatments shall be formulated for each site and structure based on the extent of deterioration and its significance. All significant features and materials shall be retained as much as possible to sustain the historical significance. To ensure that the historic integrity is not lost or compromised, any change shall be discussed and managed in consultation with the conservation architect. Extent of alterations shall be decided based on the required changes to be accommodated while adapting for new use or upgraded for existing uses. All interventions shall follow the criteria of the minimal intervention sustaining its core values.
All interventions, shall be within the realm of existing national and international charters, policies and guidelines.

1. DEFINITIONS

While each intervention within a project shall encompass some or all of the below, the following definitions from the Burra Charter (1999) are provided here for easy reference. As defined in the National Policy for Conservation by Archaeological Survey of India, a detailed definition and understanding of Authenticity and Integrity, following documents may also be referred: Venice Charter (1964), Nara Document on Authenticity (1994), and World Heritage Centre's Operational Guidelines (July, 2012).

Conservation: means all the processes of looking after a place so as to retain its cultural significance.
Preservation: means maintaining a place in its existing state and retarding deterioration.
Restoration: means returning a place to a known earlier state by removing accretions or by reassembling existing elements without the introduction of new material.
Reconstruction: means returning a place to a known earlier state and is distinguished from restoration by the introduction of new material.
Adaptation: means changing a place to suit the existing use or a proposed use.
Maintenance: means the continuous protective care of a place, and its setting.
Maintenance is to be distinguished from repair which involves restoration or reconstruction.

2. TEAM

A conservation architect and engineer shall form the core team and work with other consultants as per the requirements. The team shall be qualified and experienced in conservation and suited to the project requirements where exact details shall be stipulated based on each project requirement. The team shall specialize in conservation work with experience in research, conservation planning, project management, execution, maintenance and monitoring. They shall have experience of accomplishing similar projects as the requirement. They shall have demonstrated experience of working with traditional techniques and materials used in conservation and restoration. Similar nature works means consultancy and implementation of conservation of heritage properties such as historical buildings, structures, gardens, forts etc. They should have adequate organizational structure/associates of qualified conservation architects, architects, engineers, and specialists like, landscape architects etc. and other technical officers and staff to execute the required work.

Contractors shall be employed for conservation in consultation and approval by conservation architect and the client. The contractor shall have minimum experience and training as per the project needs. The Contractor could also be asked to furnish references for projects of similar scope of work completed, as required.

3. DOCUMENTATION AND ASSESSMENTS

Recording the existing structure along with assessing its current conditions shall be carried out using suitable and appropriate methods as required based on the scope of the work. These records shall include historical research, as-built drawings and photographs, condition assessments ; scientific investigations; which provide complete information on the structure necessary for sound conservation decisions.

The recording of the cultural heritage is essential (PRINCIPLES FOR THE RECORDING OF MONUMENTS, GROUPS OF BUILDINGS AND SITES (1996) :

a. To acquire knowledge in order to advance the understanding of cultural heritage, its values and its evolution;
b. To promote the interest and involvement of the people in the preservation of the heritage through the dissemination of recorded information;
c. To permit informed management and control of construction works and of all change to the cultural heritage;
d. To ensure that the maintenance and conservation of the heritage is sensitive to its physical form, its materials, construction, and its historical and cultural significance.

3.1 AS-BUILT DRAWINGS

The structure shall be documented to create a set of as-built drawings to facilitate the work to be carried out. If archival drawings are available then these shall be modified to create the as-built set. Various techniques and methods are available and shall be adopted based on the complexity and condition of the structure, to suit the project requirements and the expected deliverables.

Examples: Measured drawings (manual survey), Total Stations Survey and Laser Scanning.

Figure1: Laser Scanning Documentation of Isa Khan's Tomb

3.2 ARCHIVAL RESEARCH

All the background information and historical records and existing resources shall be located, examined and studied to inform the formulation of informed, well-defined proposals for the conservation of heritage site/building. The information could be collected from old records, archival drawings, newspapers, journals, listings, project reports, old images, correspondence and travelogues.

Figure2: Archival Research

3.3 CONDITIONS ASSESSMENTS

A survey of conditions or conditions assessment shall be performed to record all existing conditions. Condition assessment involves mapping the issues of the structure graphically, photographically aided by notes with information describing the condition. These conditions shall be recorded visually on site with a general understanding of the problems. For each project, a list of conditions in the form of a legend or glossary shall accompany the graphic/ photographic survey. A conservation plan shall be devised based on this mapping and other relevant investigations.

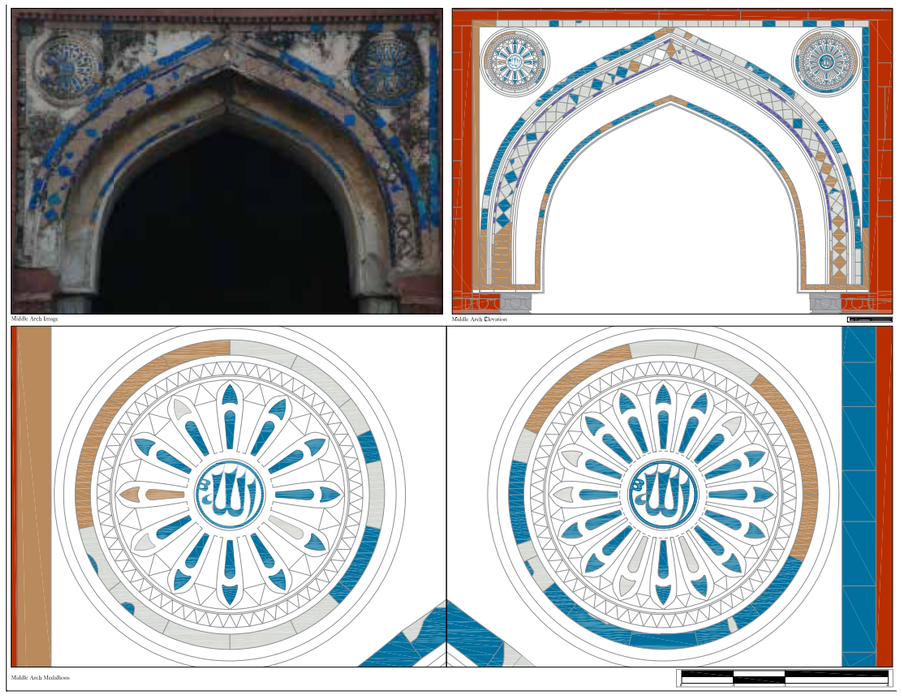


Figure3: Condition Assessment

3.4 PHOTOGRAPHY

Photography shall be used wherever possible with documentation and conditions assessment as a tool to further record information and to enhance the understanding of the structure. The images shall include overalls and details as per the requirement. Photographs shall be properly catalogued and easily accessible in an organized manner both in soft and hard copies.

This photographic documentation shall be continued through the project duration until the execution of works is completed. This could also be combined with videographic documentation to further enhance the understanding of the executed interventions.

Figure 4: Conservation works

3.5 INVESTIGATIONS

After the visual survey, inaccessible areas could be surveyed using nondestructive techniques (NDT) as suggested by the conservation architect. NDT assists in determining information about materials or structures without altering the fabric or the integrity of the structure. The findings through NDT shall augment the visual surveys and shall be incorporated in the conditions reports to make sound decisions.

Figure 5: Restoration of Painted Ceiling at Sabz Burj

3.6 MATERIAL TESTING

Shall be performed to identify, characterize and understand the properties of the deteriorated as well as replacement materials. Testing shall be performed in field or laboratories as suggested by the conservation architect. Testing helps in scientifically identifying the replacements accurately. These tests shall be done under the guidance of a conservation architect or engineer-in-charge using current IS Codes provided in Bureau of Indian Standards. If the tests are not available in the IS Codes then international standards could be followed under conservation architect's guidance.

3.7 SUBMITTALS

The drawings for conservation shall be submitted with all details indicating the work with dimensions and details at appropriate scale and other details as required.

All the information about the products to be used shall be deposited after approval from the conservation architect. Product literature shall include all details as provided by the manufacturer.

The samples of materials shall be submitted for all the work being undertaken.

3.8 MOCK-UPS

Mock-ups shall be performed for all conservation treatments as guided by the conservation architect.

- Conservation architects shall determine the location for mock-up wherever specified and have mock-ups done for the work being undertaken.
- Mock-up shall demonstrate the full range of conservation treatment works required to complete the project.
- The mock-ups shall be inspected and approved by the conservation Architect.
- More than one mock-up may be required to be acceptable for approval.
- Approved mock-ups shall become part of the work and shall serve as the quality standard for all similar work

Figure 6: Precaution and Care during Conservation works

3.9 PRECAUTION AND CARE

- Conservation workers shall be adequately provided protection against accidents and other hazards.
- All necessary protection during conservation procedures shall be provided to avoid damage to the existing structure.
- The existing adjacent building elements and materials shall be protected during conservation works.
- Visible barriers or warning tapes shall be provided around the work area.
- Surfaces shall be protected from nicks, scratches and mechanical damage during conservation works.
- Adjacent surrounding surfaces shall be protected from drips and spatters during conservation works.
- An adequate supply of tarpaulins/plastic sheets at the job site shall be maintained.
- All dismantled materials to be reused later shall be labeled with all necessary information with numbering and locations.
- All openings shall be temporarily covered and secured with rigid and waterproof material to protect against the elements and prevent unauthorized access to the building.
- All packaging, waste and debris shall be sorted and disposed of as specified by the conservation architect.

3.10 SCAFFOLDING

Scaffolding Shall be used cautiously to gain access to areas of the structures. The scaffolding design shall be discussed and approved by the conservation architect, prior to installation. It shall be of the type that when secured is not harmful to the historic fabric. All the holes and fasteners that may be invasive to the structure shall be approved before installation.

Figure 7: Scaffolding

3.11 DISMANTLING

Dismantling of any part of the structure for repairs and replacement shall be done with utmost care and caution. This shall be done under the guidance and supervision of the engineer-in-charge. Adjacent parts of the structure shall be adequately protected before dismantling. Appropriate support shall be provided to the structure during dismantling wherever required.

3.12 TEMPORARY SUPPORT

All structures shall be properly supported under the supervision of the engineer-in-charge. Appropriate methods of shoring or bracing or propping shall be used to make sure that the structure is in no danger of collapse and the work can proceed safely. These shall apply before the work begins to provide protection or stabilization until the repairs are implemented.

Figure 8: Technical Support

3.13 MONITORING

Once the conditions are mapped through appropriate and suitable methods, it is best to monitor and record conditions over a period of time to ascertain the probable causes. Monitoring shall involve collection of the same data set over a period of time and analyzing the results to detect the changes that are occurring. The collection of this information facilitates identification of recurrent problems or fabric susceptible to damage. The problem areas, once identified, can be monitored more intensively and, where appropriate, conservation action taken. Indication of underlying causes are not always easily visible through short term visual survey, requiring monitoring over extended periods of time.

Figure 9: Tell tale

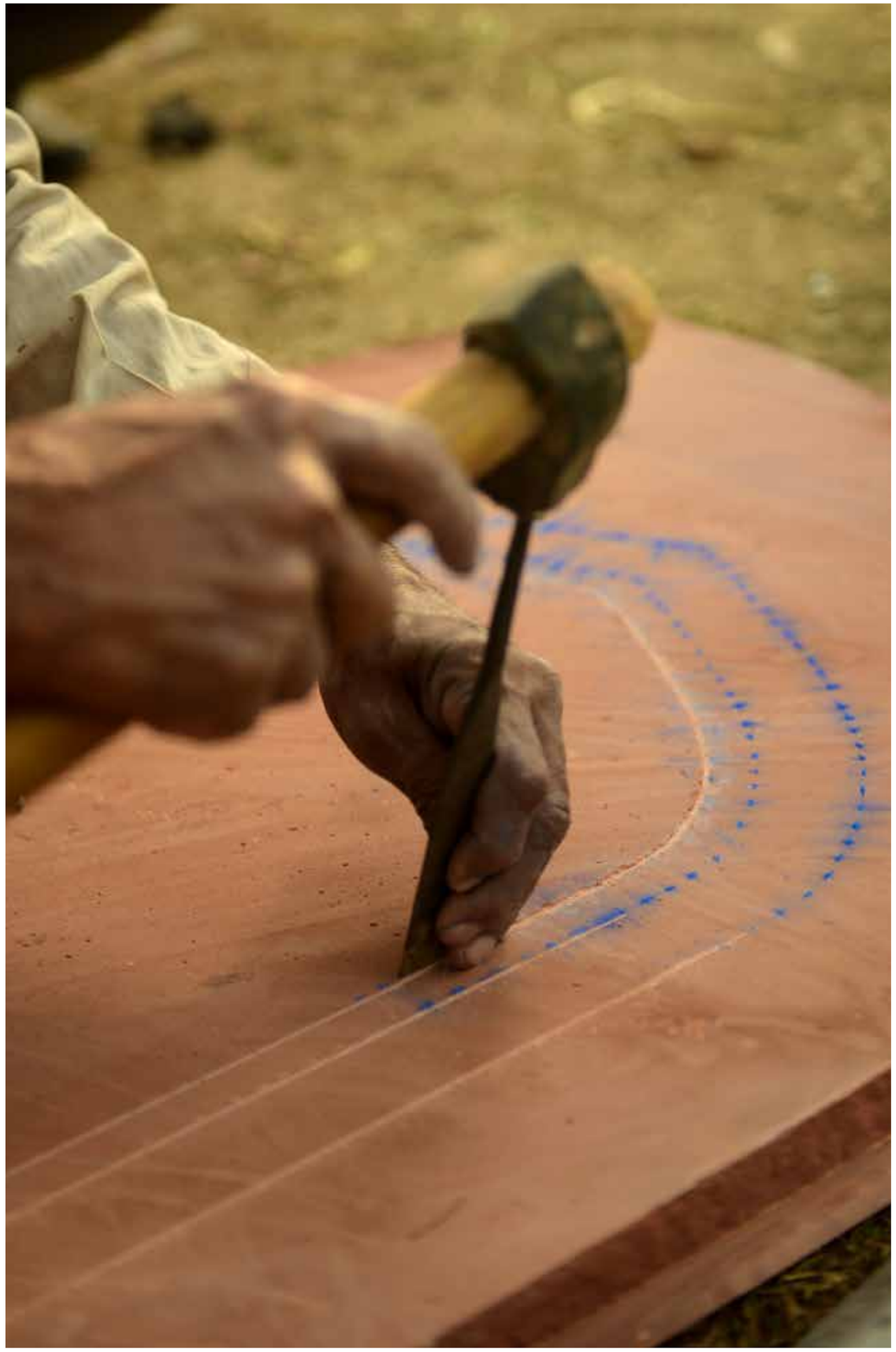
3.14 SCIENTIFIC CLEARANCE

Scientific clearance for removal of historic building material shall be carried out to a specified depth and distance around heritage structures without damaging the buried architectural parts of the building. The cleared earth shall be screened for usable objects/ articles. These shall be lifted and stacked and collected at the approved specified locations as directed by Conservation Architect or Engineer -in-Charge. The unusable and waste material shall be dumped in authorized locations as per direction of the Conservation Architect / Engineer-in-charge.

3.15 JUNGLE CLEARANCE

While jungle clearance or removal of vegetation is being carried out around a historic structure, care shall be taken to avoid any further damage to the existing structure. This will have to be monitored through the course of the project, as vegetation may continue to grow in crevices and gaps. Appropriate treatment of joints, gaps, holes, etc shall be applied to prevent further recurrence of vegetation growth.

Figure 10: Site clearance



LIME WORK

CONTENTS

1. LIME WORK

This chapter describes and provides guidance on conservation treatments for lime work in heritage structures. All the conservation treatments should be carried out in consultation with a conservation architect and engineer-in-charge as per the requirement. The chapter should only apply to plain or flat plaster, decorative or ornamental lime work but not to artistic (mural and painted) works. Conservation of ornamental and decorative lime work should be undertaken in consultation with an art conservator.

1.1MATERIALS

Materials used for conservation of lime work are given below.

1.1.1 Water

Water should be clean and free from contaminants such as oil, acids, alkalis, salts, sugar and vegetable growth. It should meet the latest standards IS: 10500 - 2012 for Drinking Water. Only potable water should be used. Sea water or tidal estuary or brackish water should not be used for any conservation work

1.1.2 Aggregates

The aggregates are extremely important in the appearance and performance of lime mortar and lime concrete. Aggregates are filler material for adding bulk and strength to the lime, helping in reduction of shrinkage. Well-graded aggregates with a range of shape and sizes should be used with a range of particle sizes. Sharp and angular aggregates provide the best properties. The aggregates should match the existing as much a possible. if the original is unavailable then an appropriate replacement should be used as specified by the conservation architect.

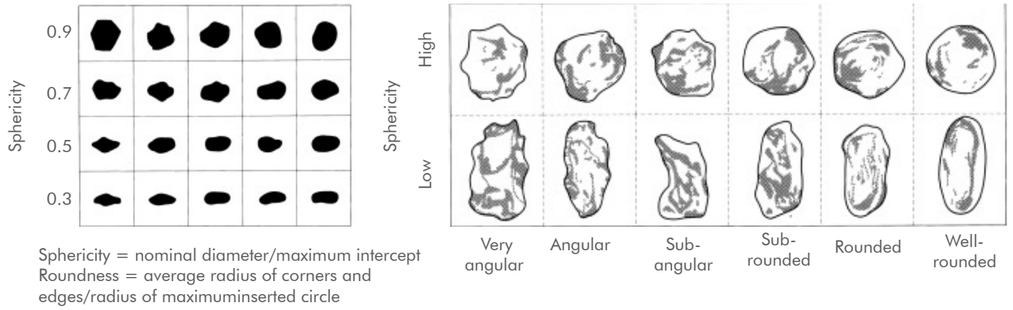


Figure 1.1: Grading of aggregates
Source: Concrete aggregates - Ian Sims, James Ferrari, in Lea's Chemistry of Cement and Concrete (Fifth Edition), 2019

The aggregate being used should not contain more than 4% of silt as determined in laboratory by sedimentation test with Andreason Pipette Apparatus and more than 8% as determined by field test with measuring cylinder, as given in Appendix 'C' of IS: 383 - 1970.

Aggregates could be of a variety of materials or as used locally. These are broadly classified as coarse and fine aggregates. Some aggregates include river sand, gravel, crushed stone, and brick aggregates.

1.1.2.1 Sand

Sand is the most common type of aggregate used with lime. The sand should match the existing as much as possible. if the original type is unavailable then an appropriate replacement should be used as specified by the conservation architect.

Figure 1.2: Sand sieving

For the purpose of this document, the definitions given in IS: 1542 - 1992, Sand for plaster should apply. The sand should be hard, durable, clean and free from adherent coatings and organic matter and should not contain clay, silt and dust more than specified. Sand can be classified as coarse sand and fine sand.

Table 1.1: Grading of sand for internal wall or external wall or ceiling plaster (As per is: 1542 - 1992)

IS sieve size (see IS: 460 - 1985)	Percentage passing
10 mm	100
4.75 mm	95-100
2.36	95-100
1.18 mm	90-100
600 micron	80-100
300 micron	20-65
150 micron	0-15

i. Coarse Sand

This should be natural or crushed and clean, sharp, strong granular, and composed of hard siliceous material. It should be free from harmful impurities such as mica shale or similar laminated materials, salts, alkalies and organic matter.

ii. Fine Sand

This should be natural river sand clean, sharp, and free from deleterious matter. Fineness modulus of fine sand should not be less than 1.4 for crushed and 1.5 for natural sands as determined by the method described in the IS code. Since in some locations, fine sand is not easily available, it should be procured or prepared on site as per requirements with the available sand by appropriate local methods.

1.1.2.2 Stone Dust

As per the site requirements and as per the existing, stone dust should be obtained from crushing hard matching stone. Fineness modulus of stone dust should not be less than 1.8 as per IS: 383 - 1970.

1.1.2.3 Marble Dust

Matching marble dust should be obtained from crushing marble stone. It should not contain more than 4% of fine dust as determined in laboratory by sedimentation test with Andreason Pipette Apparatus and more than 8% as determined by field test with measuring cylinder, as given in Appendix 'C' of IS: 383 - 1970. As a rough measure, the crushed stone must be passed through an IS. Sieve set at 300 microns.

1.1.3 Additives

Additives improve the general properties like workability, plasticity of lime mortars and vary from region to region according to local practices. Additives may be added as per the conservation architects instructions after assessing the existing mixes, climate and other factors.

1.1.3.1 Pozzolana

Pozzolans are materials that are added to lime mortars to quicken its setting process. These materials contain clay minerals which have been heated to high temperatures (either naturally in the case of volcanic dust, or artificially in the case of clay bricks and China clay). They react with lime and water to form hydraulic compounds, similar to those occurring naturally in hydraulic lime. The most commonly used pozzolans are brick dust made by crushing and sieving well burnt bricks, volcanic ash and calcined China clay. Other pozzolans could include fly ash, volcanic ashes, Portland pozzolana cement, etc.

i. Surkhi or Brick Dust

In most parts of India, *Surkhi* is commonly used as a pozzolanic additive and should be used as per the local practices. *Surkhi* should be made from well burnt and over burnt brick. It should be clean and free from admixture of foreign matter. It should be ground to pass through a sieve of 3 meshes to a cm (8 meshes to an inch) with at least 50% of it passing through a sieve of 6 meshes to a cm (15 meshes to an inch.)

ii. Ashes

These should be obtained from furnaces of steam boilers, using coal fuel only. It should be clean and free from clay dirt, wood ashes or other deleterious matter. Cinder obtained from brick kilns should not be used. At site of work, the cinder should be protected from dirt collecting on it. It should pass through a sieve of 3 meshes to a cm (8 meshes to an inch) with at least 50% of it passing through a sieve of 6 meshes to a cm (15 meshes to an inch.)

iii. Cinder

Cinder is required to be used for external work such as plastering and in foundation concrete where it is likely to be affected by dampness, should not contain more than 10% of unburnt carbon (combustible matter) and not more than 0.5% of acid soluble sulphates (expressed as SO_3). For cinders required to be used in internal work such as mortar for walls and base concrete for floors, the allowable percentage for unburnt carbon should be up to 20% and that for acid soluble sulphates (expressed as SO_3) as 1%.

Figure 1.3 Types of natural or organic additives Top Left: Jute or Fiber; Top Right: Egg; Middle Left: Jaiphal or Nutmeg; Middle Right: Gud or Jaggery; Below Left: Gond or Gum; Below Right: Tesu or Plash

1.1.3.2 Natural or Organic Additives

Along with the main components, additives are often desirable and should be added to improve the properties of lime mortar. All regions in India have their own local practices and materials that are used to enhance properties. Examples: jute fibers, sugar compounds, fruits, pulses, milk products, eggs and seeds like *methi*. However, these are largely governed by traditional practices and knowledge systems and will require experimentation and laboratory testing to assess the enhanced properties.

As per IS: 2394 - 1984, to improve the binding properties of mortar, *guggal* (armyres agal locha) at the rate of 1.5 kg/cum of mortar may be added to the mortar for the first and second coat when it is being ground. Also a solution of *gur* at the rate of 25 g of water may also be added to the mortar when it is being worked before plastering. Fibrous materials, such as cattle hair, hemp, coconut or vegetable fibre, etc. may also be added at the rate of 1 kg/cum of mortar to improve its adhesive and binding properties which are specially required for undercoats.

Table 1.2: Additives and their properties

Product/Additive	Properties
Fibers	Tensile strength and to reduce shrinkage cracks
Belgiri	For water proofing
Molasses	Plasticity and workability Reduce setting time
Fruits	Workability
Pulses/Dal	Workability
Milk Products (Curd) - buffalo milk preferred high fat content	Binding and waterproofing
Egg Whites (Final Coat not Pozzolana)	Finishing – prevent cracks
Seeds (*Methi*)	Retarder
Reetha	Surfactant

1.1.4 Lime

There is a wide range of sources of lime available with varying properties and suited to particular applications. There are some limitations to the availability of particular limes so selection should be judiciously made keeping all factors in mind in the best interest of the structure.

1.1.4.1 Sources and Occurrence of Lime

A number of natural sources that are rich in calcium carbonate are used to produce lime. These include limestone, sea shells, *kankar* lime and may vary regionally. Limestone is the most widely used base material for manufacturing of lime in India because of its wide availability and geological diversity. This also results in varying qualities of lime obtained for building lime. The methods of burning, slaking, storing, the manner in which they are used in construction and conservation works differ from one part of the country to another. Lime may be obtained from various sources within the country based on specific requirements and proximity to the site of work.

i. Limestone

Limestone is one of the main sources for production of lime. It is a sedimentary rock composed mainly of calcium carbonate ($CaCO_3$) in the form of the mineral calcite along with impurities. Limestone often contains magnesium carbonate, either as dolomite $CaMg(CO_3)_2$ or magnesite ($MgCO_3$) mixed with calcite. Such rocks are termed as 'dolomitic' or 'magnesian' limestone. The limestone is burned in kilns and quick lime is obtained which is used in conservation as mortars after its slaking. These are mainly found in Karnataka, Andhara Pradesh, Rajasthan, Himachal Pradesh, Gujarat, Meghalaya and Chhattisgarh amongst others.

ii. Shells

'Limeshell', the thick calcareous shells of molluscs deposited in the form of beds as well as present in ancient lakes and shouldow seas. The shells contain calcium carbonate which are cleaned and burnt in kilns to produce shell lime. Kerala, Tamil Nadu and Karnataka are main shell producing states.

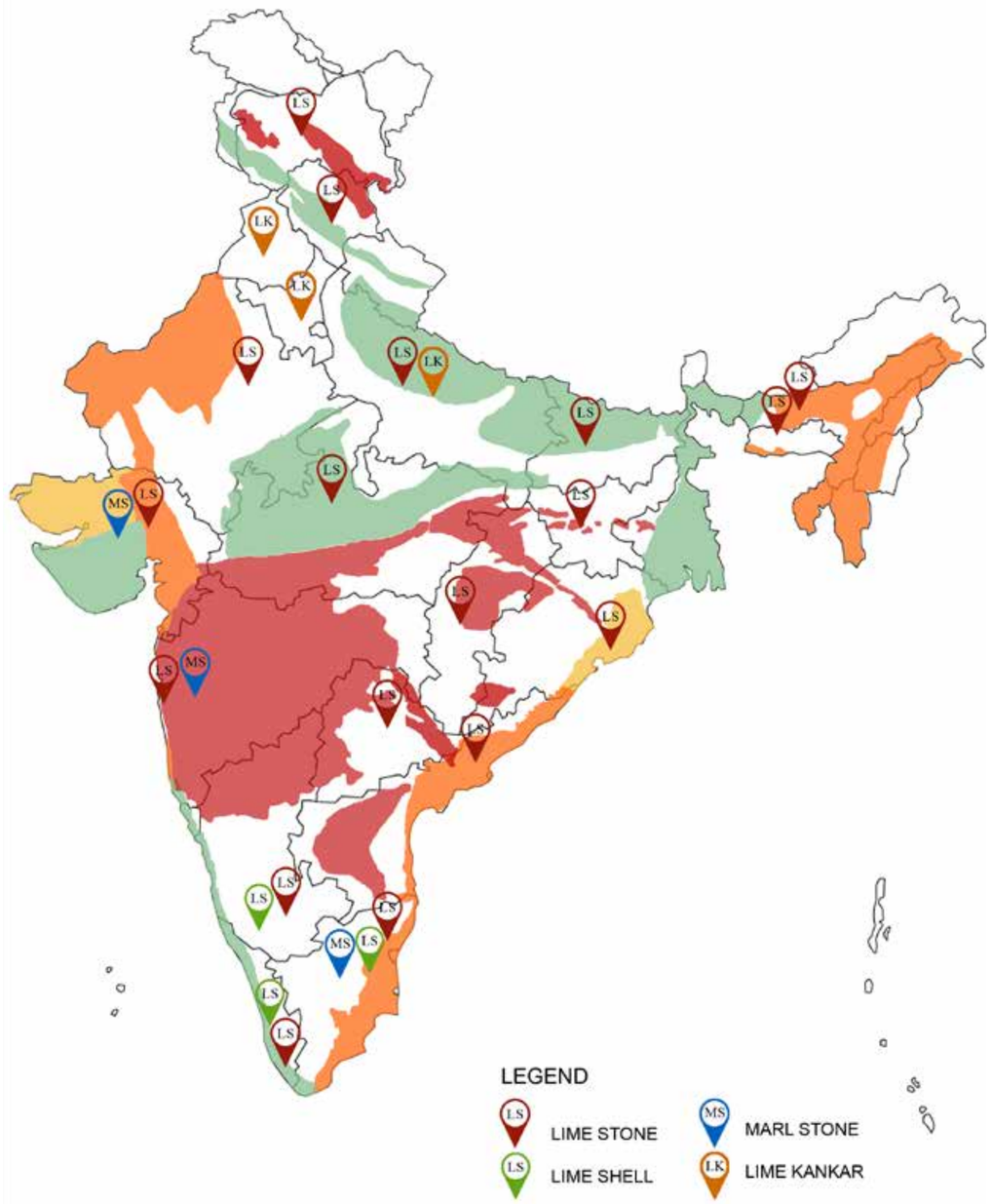


Figure 1.4: Sources of Lime in India
Source: Indian Minerals Yearbook 2017, LIMESTONE & OTHER CALCAREOUS MATERIALS

iii. Kankar Lime

Kankar Lime also known as red lime is obtained by burning *kankar*. Usually, *kankar* is found in the nodular form in the river sites under the surface of earth where the soil is damp and saline. It is an argillaceous stone and contains a kind of clay which is rich in iron. *Kankar* is also burned in kilns just like limestone to obtain lime. The completely burnt *kankar* is ground to fine particles and it is also termed as fine *kankar* lime. Semi burnt *kankar* lime can be used as coarse aggregate in lime mortar. Its nodular shape is such that it has interlocking ability with other constituent materials when are used in the mortar.

Kankar lime has hydraulic properties. It comes under the category of semi hydraulic lime as it has moderate hydraulic properties, however it can also work as a pozzolanic material when used in conjunction with non-hydraulic lime. Main states where *kankar* lime is available are Haryana Tamil Nadu and Andhra Pradesh. However, this is usually used in other industries and generally not available for construction and conservation works.

1.1.4.2 Types of Lime

i. Non-hydraulic Lime (NHL)

Limestone is one of the main sources to obtain non-hydraulic lime since it has a high calcium carbonate content. Non hydraulic limes do not set under water and are also referred to as high calcium lime, pure lime or fat lime. When small pieces of limestone (calcium carbonate) are burned in kilns, carbon dioxide from the limestone ($CaCO_3$) is released, leaving behind calcium oxide (CaO) or quicklime or unslaked lime or simple lump lime. For preparing mortars for conservation, quicklime is added to water in a process termed as slaking. Lime putty or slaked lime or hydrated lime ($Ca(OH)_2$) is produced as a result of slaking which can then be mixed with sand to form lime mortar, or with water and pigments to make lime wash. Non Hydraulic lime hardens or sets by a chemical process called carbonation by absorbing carbon dioxide in the air. During each of these processes the lime undergoes a chemical change and in the final stage, carbonation converts it back to calcium carbonate ($CaCO_3$), which is chemically and physically similar to the original limestone. This is known as the "lime cycle". Carbonation is a very slow process, so non-hydraulic lime hardens very gradually over several weeks or months, and it can take many months for it to achieve its full strength. In some instances, not fully carbonated lime has been obtained from thick walls, centuries later. If the lime mortar is not in contact with air, then carbonation will not occur. The hardening process can be accelerated by addition of pozzolanic additives.

ii. Hydraulic Lime

Hydraulic lime is a type of lime that sets under water, a property mainly attributed to the presence of impurities in the form clay. Hydraulic lime is prepared by burning impure limestones or *kankar* lime, which contain calcium carbonate and clay minerals such as silica and alumina, which become reactive when burned in the kiln, and combine with quicklime to form hydraulic compounds. Hydraulic lime gains strength faster than non-hydraulic lime, because the hydraulic compounds react with water to form solid compounds comparatively quickly. Though this type of lime is stronger, it is not easily available or produced in India.

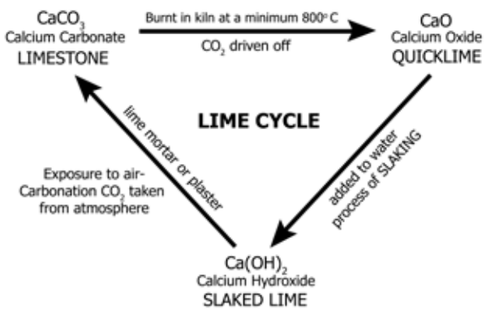


Figure 1.5: Lime cycle
Source: Guide to the use of lime in historic buildings, New Edition, Draft 2010

Hydraulic quicklime can be slaked with water in a similar way to non-hydraulic quicklime, but because hydraulic lime starts to harden by reacting with water, hydraulic lime putty would have to be used soon after slaking and cannot be stored for very long. In the past, the practice was to take hydraulic lime to the building site, where it was mixed with the right amount of sand and just enough water and subjected to grinding to make it usable.
One important point to note is that if hydraulic lime is being used to prepare mortars, it should be stored in airtight containers to prevent reactions with water vapour in the air, which initiates the strengthening process.

1.1.4.3 Preparing lime Mortars

The processes described here deal with non-hydraulic lime, except where mentioned otherwise.

i. Slaking

Tank Slaking

Lime putty should be prepared by adding quicklime (CaO) to water. A large watertight masonry or concrete tank as per site requirement should be filled with water as prescribed in IS: 1635 - 1992, to a depth of about 300 mm and to which quicklime should be added up to half the depth of the water. While quicklime is being added, water should be constantly stirred. The lime added should be levelled and completely submerged under water at all times. The slaked lime should be stored under water not less than 15 days and longer the better. This method directly results in lime putty and is thus suitable when the end product is required in this form.
For hydraulic lime, slaking should be done as soon as the lime is brought to site to avoid its air slaking or stored in airtight packaging.

Figure1.6 : Preparation of lime mortar

For providing continuous slaking operation at site, two tanks may be used, one 400 mm deep at a higher level above ground and other 750-800 mm deep at a lower level below ground. The slaking is done continuously in the higher tanks and the resultant milk of lime is allowed to flow, through 3.35 mm IS Sieve into the lower tank where it should settle and mature into putty. To obtain a continuous supply of lime putty, two or more tanks may be used at the lower level and used alternatively so that when putty is being used from one, fresh putty may be formed in the other.
It is important that in tank slaking, lime should be added to water and not water to lime. As lime slakes with evolution of heat, water begins to boil. More lime and water may be added till the desired quantity of lime has been achieved. After the apparent slaking is over, stirring should be continued for some time further to make sure that the whole of the lime has been fully slaked.
Where only one tank is used, the slaked lime is allowed to stand undisturbed in the tank. Milk of lime during this process loses moisture by evaporation and absorption and thus thickens.

Figure 1.7: Types of available lime

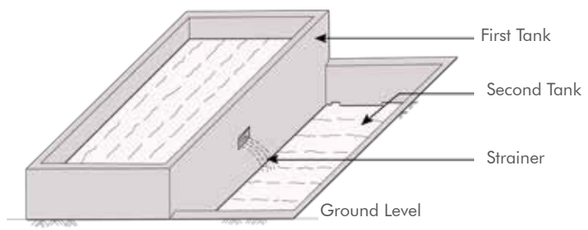


Figure 1.8: Slaking tank; Source: IS: 1635 - 1992

For maturing of lime putty at least 3 days should be allowed. This ensures complete slaking and at the same time improves workability. Lime putty should not be allowed to dry or stiffen till it is used.
Based on site observations, it is found that one volume of lime would require 8-10 volumes of water for optimum slaking.

Platform Slaking

This method of slaking converts the quicklime (CaO) into dry hydrated powder which can be used as it is or after converting it into putty. In this process quicklime is spread in a 150 mm thick layer on a water-tight masonry platform and water is sprinkled over it in small quantities through a rose can or with a hose pipe until lime disintegrates into a fine powder. As water is added, the heap of lime is turned over and over. Care should be taken that a minimum quantity of water is added as is required for complete slaking. Slaking should be allowed to continue further by itself for a period of about 24 hours or so. It should then be screened through a 3.35 mm IS Sieve. Slaked lime should be stored in a dry place under cover or may be packed in polyethylene lined gunny bags, well protected from rain.
Processed form of non-hydraulic lime is available as:

- Lime putty
- Lime as hydrated lime in dry powder form

The term 'hydrated' simply refers to lime which has been slaked, or in other words, 'hydrated' by combining with water. The terms 'hydrated lime' and 'slaked lime' mean the same.

NOTE: It is not a standard practice but if lime putty is already obtained ready-made in airtight boxes then slaking steps can be skipped and mixes for building conservation can directly be prepared. If powdered hydrated lime is obtained then slaking can be skipped as well.

ii. Mixing Lime Mortars

Mortars and plasters should be prepared by mixing and grinding lime putty, sand, *surkhi* or other pozzolanic materials in specified proportions. The mortar prepared should be used within the initial setting time. The ingredients in specified proportions should be measured using suitable equipment. Sand should be measured on the basis of its dry volume.

Manual Mortar Mill

Lime putty and sand should be mixed in specified proportions on water tight masonry platforms or in troughs. This should then be sprinkled with necessary quantities of water and ground in a masonry lined mortar mill. The mill should be constructed of first class bricks in lime mortar, the floor being laid on edge. The outer edge of the mill should be raised above the track followed by the driving animal/machine. The track itself should be sloped outward and kept well consolidated and watered. No dust or mud should be allowed to fall into the mortar being ground.

NOTE: Both hydraulic and non-hydraulic lime strengths can be improved by grinding. Grinding process increases the strength of the mortar. The strength of the mortar can also be increased by increasing the mix proportion to make a rich mortar. Beating and ramming can also be used instead of grinding.

The mortar should be kept damp and should on no account be allowed to dry. After the close of each day's work, mixing trough and pans should be thoroughly washed and cleaned. If the mortar is not being used immediately and required to be used later then it should be stored in containers or masonry tanks such that there is no contact with air and is kept under water. If the mortar has been exposed to air leading to its carbonation, then such mortar should be discarded and is not fit to be used.

NOTE: Adding pozzolans to this mix, quickens setting and should therefore only be added at the time of use. This mix should be immediately used.

Mechanical Mortar Mill

The mortar should be grounded for not less than 100 revolutions with one grinding wheel and 50 revolutions for a mortar mill with two grinding wheels. It should be raked up continuously during the process, particularly at the angles of mill. Water should be added as required during grinding. Care being taken not to add more water than that which should bring the mortar to the consistency of a stiff paste. Revolving drum cement mixer should be avoided since no pressure is applied and lime remains lumpy.

NOTE: As per site observations, it is found that a low rpm motor that produces 1 revolution in 5 seconds for minutes results in a good mortar mix.

Figure 1.9 : Mixing lime mortar

Hand Mixing

In cases, where small quantities of mortar are required, or space is a constraint, hand mixing can be used. However, since this reduces the strength of the resulting mortar, beating and ramming can be employed to improve the strength of the mix.

1.1.4.4 Precautions and Care

- The slaking operation must be carried out slowly and carefully.
- Lime mortar can cause burning sensation and should be handled carefully using appropriate safety gear.
- The slaking process may become fierce and involve spitting of unslaked particles.
- Eyes must be protected with the use of goggles and hands with suitable gloves.
- Anyone not using protective gear must be kept away from the slaking tank.

1.1.4.5 Delivery, Storage, and Handling

a. Quick lime or slaked lime delivered to site should be stored in the original unopened packaging until use.
b. Protect all materials during storage and construction from adverse conditions.
c. Lime putty may be stored for a minimum two weeks, provided it is protected from drying out by keeping the lime putty submerged under water at all times, avoiding contact with air.
d. Lime putty mixed with sand should be stored such that it does not come in contact with air.
e. Sand should be stored in a dry space and in a manner free from contamination by other site materials.

1.2. USES OF LIME IN HERITAGE STRUCTURES

Lime is used in mortars, plasters and for lime concrete in heritage structures. Mortars have been traditionally used as bonding material for masonry while plasters have been used to finish interior and exterior surfaces.

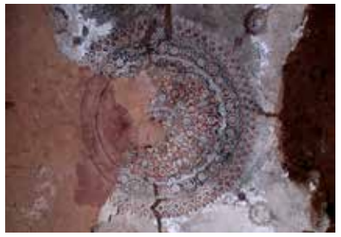
Table 1.3: Uses of Lime in Heritage Structures

Mortars		
Plasters		
Decorative Elements (Cornices, Medallions, Ribs, Squinches)		
Lime Concrete		
Lime Finishes		

1.3. DEFECTS

Lime plastered surfaces and lime pointed exposed masonry is susceptible to damages and issues like poor detailing, lack of maintenance, dampness, inappropriate materials specifications, environmental factors and poor-quality work. The defects should be assessed and diagnosed before applying corrective measures. Most typical issues with bricks are listed below but the list is not exhaustive. For each site the conservation architect and engineer-in-charge should prepare their own list/record of defects using the table below as a baseline, assess them and formulate the conservation treatments accordingly.

Table 1.4: Defects of Lime

DESCRIPTION	PHOTOGRAPHS	CONSERVATION
Cracks		Refer 1.5.1 Minor Crack Repairs
Loss of Plaster Coats A. Missing Top Coat		Refer 1.5.2 Replastering Refer 1.5.7 Lime Wash
B. Complete loss of all coats		Refer 1.5.2 Replastering Refer 1.5.7 Lime Wash
Loose Plaster		Refer 1.5.2 Replastering Refer 1.5.7 Lime Wash
Delaminated Plaster		Refer 1.5.2 Replastering Refer 1.5.7 Lime Wash
Small Voids or Loss		Refer 1.5.3 Patch Repairs
Open joints (deteriorated or no mortar)		Refer 1.5.4 Repointing
Wide Cracks in Masonry		Refer 1.5.5 Grouting
Missing Elements Damaged Elements (Decorative)		Refer 1.5.6 Plastic Repairs for Decorative Elements

1.4. TESTS

It is essential to study and characterize the lime that needs conservation treatments and match it to the new proposed mixes. The tests are performed to understand the properties of existing mortars so that a good match can be designed in terms of visual and physical properties and with similar composition. The replacement mortar should be matched to the original mortars since the original formulation may not be suitable since it has gone through weathering and deterioration.

- The lime mortars for conservation works for conservation treatments and replacement should be correctly matched for compatibility and other characteristic properties through tests as suggested by the conservation architect. These include matching visual, physical and chemical properties.
- Tests also aid in ascertaining the issues with the existing lime mixes and should be used to make informed assessments to ensure appropriate treatments.
- These tests should be done under the guidance of a conservation architect or engineer-in-charge and should be conducted either in the field or by laboratory analysis.
- The tests should be performed using current IS Codes provided by Bureau of Indian Standards.
- If the tests are not available in the IS Codes then international standards could be followed under conservation architect's guidance.

REFERENCES FOR TESTS

ASTM International (American Society for Testing and Materials)
ICCROM ARC: A Laboratory Manual for Architectural Conservators Methods
Built heritage Evaluation- Manual Using Simple Test Conservation of Historic Stone Buildings and Monuments

1.5. CONSERVATION

Structures built using lime mortars may require different treatments based on the issues and level of deterioration. Some procedures are described below as a starting point and can be modified to suit or match individual site requirements.

1.5.1 Minor Crack Repairs

Minor or narrow cracks in plaster may be filled as short term solution if the entire wall is not being re-plastered immediately. This helps stabilise the plaster around the cracks and avoids further deterioration. Minor cracks could be treated by filling with a grout and patching with lime mortar used for pointing. A strong patching mortar should be avoided and well graded fine aggregates should be used to help to keep the shrinkage to a minimum.

a. Cleaning: Clean the crack of any loose debris or residual material with soft brushes and hand tools
b. Routing: Route the crack and clean any loose material with hand tools.
c. Wetting: Spray water in the crack void and dampen the area to avoid immediate suction of the new materials.
d. Preparing grout and patching mortar: Prepare the grout and patching material to match the existing colour and texture as specified by the conservation architect. Adhesives may also be used in place of a grout if specified by the conservation architect. Grouting may be completely avoided if specified by the conservation architect and if the crack is wide enough to receive only the patching mortar.
e. Injecting grout: Inject the grout in to the crack and finished with applying patching mortar by working the material into the crack with some pressure.
f. Cleaning: Clean the surrounding area after patching.

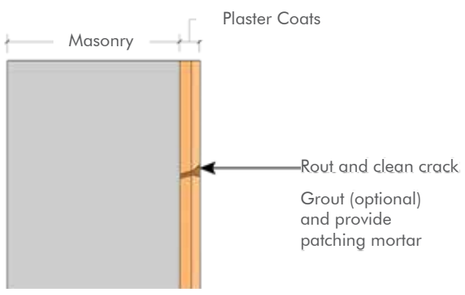


Figure 1.10: Minor crack repair

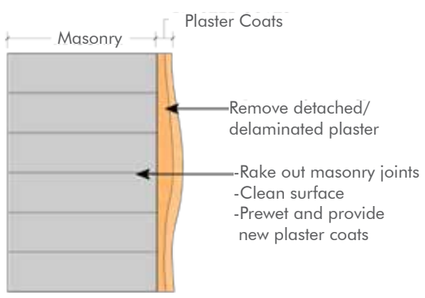


Figure 1.11: Replastering for delaminated/detached plaster

1.5.2 Replastering

Replastering damaged or missing sections of plaster should apply to plain plaster and not decorative or ornamental works.

Plastering should be executed to match the existing plaster as specified by the conservation architect or as per IS: 2394 -1984.

a. Surface preparation: Remove the loose plaster that is damaged (delaminated or detached or loose) or missing and requires replacement.
b. Preparation of surface: Clean surface or substrate beneath to remove loose material that may affect adhesion or application of new plaster. Clean surfaces using brush to remove foreign matter dirt and loose particles. Joints should be raked to a suitable depth or as specified before applying the first coat.
c. Pre-wetting: Wash and wet the substrate surface with clean water using a spray pump. If the wall is very dry, wetting should be started a day before, and then once again. If the wall is not very porous and the environment is relatively humid, spraying with a hand-held spray on the day of application should suffice. The spraying helps to prevent immediate absorption of water from the mortar. The substrate should be damp to touch before the application but not too saturated.

Figure 1.12: Application of lime plaster comprises varying stages depending on the issue.

d. Dubbing or filling: Fill or dub any depression or holes present on the surface to be plastered by using by using a stiffer mix. Apply the plaster shall be applied after this filling has dried.
e. Application: The number of coats should be determined on the basis of evidence of existing plaster through investigations & documentation or on the basis of desired finish and thickness if the evidence is not found. To determine the average thickness of plaster required on the existing surface *thayiya/*marker should be performed to get an even surface. The average thickness so worked out will determine the numbers of layers. One coat is usually considered adequate. Two coats should be applied for a good finish. The third coat is necessary if the base surface is uneven and rough.

When no evidence is found or there is no clarity on coats, the number of coats should be applied as per IS: 2394 -1984. Following range of coats are usually employed for different backgrounds while ensuring that the wall is in plumb:
Number of coats is dependent on the thickness required, because each coat of plaster should not be more than 12-15 mm thick.

Table 1.5: Coats for plastering; Source: IS: 2394 – 1984

Brickwork (internal or external)	1 OR 2
Stonework (internal or external)	2 OR 3
Wood lath	2 OR 3
Soffits and ceilings	1 OR 2

1.5.2.1 Single Coat Plaster

Apply plaster in long even spreads upwards and across, overlapping each trowel full. Lay the plaster a little more than the required thickness and then level with a timber float. Beat the coats with thapies or tapers to compact or remove shrinkage cracks. The plaster shall be of specified thickness and carried out to the full length of wall on to the natural breaking points like doors and windows. Make sure that the mortar used for plastering is stiff enough to cling and hold when laid; for ceilings the mix is required to be stiffer than for walls using sufficient pressure to force it into contact with the base. The first and strongest coat is mostly be 12 mm – 20 mm thick or as specified. It should be finished as required in case no other coats are specified.

1.5.2.2 Multi Coat Plaster

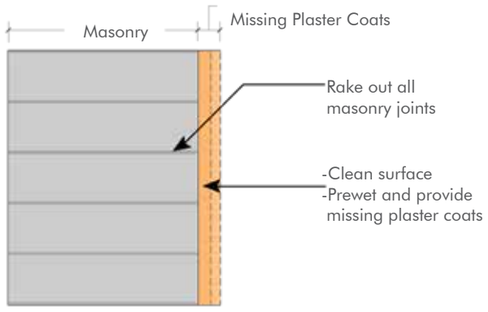


Figure 1.13: Replastering for missing or damaged plaster (all coats)

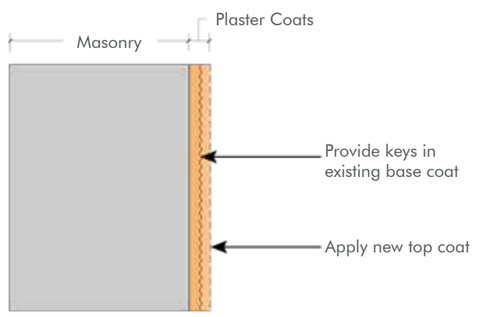


Figure 1.14: Replastering when few coats are missing.

i. Base Coat

Apply the base or the scratch coat to a nominal thickness as found in existing using the method as described in 5.2.1. This is the coarse layer is to be applied roughly and evened using timber floats. While still damp, scratch the surface with a broom to act as a key for the next coats. Leave this coat for a minimum of 3-5 days and longer depending on the weather conditions to set or carbonate before applying the next coat. A timber mallet should be used to ram the surfaces to reduce the shrinkage cracks.

ii. Successive Coats

Once the scratch coat is ready to take the next coat, brush it down to remove any loose grains and then lightly dampen it with clean water, using a hand-held spray. Apply the next coat which consists of finer composition than the base coat to a uniform surface. If more coats are desirable or was documented at the site, then after this coat, successive coats can be applied using the same methodology. The final coat is composed of very fine materials.

Leave the undercoats for at least two days, preferably seven days to ensure that the initial shrinkage is over before the next coat is applied. Tests for adhesion and strength must be performed before the next coat is applied, and the surface lightly sprayed to reduce and control suction immediately before application. The top coat should be finished with a timber float.

1.5.2.3 Lime Punning

i. Using sand

This coat should consist of equal lime and sand. The undercoat of the surface where punning is to be applied should be rough. This layer should be very fine and applied after the undercoat has dried. It should be finished smooth by using a plasterer's trowel. All corners, angles and junctions should be truly vertical and horizontal and should be carefully and neatly finished. Rounding of corners and junctions should also be punned. Curing should be done after 24 hours of punning. It should be kept wet for 7 days and during this period protection from weather should be provided.

ii. Using Marble Dust

This coat should consist of equal parts lime putty and marble dust. Punning layer should be provided to match the existing finish both in colour and fineness as found or documented at the site. Generally, a very fine layer of 1-2 or 3 mm should be used. For a coloured finish, desired organic pigments should be added where evidence of this is found like red oxide, mercuric sulphide, yellow oxide, dry *tesu* flowers, etc. Punning without colour is used as a finishing layer, often mimicking marble by polishing it using natural fibers to give a shine.

Figure 1.15: Lime Punning

Figure 1.16: Plastic Repairs

1.5.3 Patch Repairs

For small plaster damage it is not advisable to re-plaster the whole wall. Small damages or holes upto 2.5 sq. metre should be patched. The mortar of the patch where the existing plaster has cracked, crumbled and sounds hollow when tapped gently on the surface should be removed.

a. **Removing deteriorated plaster:** Cut the patch to trace the damaged area only. Ensure that edges are undercut or slightly inclined to provide overlap or key for the patch plaster.
b. **Preparation of surface:** Rake out the masonry joints which have become exposed after removal of damaged plaster to a suitable depth or to the depth where the mortar has found to have lost their strength.
c. **Raking:** Rake out the masonry uniformly with a raking tool to remove any loose mortar.
d. **Cleaning:** Scrub the surface of the masonry with coir or wire brushes to clean it of loose mortar. Wash the surface thoroughly with water and keep it wet before plastering is commenced.
e. **Application of plaster:** The method of application as described for single coat plaster work (Refer 1.5.2.1) may be used. Finish the surface and flush it with the old surrounding plaster. .

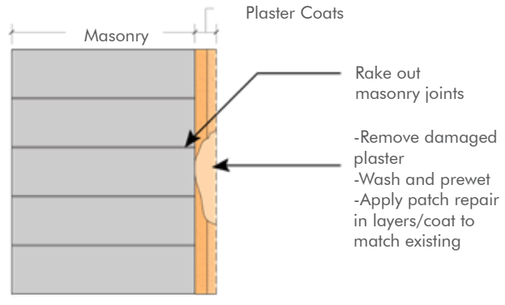


Figure 1.17: Patch repairs

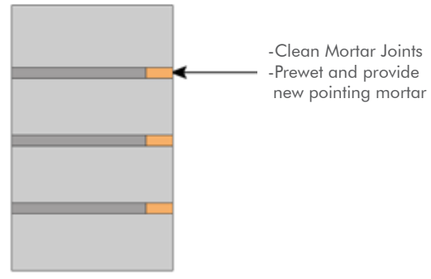


Figure 1.18: Repointing for deteriorated or open joints

1.5.4 Repointing

Repointing is the process of replacing deteriorated or missing mortar with new mortar to match the existing.

- Pointing is applied between the joints to finish the masonry work. The main function of the pointing mortar in the masonry is to prevent water penetration through the joints therefore the pointing mortar shall be carefully selected so that it protects but still allows the wall to breathe.
- The strength of the mortar should always be less than the surrounding masonry work and should be considered as a sacrificial element of the wall to be replaced when deteriorated.



Figure 1.19: Stages of pointing in stone masonry

- For exposed masonry, if the mortar joints are eroded or damaged, falling from the joints or soft and crumbling new pointing shall be provided after removing the old and deteriorated mortar.
- Provide temporary support where necessary to prevent displacement of masonry during repointing. Install necessary protection for adjacent building materials, property and persons from joint cleaning work and dirt.

Figure 1.20: Raking out joints

Figure 1.21: Repointing

a. **Removing existing mortar:** Remove and clean existing deteriorated mortar, loose dirt and debris cleaned using a stiff bristle brush. Any other material that has been used in the joints in the past should also be removed. Cut and rake old mortar from existing joints using appropriate hand tools to a specified depth up to a sound base to provide maximum surface for pointing. Care should be taken that existing masonry joints and edges are not widened, damaged or chipped in the process of mortar removal. Clean out the prepared surface with a soft or stiff bristle brush or by blowing the joints clean.

b. **Prewetting:** Wet the joints with water as per weather conditions and as required. This prior wetting of the joints is necessary before pointing to reduce immediate absorption of water from pointing mortar. Dampen the masonry units but without standing water at the time of pointing. Ensure that hand mister bottles or a garden sprayer with clean, clear, potable water is available to masons at all times during the repointing process. To prevent erosion of joints during the prewetting process, ensure only a very low pressure sprayer (garden adjusted to a fine, low-volume mist) is used to prepare large surface area.

c. **Pointing of joints:** Point the joints in layers or lifts where the joints are deeper than 20 mm. Joints greater than 20 mm deep should be filled with an initial lift to bring the joint depth to a uniform 20 mm deep. Compact each layer at the time the mortar is placed in the joint by applying firm pressure with the pointing tool. Allow each lift to become hard before applying the next lift. Leave the surface of the masonry clean. Prevent mortar from drying out too quickly. Mist walls with water to ensure slow curing of the lime mortar.

d. **Cleaning:** Clean the wall surfaces and joints after the process of pointing is complete.

1.5.5 Grouting

Grouting should be used to fill large wide cracks, voids and consolidate loose masonry cores as specified by the conservation architect and under supervision of the engineer-in-charge. It is considered to be a very mechanically efficient intervention technique. This technique is especially effective when applied to masonry with large cross sections or with many layers like three-leaf masonry with stones, bricks and mortar. An appropriate grout prepared under an engineer-in-charge's supervision can help in filling the cracks, the voids in the masonry.

Figure 1.22: Cracks in the ceiling, repaired by grouting

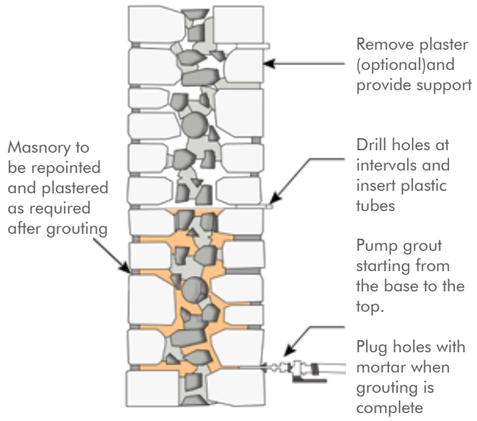


Figure 1.23: Grouting
Source: Building Conservation: Grouting Solid Masonry Walls.

The application of grouts consists of several steps given below:

a **Structural support:** The structure to be grouted must be supported adequately to make sure that the structural integrity of building is not compromised during the grouting process.

b **Preparation of masonry:** Remove the plaster from the masonry to receive grouting and to allow for better sealing of cracks and for repointing (if needed).

c **Prewetting:** Prewet the area to be consolidated so that the dry masonry doesn't suck the grout immediately.

d **Removal of loose material:** Remove all loose material and debris around the cracks and clean to allow for their opening to be visible.

e **Drilling holes:** Drill the holes as specified by the engineer-in-charge that are deep enough and at adequate distance from each other for injecting the grout into the core of the masonry. The holes should be drilled on both faces of masonry wherever possible, to form a grid but holes on one face should not coincide with the holes on the other face. The distance of consecutive holes will depend on the type and the thickness of masonry, as well as on the damages and should be specified by the engineer-in-charge. Holes are normally drilled in mortar joints and inclined downwards.

f **Installing tubes:** Install transparent plastic tubes (of a diameter equal to 10.0 mm or as specified) in all drilled holes. When decorative plaster or elements are present or in case of fine cracks, the diameter of the plastic tubes should be smaller. The tubes with their locations and sizes should be numbered and documented.

g **Grout preparation:** Suitable grout should be prepared in consultation with the engineer-in-charge and conservation architect with adequate properties like compatibility, injectability and penetrability.

h **Pumping the grout:** Pour the grout into a vessel equipped with a mechanical device of low turbulence to gently stir the grout during injection. Pump the grout into masonry using a flexible pipe with a nozzle of adequate diameter at its end equipped with a manometer (to control the pressure). The grout should be injected at low pressure as specified. Grouting should be done at various intervals along the length of the wall in the holes already drilled, starting from the base of the wall in order to ensure that the grout fills all internal voids. Maintain thorough documentation for tubes from which grout is introduced to or comes out from masonry along with the consumed grout quantity.

i Once grouting is completed, and the masonry is adequately cured, cut the protruding length of plastic tubes and plug with pointing mortar. Repoint or replaster the masonry to match the existing or as required and specified.

NOTE: In case of vulnerable structures, grouting should not be performed to a height of masonry exceeding approximately 1m per day, in order to avoid excessive internal (hydrostatic) pressure of the grout that could damage the masonry.

1.5.6 Plastic Repairs for Decorative Elements

(Mouldings, Cornices and Architraves)

All treatments to decorative elements should be provided to match the existing. As far as possible, the aim is to retain the maximum amount of original material. Every attempt should be made to treat only the areas of loss or damage using the process described for Patch Repairs (Refer 1.5.3). However, owing to the significance of the decorative work, this process requires more precision to match the existing decorative elements and further steps as described below. This work should be carried out only by trained master craftsmen with sufficient experience, as per the approved sample.

a. Preparing the patching material: Prepare the patching material using a wide range (well graded) aggregate, so that the smaller size grains fill the voids between the larger grains reducing the percentage of void to a minimum. Coarse material may be unacceptable for very fine patterns and mouldings. When coarse aggregate has to be omitted, it is very important to take great care in mixing with the lime mix, to ensure that all the aggregate grains are covered with mortar. To achieve a workable mix, add the least amount of water necessary. It is important to do mock-ups before applying a plastic repair to the area of loss or damage.
b. Application of plastic repair: Prepare a stencil or mould as applicable to match the existing design. Protect the surrounding decorated surfaces from the plastic repair material by use of sheets or any suitable material to prevent any damage during the course of work. The number of layers required will be determined by the existing plaster layers but care should be taken that the completed plastic repair matches the original in all respects including shape, size and finish.

Figure 1.24: Plastic repairs to recreate a missing medallion

1.5.7 Lime Wash

Lime wash popularly known as white wash is a very common finishing technique using lime.

Refer IS: 6278 - 1971 for Lime wash.

a. Preparation of lime wash: Slake the lime at site and mix and stir with about five litres of water for 1 kg of unslaked lime to make a thin cream. Allow this mixture to stand- for a period of 24 hours and screen it through a clean coarse cloth. Add 1 kg of gum dissolved in hot water to each cubic metre of lime cream. About l-3 kg of sodium chloride dissolved in hot water may be added for every 10 kg of lime.
b. The Surface preparation: Treat and plaster all surfaces as necessary to prepare a sound base before applying lime wash. Clean the surfaces of dust or any other deposits. Then pre-wet the surface before applying lime wash. .
c. Application: Apply the whitewash with *moonj* brush or other brush to the specified number of coats. Lay the coats horizontally (left to right) and vertically (top to down) covering all the surfaces uniformly. No patching should be done later. Whitewash the previously treated and patched areas first. Then apply one or more coats to the entire surface till a smooth uniform surface is achieved. For new work (plastered) three or more coats may be applied till the surface has achieved a smooth uniform finish, last coat being applied vertically.

Colour wash

To obtain a coloured wash, pigments may be added to match the existing finishes as given below. Mineral colours not affected by lime may be added to the whitewash solution. Natural pigments are usually preferred and may be used as specified by the conservation architect to match the existing or as per local practices.

NOTE: Sufficient quantity of colour-wash enough for the complete job could be prepared, where possible, in one operation to avoid any difference in shade.

Some commonly used pigments include and should be used as per the IS Codes.

- Yellow and Red Ochre
- Blue Vitriol
- Ultramarine Blue or Indigo

1.5.8 Other Plaster Finishes

As per the availability of lime and craftsmen various techniques are used regionally to achieve fine finished surfaces with lime plaster. These techniques as per regional or local practices should be used wherever possible and available with resources.

i. Madras plaster:

This is a special plaster finish applied in three or more coats to obtain a smooth polished surface in places where shell lime and fine sand are easily available.

ii. Araish:

This finish provides an extremely smooth and glossy plaster surface for various building elements such as walls, ceilings floors. Though this technique is used in many parts of India, the process of preparation and its application techniques varies region to region.

iii. Chettinad plaster or *Vellai Poochchu* or *Muthu Poochch*:

As the name suggests, this plaster is from the Chettinad region in Tamil Nadu and uses lime and egg as the main materials. It is extremely smooth and has a sheen on its surface.

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BRICK WORK (FIRED)

CONTENTS

2. BRICK WORK (FIRED)

This chapter provides information and guidance on conservation treatments for brickwork in heritage structures. The conservation treatments should be carried out in consultation with a conservation architect and engineer-in-charge as per the requirement. This chapter will only apply to fired or baked bricks. Chapter 4, Earth/Mud Work should be referred to for unfired mud bricks/Adobe.

2.1. MATERIALS

Materials used for conservation of brick work are given below.

2.1.1 Water

Water should be clean and free from contaminants such as oil, acids, alkalis, salts, sugar and vegetable growth. It should meet the latest standards IS: 10500- 2012 for Drinking Water. Only potable water should be used. Sea water or tidal estuary or brackish water should not be used for any conservation works.

2.1.2 Mortar

The mortar for the brick work should be as specified and conform to accepted standards. The proportions of the mortar to be used in conservation will be based on site requirements and established from samples at site. Mortar should also be matched as closely as possible in colour and texture with the existing through a mortar analysis and other relevant tests. If unable to find an existing sample, then mortar specified should follow the guidelines mentioned in in chapter 1, Lime Work or chapter 4, Earth/Mud Work or as specified based on particular site requirements. It should generally be ensured that the mortar for the repair is of the same strength or weaker than the existing brick.

2.1.3 Brick

Bricks for repair and replacement

- For conservation of brickwork, replacement bricks should be procured or fabricated to match the characteristics of existing bricks as closely as possible. Bricks used in heritage structures don't have fixed or standard sizes so it may be necessary to have replacements specifically manufactured for the work. This should be applied especially when special shapes are required.
- It is also possible to modify, cut and shape the bricks to match the existing. However, cutting will increase the surface area of the brick exposed to weathering, and is generally not preferred for exposed brickwork.
- New bricks should match the dimensions, size, shape, texture and colour range of existing bricks. The new bricks produced after matching the existing should be approved by the conservation architect or engineer-in-charge. New bricks for conservation should conform to IS: 1077- 1992, hand-moulded or as specified and should be made from suitable soils. They should be free from cracks and flaws and nodules of free lime.
- If it is possible to secure salvaged bricks, the same should be used in conservation work subject to the approval of the conservation architect. Salvaged brick should be sound, free from chips and gouges on exposed faces. Color range and fabrication markings should match with those of the adjacent bricks. Remove mortar from all faces of salvaged bricks to ensure full contact with new mortar. They should be free from fungus, have no deep or extensive cracks, damaged corners or arises, and are free from old mortar. Any replacement bricks should not exceed approved variations in colour, texture and other characteristics of approved samples. Pick the best possible sample of the original for matching.

i. Lakhori

Historically, baked bricks have been used since ancient times with varying shapes sizes and technology for manufacturing, elaborately documented in historical texts and archaeological sites. During medieval times baked bricks or lakhori bricks have been used for construction. These are flat thin red coloured burnt clay bricks without frogs that became increasingly popular element of Mughal architecture but were developed during the *Ghurian* (12-13 C) period to construct structures with typical elements such as domes, arches, mouldings, cornices, cladding and facing etc. It was easy to create intricate patterns due to the small thickness of *Lakhori* bricks. Since these were made with hand for specific sites, no standard sizes are documented, though a broad range of sizes are seen. The composition also varies regionally as also the size. Some other regional names include *nanakshahi* in Punjab and *badshahi* in Kashmir.

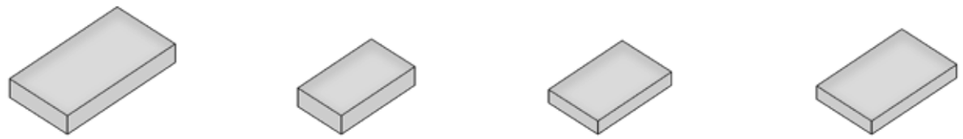

Figure 2.1: Brick sizes as documented in Punjab and Haryana
190x100x35, 130x75x35, 130x85x25, 150x95x25
Source : INTACH Directory of Traditional Building Crafts of India: Volume 2 Building with Bricks Punjab & Haryana, 2020

Lakhori bricks fall in this range but exceptions are also found pan India.
Type 1: (150-200) X (90-120) X (25-40)
Type 2: (100-140) X (110) X (25-30)

ii. Gauged and Moulded Bricks

Use of special bricks is seen in cornices, projecting courses, moulded elements and decorative features. Some of these were moulded or and cut or chiseled prior to firing to fit the design requirements. For conservation works, where necessary, these can be obtained by special orders with specific shapes, sizes and designs. When it is not possible to procure special sizes or for smaller repairs, these can be obtained by shaping available bricks to the required sizes. However, this is not recommended for exposed brick masonry. If this is to be done for exposed masonry, care should be taken that the cut surfaces are not exposed to weathering and embedded into the masonry

Figure 2.2 : Moulded bricks as documented in Punjab and Haryana.
Source : INTACH Directory of Traditional Building Crafts of India: Volume 2 Building with Bricks Punjab & Haryana, 2020

iii. Tile Bricks

Brick tiles are often used in conservation of historic brickwork as replacement of Lakhori bricks are not available. Tile bricks, newer or historic, generally conform to a thickness of 1 1/2 -2" or 4-5 cm, are moulded without frogs and are very similar to Lakhori bricks.

iv. Brick Bats

During repairs when required, brick bats should be obtained from well burnt bricks. Any portion of a brick, cut or broken across its length usually known according to its fraction from the whole size, for example, ½ bats, ¾ bats, etc.

v. Common Burnt Clay Bricks

These should conform to IS: 1077- 1992 and should be hand moulded. They should be free from nodules of free lime, visible cracks, flaws, warpage and organic matter. Newer bricks may have a frog 100 mm in length 40 mm in width and 10 mm to 20 mm deep on one of its flat sides. Historic bricks retrieved from older structures may be used without frogs.

2.1.3.1 Occurrence of Brick

Bricks have been a popular construction material across the areas with good soil especially alluvial and black soil. Bricks are also a typical characteristic of areas with lack of stone for construction. Areas with brick manufacturing and construction include but are not limited to Kashmir, Punjab, Haryana, Delhi, Uttar Pradesh and Madhya Pradesh, Maharashtra, West Bengal and Bihar.

2.1.3.2 Precaution and Care

Precautions and care while handling brick should be as specified section 6, Precautions and Care in chapter 1, Introduction

2.1.3.3 Delivery, Storage, and Handling

Proper packaging, delivery, handling and storage of brick helps to prevent breakage, cracking, chipping, spalling and other damages.

a. Bricks should be stored on a firm dry, flat surface and should avoid direct contact with the ground should be avoided..
b. Bricks should be placed in a manner that facilitates easy handling and allows adequate air circulation around the bricks.
c. Bricks should be loaded or unloaded with care, and should not be thrown or dumped.
d. Bricks should be stacked in regular tiers even as they are unloaded, to minimize breakages and defacement of bricks.
e. Bricks of different types and selected for different purposes should be stacked separately.
f. Blocks should be placed close to the site of work so that least effort is required for their transportation.
g. Bricks should be carried from the stack to the site of placement in small batches as and when necessary.

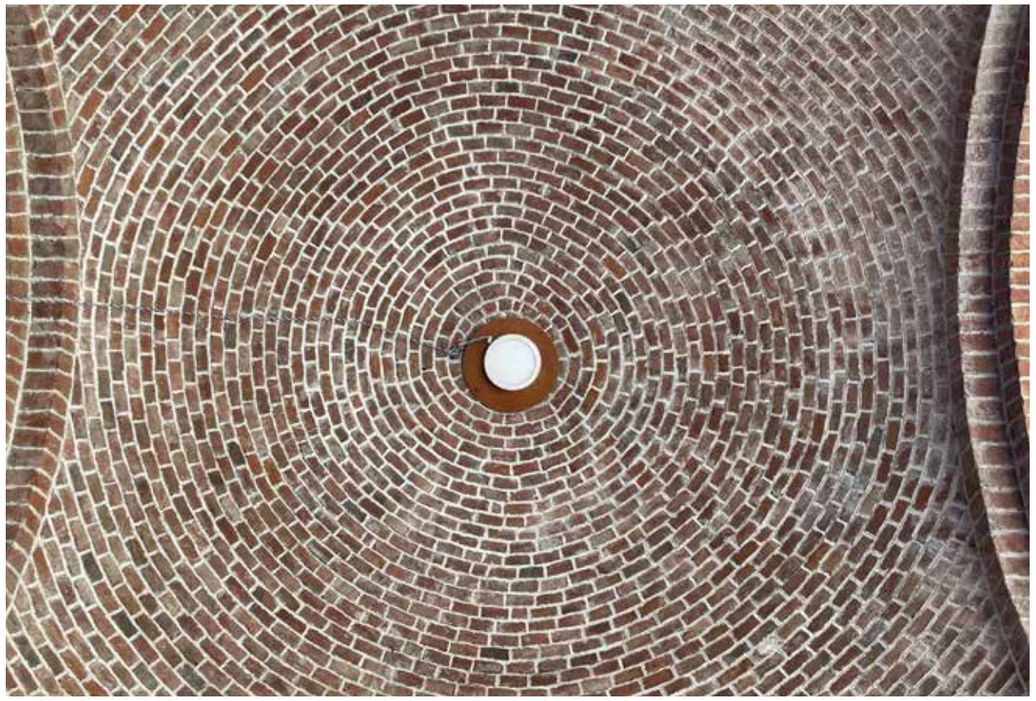

Figure 2.3: Brick Roof

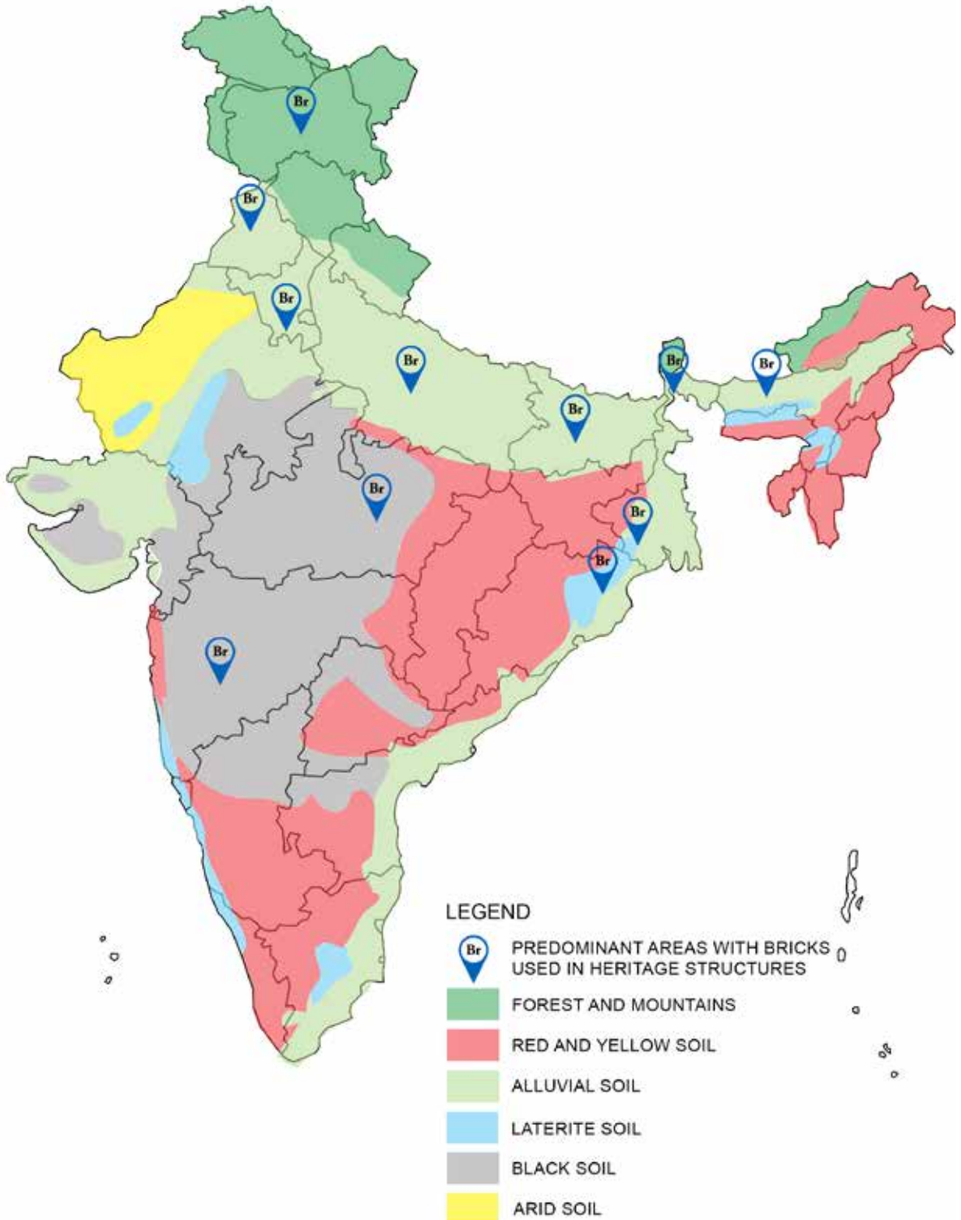

Fig 2.4: Soil types and brick occurrence in India
Source: Modified from soil and land use survey map of India

2.2. USE OF BRICK IN HERITAGE STRUCTURES

Table 2.1: Uses of Brick in Heritage Structures

Walls Exposed		
Walls Plastered		
Arches		
Domes		
Floors and Steps		
Decorative Elements		

2.3. DEFECTS

Brick masonry may have many issues due to reasons like weathering and decay, material aging clubbed with lack of maintenance, environmental factors (including pollutants), water penetration, structural faults, defects in original construction, manufacturing defects, vegetation, particularly micro bio growth, etc. The defects should be assessed and diagnosed before applying corrective measures. Most typical issues with bricks are listed below but the list is not exhaustive. For each site the conservation architect and engineer-in-charge should prepare their own list/record of defects using the table below as a baseline, assess them and formulate the conservation treatments accordingly.

Table 2.2: Defects of Brick

DESCRIPTION	PHOTOGRAPHS	CONSERVATION
Minor Cracks		Refer 2.5.1 Minor Crack and Surface Repairs
Spalling		Refer 2.5.1 Minor Crack and Surface Repairs
Loose Brickwork		Refer 2.5.2 Resetting

DESCRIPTION	PHOTOGRAPHS	CONSERVATION
Deteriorated Pointing or Open Joints		Refer 2.5.3 Repointing
Loose Masonry Cavity		Refer 2.5.4 Grouting
Cracks through Brick Masonry		Refer 2.5.5 Stitching
Deteriorated Brickwork		Refer 2.5.6 Restoration of Brickwork

DESCRIPTION	PHOTOGRAPHS	CONSERVATION
Decorative Elements		Refer 2.5.8 Conservation of Decorative Elements

2.4. TESTS

- In order to correctly match the properties of existing bricks to the new bricks, tests should be performed. These include matching visual, physical and chemical properties to find properties that are compatible compatibility for conservation works.
- Tests also aid in ascertaining the issue with the existing bricks and brickwork and should be used to make informed assessments and to ensure an appropriate repair.
- These tests should be done under the guidance of a conservation architect or engineer-in-charge and should be conducted either in the field or in laboratory.
- The tests should be performed using current IS Codes provided by Bureau of Indian Standards.
- If the tests are not available in the IS Codes then international standards could be followed guided by the conservation architect or engineer-in-incharge.

REFERENCES FOR TESTS

ASTM International (American Society for Testing and Materials)
ICCROM ARC: A Laboratory Manual for Architectural Conservators Methods
Built heritage Evaluation- Manual Using Simple Test Conservation of Historic Stone Buildings and Monuments

2.5. CONSERVATION

Conservation treatments to brickwork should be selected after correcting the underlying causes. This section presents treatments techniques for conservation and should be modified for individual site requirements.

2.5.1 Minor Crack and Surface Repairs

The surface treatments should be carried out after finding out the reason for surface deterioration and correcting it. Surface treatments of brickwork may involve patching with matching material or replacing the surface using brick slips. The choice of treatments method will often depend on the severity, location and the ease with which cutting out may be achieved.

2.5.1.1 Brick Patching or Plastic Repair

The use of plastic or mortar repairs is often used to treat damaged/deteriorated or spalled surfaces of one word brickwork. These repairs are justified where only small amount of work is needed. In this method, deteriorated brickwork is patched with matching mortar and surrounding joints pointed to achieve the appearance of good brickwork. Patch repairs should be of good quality and workmanship and should not disfigure or change the appearance of the bricks. Patching mortar should be compatible to the existing composition of brickwork. Pigments should be avoided and use of brick dust to match the colour is encouraged. Conservation architect or engineer-in-charge to note if additional ties or reinforcements are to be inserted to strengthen the patched brickwork and it is securely integrated. If the area to be patched exceeds 50% of the exposed face, the entire brick should be removed and replaced.

a. **Removal of deteriorated brickwork:** Remove deteriorated or spalling brick surface, dirt and debris from the area to be repaired. Remove only enough material to allow a minimum patch depth of 15 mm or 25 mm.
b. **Cutting:** Undercut the edges of the area to be patched slightly to improve bonding.
c. **Cleaning:** Thoroughly clean the area with a bristle brush and water prior to placing patching material.
d. **Patching material:** Prepare samples of patching material to match the brick colours and texture to be judged on its wet and dry appearance.

Figure 2.6: Missing bricks

Figure 2.7: Brick slips for surface repairs
Source : vandersanden.com

e. **Installing:** Place patching material or mortar firmly compacted in layers not exceeding 9 mm thick. Allow each layer to dry out before rewetting and placing the next. When the final layer of patching material is thumbprint hard, it should be tooled to match existing surface texture and profile with special attention to the edges. Do not featheredge patching material.
f. **Cleaning:** The surrounding brick masonry should be cleaned of mortar or other spots after the patch is provided.
g. **Pointing:** If the patch is next to a joint, then follow joints or surface finishing in the original work, and then repoint it, pointing of adjacent joints should be carried out as a separate operation. Care should be taken to not smear the mortar on good brickwork.
h. **Protecting and curing:** Protect repairs against adverse weather conditions of rain and direct sunlight and cure by keeping it moist with dampened jute/hessian by sprinkling of water for a fortnight to ensure slow drying.

2.5.1.2 Brick Slips

In some situations, where it is not possible to remove the entire brick, it may be useful to treatment small areas of brickwork using brick slips. Brick slips are facings of about 25mm (1 inch) thickness although it may be possible to cut thinner slips from whole bricks. Brick slips should match the existing bricks. Repair using brick slips should be limited to individual bricks or to relatively small areas of brickwork. Another alternative could also be used with thin brick tiles. Conservation architect and engineer-in-charge to note if additional pins or reinforcements are to be inserted to ensure that the slips are secured well.

The brick slip should be applied to clean, even and pre-wetted brick surface of the damaged brickwork with matching mortar compatible with adjacent details and profile.

a. **Cutting:** Carefully cut out the deteriorated bricks to a regular shape to receive brick slips without disturbing the adjacent bricks.
b. **Cleaning:** Clean the surrounding cavity of loose mortar and other debris by hand tools such as scalpel/ hacksaw blade/pointed tools and stiff bristle brushes. Avoid using a flat chisel and hammer to prevent any damage to the existing masonry.
c. **Brick Slips:** Prepare or procure brick slips to match the surrounding brick work in colour and texture as much as possible.
d. **Prewetting:** Spray the Brick surface to receive slips with water before applying the mortar.
e. **Installation:** Bed the slips firmly in the prepared area on a bed of lime mortar compatible with that in the original brickwork.
f. **Cleaning:** The areas should be cleaned after the installation of brick slip.
g. **Supporting:** The bricks may be temporarily supported if required and specified.

2.5.2 Resetting

Sections of brickwork should be reset if they become loose or dislodged whenever possible as directed by the conservation architect and the engineer-in-charge. If it is not possible to remove and reinstall then other methods may be specified.

a. **Cleaning surrounding joints:** Clear out mortar joints around the loose brickwork and carefully remove dislodged bricks.
b. **Providing support:** Support adjacent brickwork using timber shims etc. or some other support mechanism where required.
c. **Cleaning:** Clear all the mortar and debris from where the bricks have been removed. Then clean the bricks of dirt, mortar, and loose debris and retain it for re-use if in sound condition.
d. **Bricks:** Retain all the bricks after removal and cleaning. If some bricks are damaged, they should be replaced to match the existing as specified in section 2.1.3.
e. **Wetting:** Pre-wet the surrounding brickwork.
f. **Resetting:** Lay new bedding mortar as specified and re-set bricks to match the joint lines in courses, aligning with plumb and level of adjacent existing work. Adjust bricks wherever needed to its final position while mortar is soft and plastic.
g. **Cleaning:** Clean surrounding areas after the bricks are set.
h. **Curing:** Keep repair work damp till it is cured (48 hours plus).

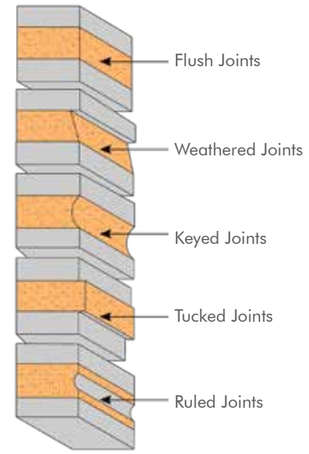

Figure 2.8: Types of pointing in brick
Source : IS CODE (IS: 2212-1991)

2.5.3 Repointing

- For brick masonry repointing refer section 1.5.4, chapter 1, Lime Work.
- Mortar in the joints weather and decay and the open joints can let the water into the building and hence it becomes necessary to replace the mortar (repoint).
- Appropriate and matching mortar should be used to repoint. Formulation of repair mortar can be made by testing the original/existing mortar in the brickwork.
- The type of pointing should match the existing or as specified by the conservation architect.

2.5.4 Grouting

- Grouting can be used for deteriorated and loose brickwork without dismantling and for areas that are inaccessible from the exterior.
- For grouting process, refer section section 1.5.5, chapter 1, Lime Work.

2.5.5 Stitching

Stitching is often used to repair structural cracks when recommended by the conservation architect and engineer-in-charge. For stitching process refer section 3.5.8, chapter 3, Stone Work.

2.5.6 Restoration of Brick Work

Brick work should be replaced only when deteriorated beyond repair and no other repair method is found to be suitable. This should be decided after a full evaluation of the building and the damage accurately. Replacement bricks should match the size, colour and texture as per the original. The bonding in the replacement brick should match with existing work.

2.5.6.1 Replacing Small Sections

When only two or three bricks are damaged or the damaged areas is less 1 sqm, it will be suitable and cheaper to replace the bricks than to rebuild the entire wall surface/column or any other element. Replacements should be either new matching brick or matching salvaged brick placed so as to replicate the existing bond pattern.

a. **Removal:** Remove individual damaged bricks with hammer and chisel without causing damage to the adjacent brickwork in good condition.
b. **Cleaning:** Remove all existing mortar and debris around the removed bricks and in joints in order to lay new brick in new matching mortar.
c. **Mortar preparation:** prepare mortar to match the existing as mentioned in section 1.1.4.3, chapter 1, Lime Work.
d. **Laying:** Prewet the cavity created by removal of bricks and lay mortar followed by bricks to match the existing joints and bond pattern.
e. **Pointing:** After the bricks are laid, pointing or plastering as required should be done to match the existing.

2.5.6.2 Replacing Large Sections

Replacements should be either new matching brick or matching salvaged brick placed so as to replicate the existing bond pattern.

a. Supporting the structure: Necessary provision for shoring should be provided to support the adjacent brick work, around the deteriorated area to be repaired as suggested by the conservation architect and the engineer-in-charge.
b. Dismantling deteriorated brickwork: Deteriorated bricks should be carefully removed by hand using a hammer and chisel. Rebuild back-up and substrate as required to replace any unsound material that was removed.
c. Cleaning: Clean the cavity of loose mortar and other debris by hand using a chisel and stiff bristle brushes.
d. Wetting: Lightly wet the exposed brick surfaces in the cavity created.
e. Laying: Lay brick units with matching mortar; butter ends with sufficient mortar to fill joints and insert into place. Each course should match the existing adjacent brickwork courses and patterns. Blend new work into existing work smoothly with no lines of demarcation and no change of pattern or coursing.
f. Cleaning: After mortar is thoroughly set and cured, remove loose mortar and dirt from new masonry surfaces. Wash down the masonry surface with clean, clear water.
g. In case of exposed brickwork, rake all joints in replacement work to receive pointing. Brush all excess mortar from the wall surface frequently during the work; protect all existing surfaces from mortar dripping and splashing. For brick work that was plastered, should be provided with new palster to to match the existing surfaces after the laying is complete.

2.5.7 Joining Old and New

In case the height of the bricks of old as well as new work is the same, the old work should be toothed to the full width of the new wall and to the depth of a quarter of brick in alternate courses. In case the height of the bricks is unequal, then the height of each course of new work should be made equal to the height of the old work by adjusting thickness of horizontal mortar joints in the new wall. Where necessary, adjustment should be made equal to thickness of old wall by adjusting the thickness of vertical joints.

For joining new cross wall to old main walls, a number of rectangular recesses of width equal to the thickness of cross wall, three courses in height and half a brick in depth should be cut in the main walls. A space of the three courses should be left between two consecutive recesses. The new cross wall should be bonded into the recesses to avoid any settlement. Joining of old brick work with the new brick work should be done in such a way that there should not be any hump or projection at the joint.

2.5.8 Decorative Elements

- To achieve decorative details in brickwork, such as mouldings, cornices, string courses, traditionally, soft bricks, cut to shape were laid on beds of lime.
- If the elements are dislodged or are loose then it should be fixed in place as much as possible.
- In case of deteriorated and missing decorative brick elements, repairs should only be carried out in the most pressing circumstances, where it is the only option. Where repairs are essential, a new replacement should be installed to match the existing.

Figure 2.9 : Restoration of deteriorated brickwork

Figure 2.10: Joining old & new brickwork
Source: vandersanden.com

- Repairs should be carried by out removing deteriorated sections of the decorative brickwork carefully and rebuilding it, using the same bricks. In case of missing bricks, new custom made matching bricks should be used when missing appropriate mortar.
- As per IS: 2212- 1991 all projecting architectural features, such as plinth projections, string courses or cornices, should be effectively bonded by tailing into the brickwork to ensure stability. Such architectural features should be set straight and true with the finished joints as far as possible.
- When such features are not to be plastered over, they should be built with brick which have high durability, resistance to abrasion and moisture penetration. Bricks specially made to required shape for this purpose should be used, if possible otherwise, selected bricks rubbed and ground to correct shape and size may be used.
- Sun shades and such projecting features which depend on the men of brick masonry over them for their stability should be kept supported till such time the brick masonry above is built and. hardened sufficiently.

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STONE WORK

CONTENTS

3. STONE WORK

This chapter provides guidance on conservation treatments for stone masonry and cladding in heritage structures. All the conservation treatments should be carried out in consultation with a conservation architect and engineer-in-charge as per the requirement. Conservation of ornamental and decorative stone work should be undertaken in consultation with an art conservator.

3.1. MATERIALS

Materials used for conservation of stone work are given below.

3.1.1 Water

Water should be clean and free from contaminants such as oil, acids, alkalis, salts, sugar and vegetable growth. It should meet the latest standards IS: 10500 - 2012 for Drinking Water. Only potable water should be used. Sea water or tidal estuary or brackish water should not be used for any conservation works.

3.1.2 Mortar

The mortar for the stone work should be as specified and conform to accepted standards. The proportion of the lime mortar to be used in conservation will be based on site requirements and established from samples at site. Mortar should also be matched as closely as possible in colour and texture with the existing through a mortar analysis and other relevant tests. If unable to find an existing sample mortar, then it should be as specified in chapter LIME. It should generally be ensured that the mortar for the repair is of the same strength or weaker than the existing stone.

3.1.3 Anchorage: Cramps and Dowels

Cramps and other dowels have been used for anchoring or support in stone masonry and cladding work in heritage structures. Existing original anchoring systems should be used if in sound condition, salvageable by cleaning. A common problem across heritage sites, is the corrosion of anchors embedded in the masonry. These corroded and unsound anchors, would need to be replaced as well as necessary, with new stainless steel anchors or as specified by the conservation architect or engineer-in-charge of the same approximate size and shape.

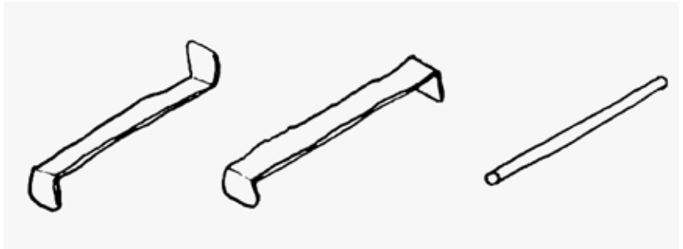

Figure 3.1: Anchorage ties
Source: Conservation of Historic Stone Building & Monuments, 1982

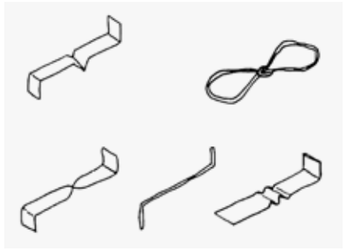

Figure 3.2: Cavity wall ties
Source: Conservation of Historic Stone Building & Monuments, 1982

3.1.4 Stone

Stone for repair and replacement

The type of stone for use as replacement is to be approved and confirmed by the conservation architect following comparison with the original. The stone should be of the type specified to match the existing and should be obtained from the sources approved by the conservation architect or engineer-in-charge.

- Where salvaged stone is available, this can be used for the repairs, provided the salvaged stone is found to be of good quality that matches the original and is approved by the conservation architect. Mortar should be removed from all faces of salvaged stones to ensure full contact with new mortar.

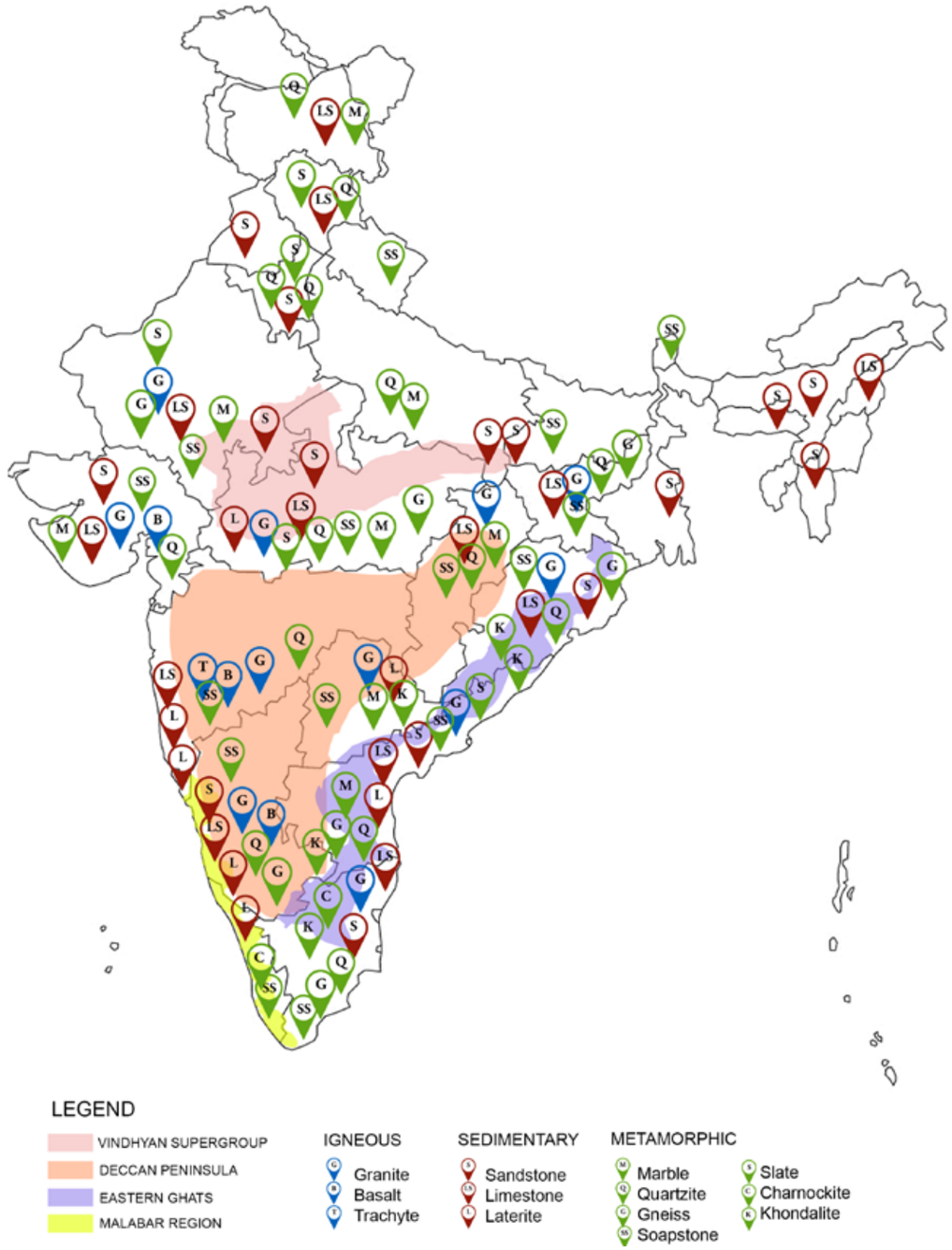

Figure 3.3: Types of rocks in India
Source: Modified from Geological Survey of India, Map & Cartography Division Southern Region, Hyderabad, Government of India Ministry of Mines, 2010

- Where salvaged material is unavailable, use of natural stone dressed to match the existing masonry is generally preferable for replacement. However, accurate replacement may depend upon locating a suitable source and a satisfactory match to the size, shape, texture and colour range of adjoining stone work.
- When undertaking repairs, it is useful to determine where the original stone is from and whether it is still available. If the same option is not available then the closest match should be tried to be procured in consultation with the conservation architect.
- Both new and salvaged stones, should be hard, sound, durable and free from weathering decay and defects like cavities, cracks, flaws, sand holes, injurious veins, patches of loose or soft materials and other similar deficiencies that may affect its strength and appearance. As far as possible stones should be of uniform colour, quality and texture. Generally stone should not contain crystalline silica or chart, mica and other deleterious materials like iron-oxide organic impurities etc.
- Before carrying out any conservation interventions it is important to document how the stone was used in the structure, complete construction details including anchoring systems.

3.1.4.1 Occurrence of Stone

In India many types of stones have been used for heritage structures and other details depending on the local availability and the nature of work. All natural stones and their suitable properties should be identified using IS: 1123-1975. Regional names may vary but some of the common building stones in India are listed below:

Igneous Rocks: Granite, Granodiorite, Syenite, Diorite, gabbro, Basalt, Dolorite, Rhyolite, Andesite and Trachyte
Sedimentary Rocks: Sandstone, Limestone & Dolomite and Laterite
Metamorphic Rocks: Charnockite, Gneisses, Quartzite, Marble, Khandolite, Slate, Phyllite, Schists.

3.1.4.2 Precaution and Care

Precautions and care while handling stone should be as specified in section 6, Precautions and Care in chapter 1 Introduction.

3.1.4.3 Delivery, Storage, and Handling

a. Stone should be delivered to the site in undamaged condition.
b. Stones should be moved carefully with appropriate equipment. For easy handling and avoiding ground contact, the stones should be stored on wooden scantling.
c. Stones should be lifted and not dragged.
d. Stone should be stored and handled to prevent its deterioration or damage due to moisture, breakage, chipping or other causes.
e. Lifting, moving and handling of heavy stones should be done better by the use of cranes (where permitted) and heavy-duty cargo lifting nylon/fabric belts.


Figure 3.4: Lifting and moving of heavy stones

3.2. USE OF STONE IN HERITAGE STRUCTURES

Stone can be found in almost all heritage building elements from foundation, super structure to cladding and decorative elements. Some of the documented uses are illustrated below for better understanding of its applications.

Table 3.1: Uses of Stone in Heritage Structures

Masonry Work		
Cladding		
Arches		
Domes		
Floors and Steps		

Elements: Jaalis		
Elements: Brackets		
Elements: Chajjas/ Sun Shading Devices		
Elements: Parapets and Cornices		
Opening support: Lintels, Frame and Threshold		

3.3. DEFECTS

Stone masonry and cladding may have many issues due to various reasons like material aging clubbed with lack of maintenance, environmental factors (including pollutants), water penetration, structural faults, defects in original construction, natural defects etc. The defects should be assessed and diagnosed before applying corrective measures. Some of the most typical issues with stone are listed below but the list is not exhaustive. For each site the conservation architect with engineer-in-charge should prepare their own list/record of defects using the table below as a baseline, assess them and formulate the conservation treatments accordingly.

Table 3.2: Defects of Stone

DESCRIPTION	PHOTOGRAPHS	CONSERVATION
Minor Cracks		Refer 3.5.1 Minor Crack Repairs
Loss of Material		Refer 3.5.2 Patch Repairs Refer 3.5.3 Dutchmen Repairs
Loose Stone Cladding (Facing Stone)		Refer 3.5.4 Resetting Stone Cladding

DESCRIPTION	PHOTOGRAPHS	CONSERVATION
Deteriorated Pointing or Open Joints		Refer 3.5.5 Repointing
Loose Masonry Cavity		Refer 3.5.6 Consolidation and/ or Refer 3.5.7 Grouting
Loose Masonry Cavity		Refer 3.5.6 Consolidation and/ or Refer 3.5.7 Grouting
Cracks through Stone Masonry		Refer 3.5.8 Stitching

DESCRIPTION	PHOTOGRAPHS	CONSERVATION
Deteriorated Stonework		Refer 3.5.9 Restoration of Stone Masonry
Missing Elements		Refer 3.5.10 Replacing Elements
Damaged Inlay		Refer 3.5.11 Conservation of Inlay Work
Delamination		Refer 3.5.2 Patch Repairs for Minor Damage. Refer 3.5.9 Restoration of Stone Masonry for Extensive Damage

3.4. TESTS

- The stones for repair and replacement should be correctly matched for compatibility and other characteristic properties through tests as suggested by the conservation architect. These include matching visual, physical and chemical properties.
- Tests also aid in ascertaining the issues with the existing stones and should be used to make informed assessment to ensuring appropriate repairs.
- These tests should be done under the guidance of a conservation architect or engineer-in-charge and should be conducted either in the field or in laboratory.
- The tests should be performed using current IS Codes provided by Bureau of Indian Standards.
- If the tests are not available in the IS Codes then international standards could be followed guided by the conservation architect or engineer-in-incharge.

REFERENCES FOR TESTS
ASTM (American Society for Testing and Materials)
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Built heritage Evaluation- Manual Using Simple Test Conservation of Historic Stone Buildings and Monuments

3.5. CONSERVATION

Conservation treatments to stone work should be carried out after correcting the underlying causes. This section presents treatments techniques for conservation and should be modified for individual site requirements.

3.5.1 Minor Crack Repairs

- Cracks should be evaluated and classified by the conservation architect or engineer-in-charge.
- Causes of the cracks should be ascertained and addressed before undertaking any conservation interventions.
- In some cases cracks may need to be monitored by using tell tales, as specified by the conservation architect or engeineer -in-charge as a part of investigations and assessments.
- Minor cracks in the stone surfaces (few in number) could be repaired by carefully routing the crack, grouting if required and filling it with patching mortar as explained below.

a. Cleaning: Clean the crack of any loose debris or residual material with soft brushes and hand tools.
b. Routing: Route the crack to receive the repair materials and clean any loose material after routing with hand tools.
c. Wetting: Spray water in the crack void and dampen the area to avoid immediate suction of the repair materials.
d. Preparing grout and patching mortar: Prepare the grout and patching repair material to match the existing colour and texture. Adhesives may also be used in place of a grout if specified by the conservation architect. In some cases, grouting may be completely avoided if specified by the conservation architect.
e. Injecting grout: Inject the grout in to the crack and finish by applying patching mortar by working the material into the crack with some pressure.

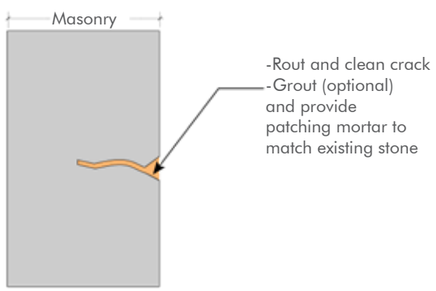

Figure 3.5: Crack repair

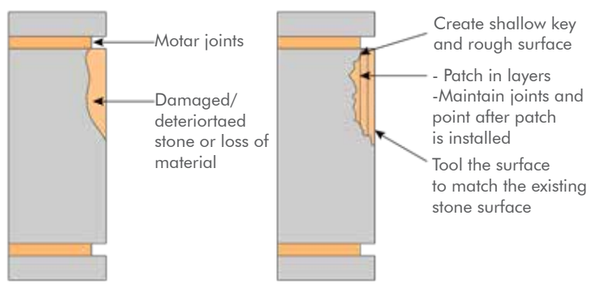

Figure 3.6 : Patch repair

f. Surface finishing: The finish of the repaired surface should match with the existing stone.
g. Curing and cleaning: Clean the surrounding area after patching and cure as required or as specified.

3.5.2 Patch Repairs

- Mortar may be used to patch the minor cracks and small areas less than 2 inches wide and with spalling and other small losses due to deterioration. This type of repair is used for aesthetic improvement to areas that have suffered superficial damage to the surface. These repairs are only suitable for small or localized areas.
- These surface repairs are sometimes also fixed using non-ferrous cramps with successive layers of mortar build-up to form a composite repair.
- Patching materials should be weaker than the stone substrate. To match the color and texture of the patching material to the existing stone, appropriate aggregate ground stone and / or pigment should be used along with ground stone.


Figure 3.7: Patchrepairs

For providing patches the following steps should be followed.

a. Removal of deteriorated stone: Cut out the deteriorated or damaged areas (or previous poor mortar repairs) undercutting the edges to provide shouldow keys. Roughen the surface to provide better bond for receiving the mortar patch.
b. Cleaning: Wash out the cleaned cavity and saturate the with water to prevent sudden absorption when patching material is placed.
c. Patching material: Prepare samples of patching material to match the various conditions of weathering and various stone colours on a piece of stone or tile to be approved for its wet and dry appearance.
d. Installing the patch: Place the repair mortar compacting in layers not exceeding 9-10 mm in thickness in any one application and having no feather edges. Allow each layer to dry out before rewetting and placing the next. Finish repair to the required profile using a wood float, or with a damp sponge or coarse cloth. If the patch is next to a joint, then follow joints or surface finishing in the original work, and then repoint it.
e. Protection: Protect repairs against adverse weather conditions such as rain and direct sunlight. Keep it moist with dampened jute or hessian by sprinkling water for a fortnight to ensure slow drying.

3.5.3 Small Repairs or Dutchman Repairs

- For small repairs (less than 2 inches or less than 10 %) or as specified by the conservation architect
- in stone with chipped or damaged sections, a dutchman can be used if the whole piece is not being planned to be removed. This repair process is used in cases where it is not possible to remove the entire block of defective stone i.e., if removal causes structural instability. The new stone piece should match the existing type of stone and in visual properties like colour and texture.
- Dutchman is wedged in place, secured with adhesive, or set with pins or both; larger pieces may be set in mortar as specified by the conservation architect or the engineer-in-charge. To maintain the appearance of a continuous stone unit, the joint between the repair piece and the existing stone should be as narrow as possible.
- Dutchman should be fastened with stainless steel wire, pins, and anchors, as necessary, designed to facilitate mechanical locking and to prevent possible slippage of the stone.

Figure 3.8: Dutchman repairs on a dome

Figure 3.9: Dutchman installation

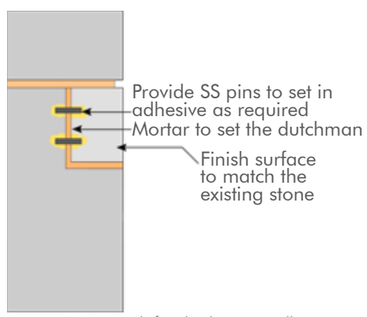

Figure 3.10: Details for dutchman installation

The repair procedure may be carried out as outlined below:

a. **Removal of deteriorated stone:** Carefully remove loose stone fragments of damaged stone. Protect the main stone during the process of installation and any deposits should be cleaned after the process.
b. **Undercutting:** Cut the damaged area to minimum depth required and to match vertical and horizontal joints, square to the face and with sharp arises as specified by the conservation architect.
c. **Cleaning:** Remove dust and debris from cavity and fragments using a stiff bristle brush.
d. **Preparation of dutchman:** Prepare a replacement stone (dutchman) of dimensions such that it will fit into the remaining space left by stone removal with a gap on all sides. Dutchman surface should match existing stonework. All tooling should run in the same direction to match existing adjacent stonework. All rustication should be done by hand tools only unless otherwise specified.
e. **Fixing:** Drill holes (size determined by size of reinforcement selected if specified) into both the sound stone and the dutchman. Inject appropriate adhesive or grouting material as specified, into the holes and set specified type of pins into the holes. Install dutchman into existing stone assuring true and level fit. Clean any residues from the edges using a clean soft cloth.
f. **Pointing:** Point with matching mortar finished flush with the face. Mortar colours to match stone as closely as possible. Make sure the surrounding areas are clean.
g. **Curing:** Wet the stone with clean water for 48 hours or as specified.
h. **Supporting:** Dutchman must be temporarily supported in place with wood wedges or other means until the mortar has sufficiently set.

3.5.4 Resetting Stone Cladding

For securing facing stones and loose cladding panels, tresetting should be undertaken as far as possible. At several locations it may not be possible to remove and reinstall. In such cases grouting and pinning in place may be the best option or as advised by conservation architect or engineer-in-charge.

a. **Cleaning surrounding joints:** Clear out mortar joints around the stone panel and carefully remove dislodged and loose stone.
b. **Providing support:** Support adjacent stones using timber shims etc or some other support mechanism where required.
c. **Cleaning substrate and stone:** Clear backing and bedding mortar from the surface of the substrate from where the stone has been removed. Clean the stone of dirt, mortar, and loose debris and retain it for re-use.
d. **Anchors:** Clean any exposed metal anchors of corrosion by specified method sand coat with a corrosion inhibiting primer. Replace any unsound anchors as necessary with new stainless-steel or other specified anchors as per the structural requirement.
e. **Resetting:** Install treated or replacement anchors as specified. Wet the surrounding masonry and lay new bedding mortar as specified and re-set stone, aligning with plumb and level of adjacent existing work. Adjust stone units to final position while mortar is soft and plastic. Fill remaining depth with mortar and finish to match the existing. Point joint as necessary
f. **Cleaning:** Clean surrounding areas after the stone is set.
g. **Curing:** Keep repair work damp till it is cured (48 hours plus).

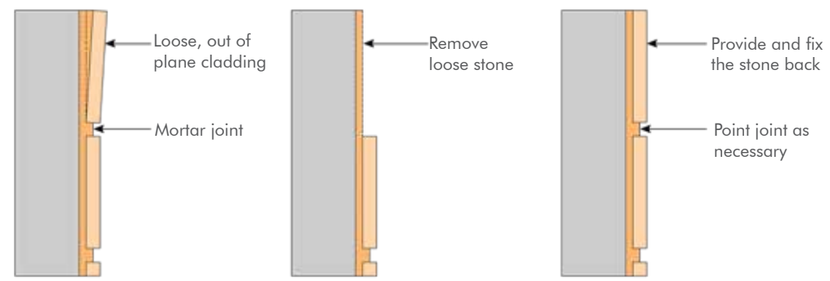

Figure 3.11: Resetting

3.5.5 Repointing

- For stone masonry repointing refer section 1.5.4, chapter 1, Lime Work.
- Mortar in the joints weather and decay and the open joints can further lead to the water ingress into the building and hence it becomes necessary to replace the mortar (repoint).
- Appropriate and matching mortar should be used to repoint. Formulation of repair mortar can be made by testing the original/existing mortar in the brickwork.
- The type of pointing should match the existing or as specified by the conservation architect.

3.5.6 Consolidation

To fix loose stones in masonry work without removing the stones, consolidation or filling with mortar should be used followed by deep pointing.

a. **Cleaning:** Clean the joints of loose mortar, dirt and debris using a stiff bristle brush. Clean any other material that has been used in the joints in the past.
b. **Raking:** Cut and rake old mortar from existing joints by hand using a hammer and chisel to a depth specified. Raking out should leave a clean, face at the back of the joints to provide for maximum contact of mortar with the masonry. Do not spall or chip the surrounding masonry edges in the process of mortar removal.
c. **Prewetting:** Thoroughly flush out joints with clean water. Masonry units should be damp but without standing water at the time of filling and applying mortar.
d. **Grouting:** Grouting should be carried out as the first step to consolidate the loose stone as described **in section** 1.5.4. chapter Lime Work.
e. **Mortar filling:** Deep cavities visible and accessible from the surface through the joints should be filled with mortar as specified. Compact the already filled mortar and then add more till it is completely packed.
f. **Pointing:** Point the joints if required or specified, after mortar filling.

Figure 3.12: Consolidation of stone masonry

3.5.7 Grouting

- Grouting can be used for deteriorated and loose masonry without dismantling and for areas that are inaccessible from the exterior.
- For grouting process, refer section 1. 5.5, chapter 1, Lime Work.

3.5.8 Stitching

- Stitching cracked masonry primarily requires using matching material as the masonry to be inserted and placed into the courses overlapping the crack in the wall.
- Sometimes other materials are also used as specified like a cast RCC block /slab. Some stones may still require to be replaced around the crack.
- Structural cracks in masonry should be assessed and suitable treatment should be determined in consultation with the conservation arcitect or structural engineer. After treating and addressing the cause of structural cracks, all the details like the type of crack, thickness & width, and location should be used to determine whether stitching is the appropriate repair.
- Stitching of masonry should be carried out as described below in consultation and under supervision of conservation architect and engineer-in-charge. Same method is also applicable to brickwork.
  a. **Protection:** Before undertaking stitching, protect the adjacent masonry work using appropriate methods.
  b. **Supporting:** Provide appropriate shoring or support to the structure before providing stitches to the stone masonry in consultation with the engineer-in-charge.
  c. **Removal of masonry:** Carefully cut out a horizontal slot or chase in the masonry by removing stones, just over either side of the vertical crack and to the correct depth, depending on the wall thickness.
  d. **Removal of mortar:** Clean the mortar around the removed masonry. Remove all loose material, clean the cavity and pre-wet with water.
  e. **Spacing chases:** Make vertical spacing for similar chases for every 4 - 6 courses or as specified by the engineer-in-charge. Do not damage the arises of the masonry by the surrounding retained masonry.
  f. **Application of mortar:** Apply mortar to the chase, before placing the new stone spanning the entire crack.
  g. **Placing the stone:** Place the stone lintel and insert into the chase making sure it extends on either side of the crack. Fill the hole with stones, to match existing stonework.
  h. **Pointing:** Finish the masonry with pointing to match the wall as per Section 1.5.4 in chapter 1 Lime Work.

NOTE:

- Sometimes the stitches are placed inside the masonry after removing the facing stones and then the facing stones are installed again.
- Proprietary stitching systems may also be used, when appropriate, if traditional are not suited for this type of repair. This will be done in consultation with the engineer-in-charge and the conservation architect.

3.5.9 Restoration of Stone Masonry

Stone replacement should be considered where other repair and patching techniques are impractical or ineffective, or where stone units are missing or so severely damaged, or deteriorated as to be unrepairable. Stone replacement should only be undertaken if the stone has been damaged to such an extent as to be structurally unsound or unsafe. This should be decided after a full documentation and evaluation of the building and the damage accurately by the conservation architect.

a. **Removal of deteriorated sections:** Carefully dismantle and remove deteriorated section of the masonry by hand, and tools as specified. Carefully cut out perimeter joints of masonry by hand using a hammer and chisel. Break down the rest of the damaged masonry with a hammer and chisel.
b. **Support:** Provide support as necessary so that the adjacent masonry is not disturbed
c. **Cleaning:** Carefully clean out the cavity to receive the replacement stone masonry. Remove mortar, loose particles and other debris in preparation for reinstallation.
d. **Preparing the stones:** Prepare the replacement stones cut to size and tooled, surface to match existing stonework. All surface finishing should match the existing adjacent stonework and should be done by hand tools only unless otherwise specified.
e. **Pre-wetting:** Thoroughly wet the cavity with water; dampen the replacement stones with water. Spread mortar as specified into the open cavity; the new mortar should match the original mortar as far as possible.
f. **Laying:** Set and lay down the courses of stone with mortar to match the existing.
g. **Joints:** Fill the joints with matching mortar or as specified to match joints with surrounding stone work.
h. **Pointing:** Point the joints with specified mortar and remove all excess mortar as the work progresses.
i. **Cleaning:** After mortar is thoroughly set and cured, clean new masonry surfaces of all loose mortar, and dirt and lastly wash down all masonry walls, leaving them clean and neat.

Figure 3.13: Replacing deteriorated stone masonry

Figure 3.14: Installation of stone chajjas

3.5.10 Replacing Elements

In the case of individual decorative elements, replacements should only be carried out in the most pressing circumstances and where it is the only option. These elements should be conserved and treated in place as much as possible. If the damaged or deteriorated elements can't be repaired in place, then they should be removed, repaired and installed back.

Often it is desired to replace a missing element such as a chajja, to achieve the purpose it serves like protection from water, sun etc. A replacement should be installed in such cases to match the adjacent similar elements and when the element is damaged or deteriorated beyond repair.

a. **Removing damaged elements:** Remove mortar from around element to be replaced by hand, being careful not to chip the edges of adjacent sound elements. Insert wedges as required as mortar removal progresses to hold damaged elements in place until they can be removed. Carefully remove damaged elements and all loose mortar in the cavity behind the element.

b. **Documentation:** It is most vital to document the damaged or deteriorated elements like *chajjas, brackets,* copings and *jaalis.* While documenting, attention should also be paid to the installation system and the fixing details. Once accurate documentation is complete then the replication should be executed using existing details..
c. **Surface preparation:** The area to receive the elements should be thoroughly cleaned of any loose material and then with dry brushes.
d. **Preparation of replacement elements:** Create an exact replica of the damaged original element using the documentation carried out earlier. The replica should match the original in all respects. Pre-wet the replacement pieces with clean water prior to installation. The pieces should be damp at the time of installation.
e. **Preparing the anchoring system:** Inspect the existing anchors and reinforcing system thoroughly for any signs of corrosion. Remove any corrosion from anchors which can be reused and coat with a corrosion inhibiting primer. For unsound anchors replace anchors and install new anchors as required and as specified by the conservation architect and engineer-in-charge. If the anchors are found to be loose, these should be reset while replacing the element. If the anchoring system is found to be inadequate, then these should be replaced with a better mechanism as specified.
f. **Mortar application:** The elements should be set in place using mortar and anchors in the original locations and packed with mortar.
g. **Fixing:** While setting the element it should be repeatedly tapped with a mallet to eliminate all voids in the setting bed to adjust the element to its desired position.
h. **Support:** In addition, a support system, such as, wooden wedges, should be provided by suitable wooden shores exerting a constant required pressure for a sufficient number of days to support the elements.
i. **Tooling and pointing:** All mortar joints should be pointed after raking. Wipe all excess mortar as the work progresses.
j. **Cleaning:** After mortar is thoroughly set and cured, wash surrounding areas of loose mortar, and dirt.

3.5.11 Conservation of Inlay Work

Inlay work is a specialized decorative stone work that is used in a number of elements like floor, walls and other surfaces to achieve an ornate finish. These are done on stone, with stone inserts precious/semi previous stones and tiles, etc. The repair of such surfaces should be handled with extreme care and precision and made sure that the original design finishes are not altered.

a. **Documentation:** Carefully document all the areas under repair, for precise location, shapes and sizes of stones.
b. **Removal of deteriorated stones:** Carefully remove deteriorated or damaged pieces with hand tools without disturbing the adjacent stones.
c. **Cleaning:** Clean the cavity created by removal of the stone or the missing stone with dry brushes.
d. **Preparing new inserts:** Carefully and precisely match the right colour and properties of the new inserts for inlay. The pieces should then be prepared by cutting to match the existing size, shape and design.
e. **Setting:** Set the new piece in the cavity using lime mortar or as specified after pre-wetting the base stone. Clean the area after the stone is set.

NOTE: Adhesives and small pins should be used as specified.

Figure 3.15: Inlay work

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EARTH / MUD WORK

CONTENTS

4. EARTH/ MUD WORK

This chapter provides information and guidance on conservation treatments for unfired mud bricks or adobe and rammed earth construction in heritage structures. The conservation treatments should be carried out in consultation with a conservation architect and engineer-in-charge as per the requirement. Earth is also often referred to as mud in India. chapter 2, Brick Work should be referred to for fired or baked bricks conservation.

4.1. MATERIALS

Materials used for conservation of earth/mud work are given below.

4.1.1 Water

Water should be clean and free from contaminants such as oil, acids, alkalis, salts, sugar and vegetable growth. It should meet the latest standards IS: 10500-2012 for Drinking Water. Only potable water should be used. Sea water or tidal estuary or brackish water should not be used for any conservation works.

4.1.2 Aggregates

Graded stone and brick ballast should be used to match the existing or as specified. A well graded aggregate should be preferred.

4.1.3 Additives

Additives are often used to improve qualities of the mixes used for mortars, plasters, mud concrete, mud bricks and rammed earth wall such as tensile and shear strength, to reduce shrinkage. Hay, straw, plant juices, apricot juice, gum arabic, sugar or molasses, cow dung, animal urine, tannic acid, oil are some of the examples of additives used in India.

4.1.4 Earth

Earth or mud should be free from organic matter like grass, roots, and kankar stones etc. It should be fairly stiff when dry, clay laom or sandy clay loam in texture. The earth or mud should be reduced to a powdered state with all clods being broken. If earth or mud is of tenacious nature an adequate proportion of sand should be mixed to it such as a dried lump of mixture should not allow signs of cracking. This should apply to all eathen work.

4.1.4.1Mud Bricks

For conservation, replacement bricks should be fabricated to match the characteristics of existing bricks as closely as possible. Bricks from heritage structures don't have fixed or standard sizes so it may be necessary to have replacements specifically manufactured for the work.

Mud bricks should match the existing in shape, size, colour and other properties. Earth for making mud bricks should be procured locally, preferably clayey. Earth or mud with high sand should be avoided. Bricks should be moulded after keeping the earth or mud-water mix for 24 hours. The blocks should be allowed to dry out of the moulds so as to allow free shrinkage without developing cracks.

4.1.4.2 Rammed Earth

For rammed earth conservation, earth or mud with properties similar to the existing should be used. Additives and aggregates should be added to match the existing composition determined through testing. If mud bricks are used as inserts or as fillers, then these should be match the existing rammed earth.

4.1.4.3 Mud Mortar

Earth or mud as specified above, should be mixed with water and tempered for at least 24 hours. During this period it should be worked up at intervals with men s feet and with *phawras* so as to become a homogeneous sticky paste free from lumps clods etc. The mud 'mortar' used to join the mud bricks together should be the same earth or mud as used in making mud bricks. However, to make it non shrinking, straw in the ratio 1 : 1, by volume, or as per the climatic conditions specified by the conservation architect. The wet mix should be allowed to rest for 7 days (minimum 3 days) before use.

4.1.4.4 Mud Plaster

The earth should be reduced to a powdered state and mixed with plenty of water in a pit adding chopped straw as specified. The mixture of earth straw and water should be allowed to rot for 3-4 days. During this period it should be worked up at intervals with mens feet and with *phawras* so as to become a homogeneous mixture of workable consistency. For external plaster hay and *markalak* or other local additives is should be added to the earth. The soil is sieved before making plaster mix. For plasters on stone surfaces, the mortar mix is not very fine and is not sieved. It contains small aggregates which help to fill up any gaps on the stone wall.

4.1.4.5 Mud Concrete

Mud mortar and aggregate should be mixed in specified proportions to match the existing. Mixing should be done on a platform. Laying should be done in layers of 6" consolidated thickness, similar to lime concrete. Each succeeding layer should be placed before the previous one dries out. No water should be sprinkled before laying the succeeding layer, nor should any curing be necessary.

4.1.5 Precautions and Care

a. Any sources of water should be kept away from the existing structure being repaired to reduce damages.
b. Care should be taken to provide all necessary protection to avoid damage to existing structure.
c. Decorative work and other features should be appropriately protected in consultation with an art conservator.
e. Window openings from where windows shutters are removed should be temporarily covered and secured with rigid and waterproof material to protect against the elements and prevent unauthorized access to the building.

4.1.6 Delivery, Storage, Handling

Proper packaging, delivery, handling and storage of all materials helps to prevent damage. All materials should be stored on a firm dry, flat surface and should avoid direct contact with the ground.

a. Mud bricks should be placed in a manner that facilitates easy handling and allows adequate air circulation around the bricks.
b. Mud Bricks should be loaded or unloaded with care, and should not be thrown or dumped.
c. They should be stacked in regular tiers even as they are unloaded, to minimize breakages and defacement of bricks.
d. They should be carried to the site in small batches as and when necessary.

4.2. USES OF EARTH/ MUD IN HERITAGE STRUCTURES

Earthen construction has been extensively used in heritage structures in India especially in areas with relatively dry climate, with plenty of earth for construction, or lack of stone for building.

Table 4.1: Uses of Earth work in Heritage Structures

Parapet		

Adobe walls		
Rammed Earth Wall		
Flooring		
Roofing		
Mortar and Plasters		

4.3. DEFECTS

Earthen structures can have many issues but the most deteriorating factor is water and wind. Water damage from roofs or water runoff from near the building, back splash from outlets, rains, rising damp, improper drainage, winds, material aging and factors along with the change in climatic conditions. All the defects should be assessed and diagnosed before applying corrective measures. Most typical issues with earthen structures are listed below but the list is not exhaustive. For each site the conservation architect and engineer-in-charge should prepare their own list/record of defects using the table below as a baseline.

Table 4.2: Defects of Earth/ Mud Work

DESCRIPTION	CONSERVATION
Small Loss and Cracks	Refer 4.5.1 Patch Repairs
Large Areas of Damage	Refer 4.5.2 Filling Large Voids
Structural Cracks	Refer 4.5.3 Stitching
Damaged or Missing Plaster	Refer 4.5.4 Replastering
Damaged or missing walls	Refer 4.5.5 Rebuilding

4.4. TESTS

- It is essential to study and characterize the mud bricks and rammed earth that needs treatments and formulate the repairs to match the properties of the existing structure.
- The earth or mud for conservation works for repair and replacement should be correctly matched for compatibility and other characteristic properties through tests as suggested by the conservation architect. These include matching visual, physical and chemical properties.
- Tests also aid in ascertaining the issues or deficiencies with the existing and should be used to make informed assessments to ensure appropriate repairs.
- These tests should be done under the guidance of a conservation architect or engineer-in-charge and should be conducted either in the field or laboratory.
- The tests should be performed using current IS Codes provided in Bureau of Indian Standards.
- If the tests are not available in the IS Codes, then international standards could be followed guided by the conservation architect or engineer-in-charge.

REFERENCES FOR TESTS

ASTM International (American Society for Testing and Materials)
ICCROM ARC: A Laboratory Manual for Architectural Conservators Methods
Built heritage Evaluation- Manual Using Simple Test Conservation of Historic Stone Buildings and Monuments

4.5. CONSERVATION

Conservation treatments should be carried out after identifying, understanding and analyzing the causes of the deterioration. The causes of the problems should be addressed before carrying out any repairs. Complete documentation of the selected area should be done before performing any conservation work. This section presents several techniques which are appropriate for treating of a particular problem and should be modified for individual site requirements. As much as possible the repairs should be done in place using available techniques and materials, preferably traditional and local.

- Replacement should be performed where the structure is deteriorated beyond repair.
- New elements for the reinforcement of the old structure should be introduced to strengthen and to make the repairs last.

4.5.1 Patch Repairs

Earthen buildings develop minor cracks and holes due to reasons such as erosion, damage due to winds or water. If the depth of the damage is less than four inches, it should be repaired by using layers of compatible earthen mixture.

a. Removing deteriorated materials: Carefully scrape and remove all debris and loose material from the surface followed by cleaning with a brush.
b. Prewetting: Dampen the cavity or the void by spraying water to avoid immediate suction of the new mix.
c. Patching material: Prepare a compatible mud mixture matching the existing.

d. **Installing the patch:** Fill the voids with the prepared mixture in layers not exceeding ¾ inches in thickness and is best built up extra. Allow each layer to dry before the application of the next layer. When the final layer of patching material is hard and workenough, finish it to match the existing surface texture and profile with special attention to the edges.
e. **Cleaning:** Clean the surrounding area of mortar or other spots after providing the patch.

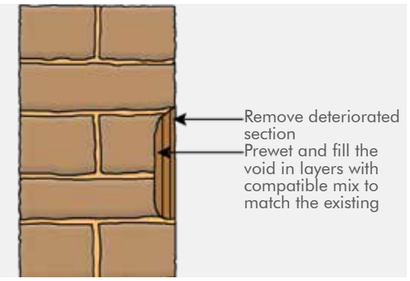

Figure 4.1: Detail of patch repair

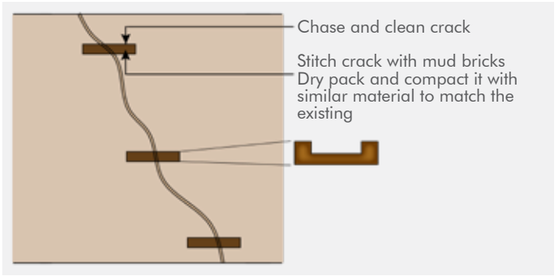

Figure 4.2: Detail of repairing a structural crack

4.5.2 Filling Large Voids

If the damaged area is deeper than four inches then the repairs should be carried out by removal of the deteriorated sections and providing new replacement material. Deteriorated mud bricks should be replaced with new mud bricks to match the existing. For rammed earth construction after removing the deteriorated sections, either mud bricks could be inserted to fill the cavity with appropriate mortar or replacement mix could be laid in layers. In all cases, the finished repairs should match the existing surfaces.

- **Supporting the structure:** Support the structure adequately before carrying out the conservation treatments, supervised by the engineer-in-charge.
- **Removal of deteriorated sections:** remove deteriorated wall sections carefully.
- **Cleaning:** Clean the cavity of any debris or loose material
- **Supporting the cavity:** Support the wall above the cavity using small supports (shims).
- **Replacement material:** New mud bricks or adobe should prepared to match the existing as per section 4.1.4.1. In case of rammed earth structure, mud bricks as per section 4.1.4.1 or an appropriate mix for filling the cavity as per section 4.1.4.2 should be prepared as guided by the conservation architect.
- **Prewetting:** Dampen the surfaces of the mud bricks that will be in contact with the mortar. Prewet the cavity to receive the replacement material.
- **Providing new material:** Place the mortar on the damp surfaces and set the bricks by pressing it slightly into the mortar. Reconfigure the supports as the laying proceeds so that the upper sections are always supported. Keys or half bricks may be installed at the ends to make the repair continuous with the existing wall.

For rammed earth, mud bricks should be inserted if specified as described above. If new mix is decided to be used, then it should be provided in layers after prewetting and compacted before the next layer is laid.

4.5.3 Stitching

Structural cracks should be assessed and suitable treatment determined in consultation with the engineer-in-charge. Structural cracks can be treated by using various traditional and contemporary techniques. A single technique or a combination of compatible methods can be effectively employed. Cracks should only be repaired when the wall indicates no further tendency to move or readjust itself.

Stitching can be used as one of the techniques for repairing structural cracks. The technique of stitching primarily requires using matching material to be inserted as soft stitch, with mud bricks or other suitable material interlaced with a soft organic matrix and placed into the courses overlapping the crack in the wall being repaired. Stitching should be carried out as described below in consultation and under supervision of conservation architect and the engineer-in-charge.

a. **Supporting:** Adequately support the structure from outside as well as inside before undertaking stitching in consultation with the engineer-in-charge.
b. **Cutting chases:** Carefully cut a chase spanning either side of the crack to a depth of almost half the thickness of the wall.
c. **Cleaning:** Clean the chase or the cavity of all loose soil and debris.
d. **Prewetting:** Wet the chase and keep it constantly moist to avoid hairline cracks and immediate suction of mortar.
e. **Providing the stitch:** Place mud bricks alternating with wet vegetation or woven matting as spec(Yagzeez grass or Umbo). Fill the last or the top course of the stitch with loose material, identical (same composition) as the mud bricks and dry pack it and compact it. The dry packing presses down the whole stitch into a dense and strongly rammed fill.
f. Provide similar stitches along the length of the wall at intervals as instructed by the engineer-in-charge.

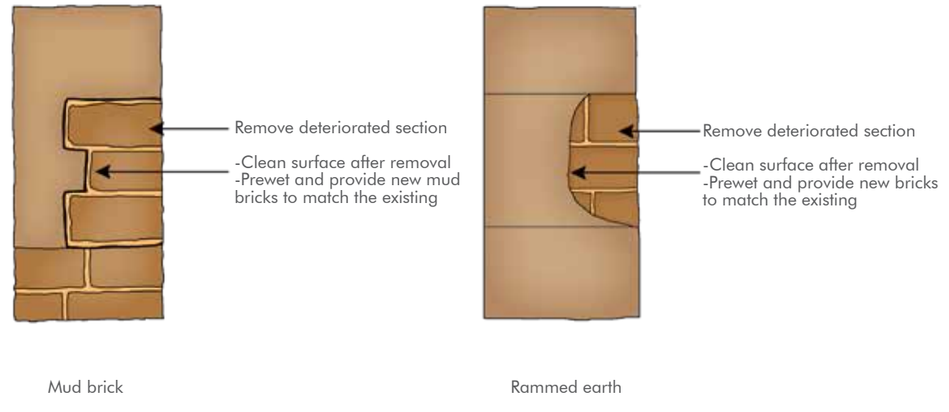

Figure 4.3: Detail of filling larger voids for mud brick and rammed earth constructions

4.5.4 Replastering

Plaster should be provided when the existing plaster is damaged, missing or needs to be renewed. Plastering is done in two layers or to match the existing after removing the damaged plaster. Initial or the first coat is applied by throwing plaster mix on the walls from a distance. The second and the subsequent coats are applied over the first one. The internal plaster is often single layered or more depending on the desired finish and the existing coats. Surfaces should be plastered using the following steps.

g. **Removing deteriorated plaster:** Remove existing damaged plaster carefully without disturbing the structure.
h. **Preparation of surface:** Rake the joints carefully.
i. **Prewetting:** Wet the joints and all the surfaces before applying plaster.
j. **Plastering:** The number of coats should be as specified to match the existing. Start the plastering from the top and work towards the ground. Apply the mixture to the surface in a uniform coat to a specified thickness to match the existing. It should then be smoothed and made even with long wooden plane faces and finished to uniform thickness. Neatly finish all corners, angles and junctions and make them vertical or horizontal as the case may be.
k. **Cleaning:** Clean the surrounding areas after the plaster application.
l. **Protection:** Protect the surface from damage till it dries out.

4.5.5 Rebuilding

For sections of walls that are damaged beyond repairs and other methods can be applied, should be rebuilt.

Damaged rammed earth walls should be rebuilt by using a similar technique as existing with matching materials. Two parallel wood planks should be held apart by metal rods and clips or bolts, or by small cross pieces of wood and stiff earth or mud is provided in between these two planks. The earth should then be rammed down with either a wooden or metal ramrod. When one section is completed and hard, the two planks are then raised up and a second course of rammed earth is repeated over the first. This should be done as per IS 13827 : 1993

For mud brick walls, the walls should be made with matching bricks and mortar. The courses and joints should be carried out carefully to match the surrounding work. In general, it should be made sure that all courses should be laid level, the vertical joints should be broken between the consecutive courses by overlap of mud bricks and should be fully filled with mortar and the perpendicular joints between walls should be made in such a way that through vertical joint is avoided. The lower layer of mud bricks should be moistened before the mortar is laid. Also, the surface of the mud bricks to be laid should be moistened for a few minutes before they are laid. This should be done as per IS 13827 : 1993

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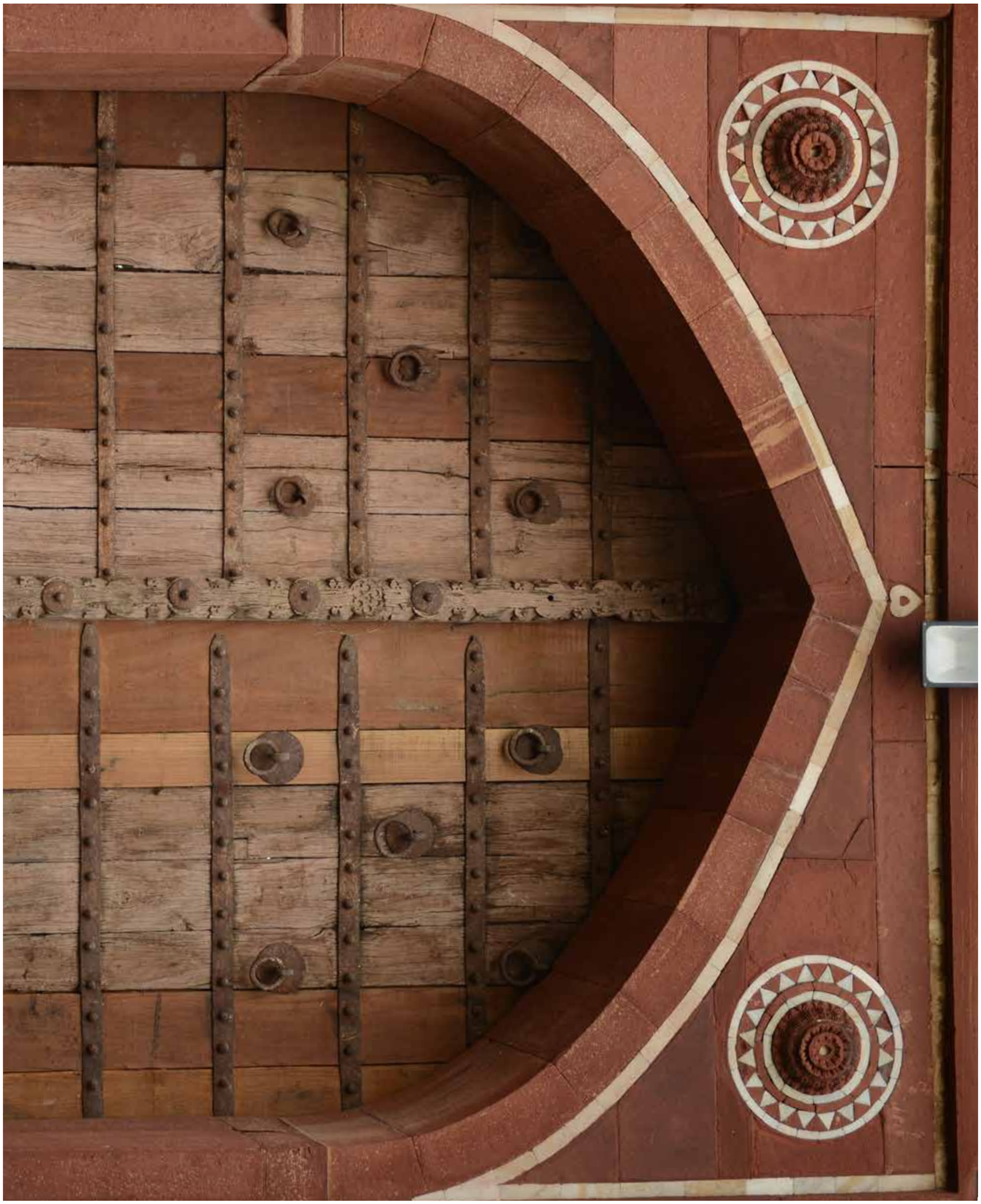

TIMBER WORK

CONTENTS

5. TIMBER WORK

This chapter provides information and guidance on conservation treatments for Timber work in heritage structures. All the conservation treatments should be carried out in consultation with a conservation architect and engineer-in-charge as per the requirement. Timber is found in Structural, non-structural and decorative parts of heritage structures, in almost all states in India. Traditional craftsmanship in timber is still in available and widely used. This chapter will apply to timber element with an exception of timber flooring and shingles. Chapter 7 Flooring and chapter 8 Roofing should be referred to for timber flooring and timber shingles respectively. Conservation of ornamental and decorative timber work should be undertaken in consultation with an art conservator.

5.1. MATERIALS

Materials used for conservation of Timber work are given below.

5.1.1 Preservatives

Preservatives should be of the following three types as per IS code: 401-2001 or otherwise specified by the conservation architect or as per regional/local practices. Preservatives should be applied as specified by the conservation architect either after repairs for existing timber or before installing new members as required.

a. Type 1 — Oil Type
   Coal/Lignite tar creosote with or without admixture of coal tar petroleum oil, fuel oil or other suitable oil having a high boiling range.
b. Type 2 — Organic Solvent Type
   Copper and zinc naphthenates, copper and zinc abietates, trichlorophenol, gamma- BHC (Lindane), chlorpyrifos and synthetic pyrethroids.
c. Type 3 — Water-Soluble Type
   Water-Soluble (Leachable) Type Zinc chloride, boric acid, borax, sodium pentachlorophenate, gamma-benzene hexachloride (water dispersible powder), sodium fluoride, chlorpyrifos and synthetic pyrethroids. Water-Soluble (Fixed) Type Copper-chrome-arsenic composition, acid-cupric chromate composition, copper-chrome boron composition, zinc meta-arsenite, berated copper chrome-arsenic composition and ammoniacal copper arsenate composition.

5.1.2 Hardware

Materials for new hardware should be of the same shape, size, colour and finishing as existing or as specified by the conservation architect. The hardware should be well made and free from defects. They should be finished correct to shape and dimensions. All sharp edges and corners should be removed and finished smooth so as to facilitate easy handling.

- Original hardware should only be replaced with or dissimilar or non-original (like stainless steel) when specified by the conservation architect.
- Nails and screws should be of sizes required to adequately secure the work.
- Fasteners wherever required, should be of a material and finish appropriate to the intended use as specified by the conservation architect.
- Wood dowels should be used to connect and fasten as per the original construction details and techniques. If deteriorated dowels should be replaced by a matching dowels of same shape size, configuration with any other details as the original.

5.1.3 Adhesives and Fillers

- Wood glue should be carpenter's or wood working glue as specified.
- Wood filler and Glaziers putty or wood putty as specified.
- Adhesives should be used as specified and should be non-shrinking, moisture resistant and paintable.

5.1.4 Finishing Materials

Finishing materials could be to match the existing or as specified by the conservation architect. All the materials should be of approved brand and manufacture and brought to site in their original packing in sealed condition.

5.1.5 Timber

New or Replacement Timber

- Salvaged timber should be used for repairs, subject to the approval of the conservation architect. Unsound, warped, bowed, twisted, improperly treated, not adequately seasoned should be discarded. Salvaged timber that is too small to fabricate or reuse with minimum of joints or optimum required jointing arrangements should not be used.
- If no salvaged timber cannot be found new timber should be used. No attempt should be made to artificially age replacement timber.
- All new timber should be from the heart of a sound tree of natural growth entirely free from sap wood. It should be uniform in texture and should be well and properly seasoned. It will be free from decay, large, loose, fungal growth, boxed heart, pitch pockets or streaks on the exposed edges, splits and cracks dead or cluster knots, wedges, injuries, open shakes, borer holes, rot, decay date, discoloration, soft or spongy spot, hollow pockets, pith or centre bore and all other defects or any other damages of harmful nature which will affect the strength, durability, appearance and its usefulness for the purpose for which it is required.
- Scantling of all types of timber should be straight. Warped scantling should not be used. Before use in works, the scantling should be kept in a covered area and well-ventilated place and should be approved.
- The workmanship should be of best quality. All wrought timber is to be sawn, planed, drilled or otherwise machine worked to the correct sizes and should be as indicated in drawing or as specified.
- The timber should be applied with preservative only where required and after careful consideration. All the embedded timber should be treated before installation before erection.
- New timber for battens, rafters etc should conform to the requirements for structural timbers specified in IS: 3629- 1986 or as specified by the conservation architect.
- Only properly seasoned timber should be used. New Timber for repairs should be of sound stock, thoroughly seasoned, air or kiln dried as specified. The final moisture content to which timber should be seasoned before use depends upon requirements of the finished article and the regional climatic conditions where it is to be used, and should conform to IS: 287-1973. The average moisture content attained in use will be as specified according to the use or 15% to 18%. All new timber members to be seasoned conforming to IS: 1141-1993. Methods of determination of moisture content have been laid down in IS: 11215-1991.
- Seasoning may not be necessary for salvaged timber and some varieties of timber and should be decided by the conservation architect.
- All joinery work should fit truly and without wedging or filling. Timber restoration work should follow the original or as specified.
- The new or the salvaged timber should match the existing and be of the same species as the original wherever possible or specified alternates. The grain direction and pattern, should have similar characteristics of grain where it will be visible. Tool marks, should be worked using similar craft methods and tools as the original as far as possible. Replacement timber should match in color and should be provided with similar finishes.

5.1.5.1 Occurrence

Many species and types of timber have been used for structures and other details depending on the local availability and the nature of work. Timber and their suitable properties should be identified using IS: 399-1963. Regional names may vary but some of the common building timber in India are listed below:

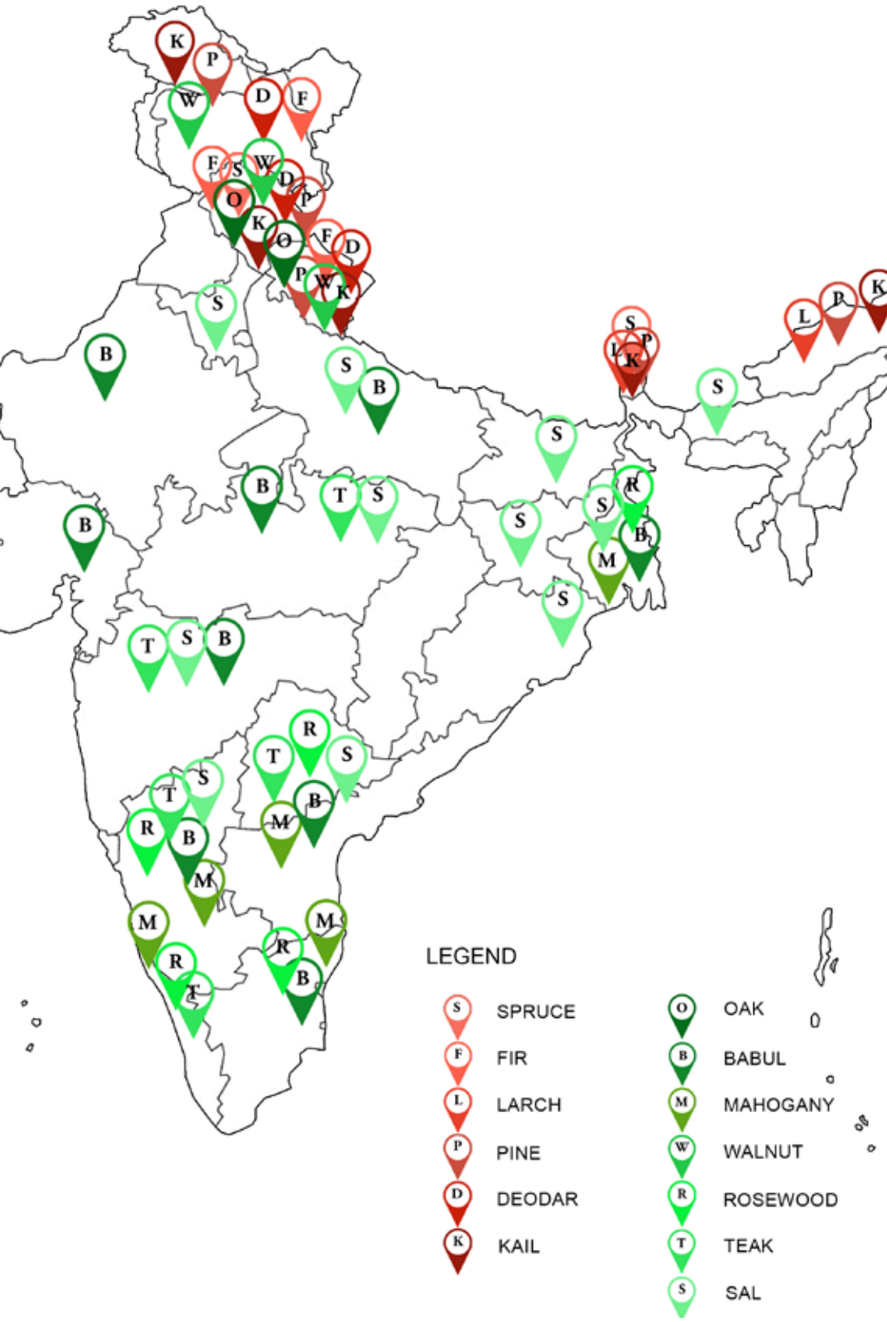

Figure 5.1: Types of timber available in India, Source: Modified from CPWD Specifications 2019.

5.1.5.2 Precaution and Care

a. Protect adjacent masonry, glass and surrounding surfaces in work areas.
b. Protect finished floors in work areas from damage.
c. Windows and doors openings from where shutters are removed should be temporarily covered and secured with waterproof material to protect against the elements and prevent unauthorized access to the building.
d. All windows and doors shutters removed from the site should be labeled with all necessary information including their numbers and their location to ensure reinstallation in the proper location.

5.1.5.3 Delivery, Storage, and Handling

As far as possible, seasoned timber should be promptly used before its moisture content has had time to alter due to climatic changes. IS: 1141-1993 should apply for storage and transportation.

- Timber should be stored with appropriate labeling to enable relevant information being communicated.
- All salvaged and new timber should be stored indoors in a clean, secure, well-drained area free of dust in a shed as much as possible. The shed should be maintained under dry conditions to retard moisture content change.
- Store all materials on flat surfaces, protected from exposure to harmful weather conditions and at temperature conditions specified.
- Timber should be stored in closed stacks. Stack vertically or on edge so that water cannot accumulate on or within materials. Contact with floor should be minimized and some gap should be provided for air circulation.
- Stacks may be further protected by tarpaulins or polythene covers enclosing each stack from all sides and the top. Planks and scantlings may be stored after strapping with metal bands in small lots.
- Decorative pieces should be handles with utmost care and under supervision as instructed by the conservation architect.
- Seasoned timber should be transported in close stacks in covered wagons or under tarpaulin covers to protect it against rain. Seasoned half-wroughts of timber for special use should preferably be packed in gunny bags for transport.
- Store solvents and chemicals indoors in a cool, dry location away from direct sunlight. Ensure that products remain within the temperature range specified by the manufacturer.

Figure 5.2: Methods of stacking: a) one and nine stacking, b) close-crib stacking, c) open-crib stacking.
Source: IS: 1141-1993

5.2. USE OF TIMBER IN HERITAGE STRUCTURES

Timber is found in many heritage buildings in the form of structural, non structural and decorative elements. Some of the documented uses are illustrated below for better understanding of its applications

Table 5.1: Use of Timber in Heritage structures

Beams and Columns		
Doors		
Flooring		
Trusses		
Brackets, Balusters, Railings		

5.3. DEFECTS

Timber work may have many issues due to various reasons like lack of maintenance, environmental factors, water penetration, structural faults, and defects in original construction. However, the most adversely impacting cause is natural bio deterioration to cause the timber work to fail. These include bacteria, fungi (rots), molds, insects (beetles, bees, ants) and borers. The defects should be assessed and diagnosed before applying corrective measures , assess them and formulate the conservation treatments accordingly. Some of the most typical issues with stone are listed below but the list is not exhaustive. For each site the conservation architect and engineer-in-charge should prepare their own list/ record of defects using the table below as a baseline.

Table 5.2: Defects of Timber Work

DESCRIPTION	CONSERVATION
Deteriorated or Decayed Timber	Refer 5.5.1 Partial Replacement
Small Holes and Cracks	Refer 5.5.2 Plastic Repairs
Loss of Material	Refer 5.5.3 Dutchman Repair Refer 5.5.4 Strengthening / Reinforcement
Hardware Missing or Loose Loose Joints Damaged Glass, Putty and Fillets Frames and Shutters New Doors	Refer 5.5.5 Doors and Windows
Decorative Wood Elements	Refer 5.5.6 Conservation of Decorative Wood Elements
Preserving Timber	Refer 5.5.7 Application of Preservatives
Deteriorated Finishes	Refer 5.5.7 Conservation of Finishes

5.4. TESTS

- The timber species and type should be identified correctly using scientific tests. Test should also be performed to determine the finishes in any have been applied to the timber components.
- The timber for repair and replacement should be correctly matched for compatibility and other characteristic properties through tests as suggested by the conservation architect. These include matching visual, physical and chemical properties.
- Tests also aid in ascertaining the issues with the existing timber and should be used to make informed assessment to ensuring appropriate repairs.
- These tests should be done under the guidance of a conservation architect or engineer in charge and should be conducted either in the field or in laboratory.
- The tests should be performed using current IS Codes provided in Bureau of Indian Standards.
- If the tests are not available in the IS Codes then international standards could be followed guided by the conservation architect or engineer.

REFERENCES FOR TESTS

ASTM International (American Society for Testing and Materials)
ICCROM ARC: A Laboratory Manual for Architectural Conservators Methods
Built heritage Evaluation- Manual Using Simple Test Conservation of Historic Stone Buildings and Monuments

5.5. CONSERVATION

Conservation treatments should be carried out after the source of the problem is identified and has been corrected. This section presents treatment techniques for conservation as a broad overview and should be modified for individual site requirements.The elimination or reduction of moisture sources must be carried out prior to remedial measures for bio deterioration defects.

- Repairs should be done in place using available techniques and materials, preferably traditional and local.
- New elements could be introduced for the reinforcement of the old structure where repair in place is not possible.
- Before dismantling consolidation using synthetic resin adhesives could be tried to repair in place.
- Dismantling should be last resort to replace damaged parts with replication by using local traditional techniques and materials
- Where necessary, ensure sufficient support/ propping has been set in place before the work is carried out.

5.5.1 Partial Replacement

- Partially deteriorated timber should be repaired, stabilized, to achieve a sound condition. Timber elements that are deteriorated beyond repair, should be selectively replaced.
- Depending on the location and use of the timber member a call should be taken on selective replacement or full replacement. For structural members an engineer-in-charge should be involved in decision making.
- Repairs should be carried out in timber using traditional carpentry methods, retaining all sound existing material, and replacing only what is necessary in order to restore structural integrity. Badly deteriorated or seriously split members or parts of members should be carefully cut away and new sections spliced in, using timber of the same species and scantling as the original.
- Members to be dismantled and removed should be documented and catalogued for the convenience of putting it back accurately.

Where old wood is damaged or deteriorated beyond repairs, it should be replaced by the new wood as prescribed below. New wood should be carefully be inserted where the deteriorated wood has been neatly removed.

a. **Removal of deteriorated timber:** Carefully remove timber at locations where it is damaged or deteriorated. Unless indicated otherwise, replace the entire length of the existing damaged piece to the next joint or upto the extent of the defect that needs to be addressed.
b. **Preparation:** A new piece should be prepared by neatly cutting to the required shape and size. The grains should be aligned and it should be leveled and fit well.
c. **Providing replacement:** Install the replacement piece, leveled, aligned and straight with no distortions using shims as required. Install with the minimum number of joints as much as possible. Joints should be provided using with standard joinery and should be staggered for adjacent members. Secure the members with nails or fasteners as to match the existing or as specified.
d. **Finishing:** Finish replacement woodwork to match adjacent woodwork surfaces.

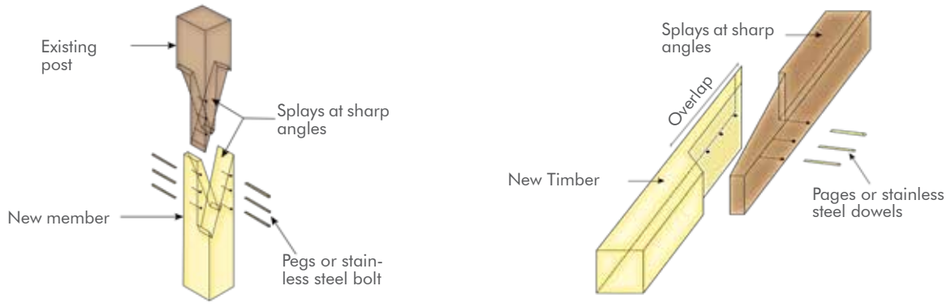

Figure 5.3: Rafter repair detail, Source: The Society for the Protection of Ancient Buildings, UK

5.5.2 Plastic Repairs

For small holes, indentations, gouges, deep should be repaired using fillers made at site or according to manufacturer's instructions for ready to use material. This type of repair is used for aesthetic improvement to areas that have suffered superficial damage to the surface. These repairs are only suitable for small, localized areas.

a. **Cleaning of surface:** Remove all minor surface imperfections such as scratches, dents, etc., by rubbing the surface with a fine sandpaper.
b. **Cleaning the holes:** Rout out hole or cracked woodwork to receive filler materials.
c. **Providing patch:** Patch all holes and cracks in timberwork across with timber filler (make it or buy it) tinted to match existing timber.
d. **Finishing:** Carefully rub the filled area with a fine sandpaper to match surface characteristics of adjacent timberwork. Touch-up the repaired area during finishing so that color and other appearance characteristics of filled area match the finish of adjacent timberwork.

Making filler

- **Sift sawdust:** To ensure that the timber filler is effective, it should be ensured that it does not contain any shavings or large pieces of timber. Spread the sawdust out on a flat surface and carefully sift through it to remove any larger pieces or debris that may have inadvertently collected along with it.
- **Add glue:** Gather the sawdust together into a pile and add a small amount of glue. Be sure to carefully choose the type to mix with the sawdust.
- **Mix:** Use a dowel to combine the mixture and gradually add more glue, making sure that the two components are thoroughly combined. Continue until a putty-like substance that can be manipulated with clean fingers is formed. If it appears too wet then it should be rectified by adding more sawdust and if it is too dry can be modified by adding more glue. It should be ensured that it is thoroughly mixed before use. The mix should be used as soon as it is ready to prevent it drying out early.

5.5.3 Small Repairs with Dutchman

Small sections of deteriorated timber work or voids and missing timber work should be carefully filled with timber dutchman (plugs). Dutchman repairs should match the existing adjacent timber species and grain orientation.

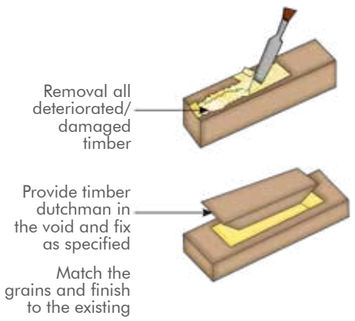

Figure 5.4: Dutchman repair, Source: Home repair, restoration & improvement, Tom Pawlak, 2018

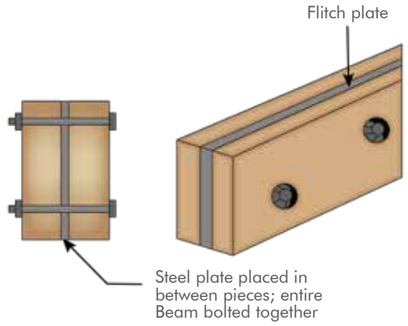

Figure 5.5: Steel plate placed in between pieces; entire beam bolted together. Source: English Heritage Buildings

a. **Removal of deteriorated timber:** Neatly cut out deteriorated materials to form prismatic profile with inclined sides.
b. **Preparation of dutchman:** Cut dutchman to exactly fit the void with tapering edges and base to fit the prismatic void. The grain of dutchman material should align with the grain of the receiving member. It should be slightly larger than the void so when it's driven inside the extra can be shaved or cut off.
c. **Providing dutchman:** Secure dutchman with wood glue or nails depending on the size and location of the repair in place. Dutchman patches should fit snugly on all sides, leaving only hairline gaps.

5.5.4 Strengthening / Reinforcement

It's often possible and preferable to leave timber structural member in place and support using an alternative member. Timber members should be mechanically strengthened when it is not possible or desired to repair in situ or by dismantling. Such timber members can be splinted with new timber, steel, or other materials by means of gluing, screwing, or bolting as specified by the conservation architect and the engineer-in-charge some techniques for strengthening are listed below.

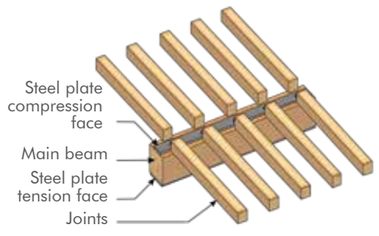

Figure 5.6: Reinforcing the rotten timber with top and bottom plates, Source: Conserving of Timber Structures in India, Benny Kuriakose, 2007

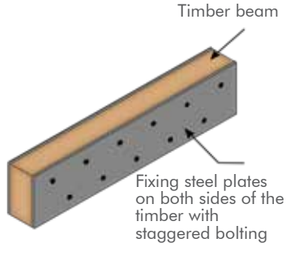

Figure 5.7: Reinforcing the rotten beams with side plates, Source: Conserving of Timber Structures in India, Benny Kuriakose, 2007

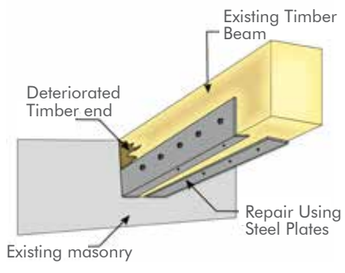

Figure 5.8: Reinforcing the rotten timber end with steel brackets/plates Source: Joist repair plates, AG Bell

5.5.4.1 Flitch Plates

A flitch beam is a compound beam made up of a steel plate or a flitch plate sandwiched between the solid timber beams, held together by bolts.

5.5.4.2 Side Plates

Steel plates can be fixed on either side of a weak member and can be bolted horizontally to the timber beam. The side plates must not be fixed against uneven surfaces as the voids behind them form breeding grounds for insects.

5.5.4.3 Bottom and Top Plates

In this method, the metal plates are bolted to the bottom and top of the weakened timber beam. The steel plates act as the top and bottom flanges of an I section, and the timber beam acts as the web. The bolting of the plate to the beam must be a rigid joint spread over a wide area, to reduce the splitting of the timber. The bolt holes must be spaced out to avoid the weakening of the beam. To allow for seasonal movement, the bolting of the plate to a joint must be flexible. It can be made through angled holes and should not be filled with glue or grout.

5.5.4.4 Brackets

Failed or weak connections can be strengthened or replaced by special brackets, angle irons, fishplates, stirrups, and hangers.

5.5.4.5 Extending

The bearing can be extended by introducing steel or timber bolted under or sides of the beam; by forming a whole box section steel shoe attached into the beam. Another method with timber members strapped and bolted to extend could also be used.

NOTE: In addition, a beam pulling out of an adjacent beam can be picked up with a fabricated strap like a joist hanger or by creating a timber or steel corbel on the wall beneath the end of the timber or by creating a bearing.

The timber may be reinforced with dowels or pegs of timber, metal, or glass fiber reinforced plastic. Carbon fibre reinforced polymer, clamps or wedges such as "butterfly clamps" may be inserted.

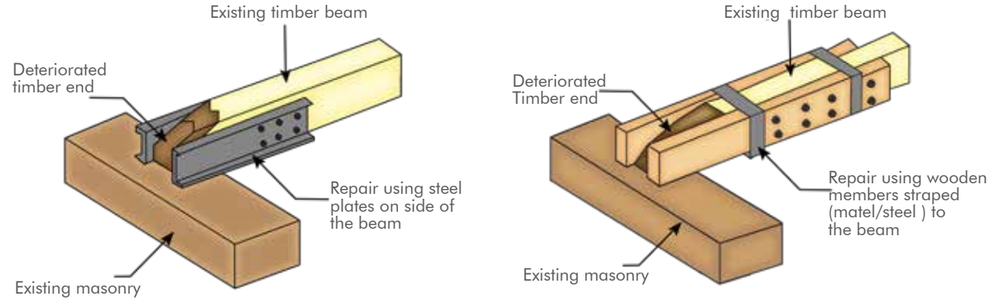

Figure 5.9: Reinforcing the rotten timber end with side plates and timber members using metal/steel straps, Source: Repair and Strengthening of Traditional Timber Roof and Floor Structures, 2018

5.5.5 Doors and Windows

- Old windows and doors contribute immensly to the value of a historic building. Substitutes using other materials such as aluminum and PVC must not be done. Retention and repair of historic doors is the most appropriate treatment for heritage structures. Repair options should be evaluated prior to considering replacement. The first step is to evaluate the condition of existing doors, which can often be done simply through close visual inspection. In the case of a localized defect, the affected part may be removed and replaced with new pieces of timber as discussed above in 5.1.1.
- Old doors and windows should be replaced with new ones only when the timber members have deteriorated beyond 50%. Specifications for new timber members are detailed in Section 5.1.5.
- In case of replacement of a missing door or window, a suitable design in conjunction with the original design of the doors and windows should be installed as per design drawings issued by the conservation architect.
- Selective, in-kind replacement may also be needed to address issues such as bottom rail rot or stiles that have been heavily damaged.
- The joints for all the work should match the existing or the traditional methods of the period as approved by the conservation architect.

5.5.5.1 Loose or Missing Hardware

Hinges, which attach the doors and windows to the jamb with screws, may become loose over time. As a result, the doors can become unbalanced.

a. Loose hinges should be tightened with existing or new screws.
b. If the screw holes are stripped, longer replacement screws or the use of wood dowels to reinforce screw holes may be needed.

i. Hardware

New hardware should be installed to match the existing while the missing or the old existing hardware should be treated and re-fixed.

Figure 5.10: Damaged base of door and missing hardware..

a. Remove and clean existing hardware to be re-used, removing encrusted paint, grime and grease using detergents and cleaning solvents as required. The use of abrasive cleansers should be avoided.
b. Cleaned hardware should be accurately and properly installed.
c. Adjust all new and existing hardware for proper operation and lubricate if necessary

5.5.5.2 Open or Loose Joints

Doors are comprised of stiles, rails, and panels connected through joints, and are held in place with glue and wedges or pegs, nails and may become loose over time. Gaps may form between the different parts of the doors, affecting its ability to shut completely and smoothly. Wedges and nails should be replaced nd new glue applied to restore its functioning.

5.5.5.3 Replacing Damaged Glass, Putty and Fillets

i. Glass Panes

Damaged, broken glass panes should be replaced with new to match existing. When the same glass is unavailable, replacements should be specified by the conservation architect. This refers to plain and coloured glass and not stained glass.

a. Removing broken glass panes: Carefully take out old putty or wooden fillets with a putty knife and other hand tools. Remove the brad (small nails without head) and pieces of broken glass from the rebates. The pieces of glass panes as found useful should be handed over to the Engineer-in-Charge of the work .
b. Cleaning: Clean, scrape and sand to remove any remaining putty and paint down to bare timber. Make sure the sash is dry and clear of all dust and debris. Apply boiled linseed oil to the exposed timber and/or prime with an oil-based. No glass should be inserted in frames until they have been primed and prepared for painting so that the timber may not draw oil out of the putty.
c. Installing new glass panes: Cut the floating glass panes so that it fits slightly loose in the frame. Prepare a thin layer of Putty conforming to IS: 419-1967 to form a stiff paste. The putty so prepared in the form of a stiff paste should be installed along the inner edge of the rebate. The specifications for glass panes and their fixing should be the same as per IS: 14900-2018.
d. With putty: Put the glass pane in position, pressed against the thin layer of the putty, and secured in rebate by new brads. Clean the putty that squeezes out after putting in the glass. Apply the putty in the rebate uniformly, sloping from the inner edge of the rebate. The putty filled in the rebates should be levelled smooth and finished in a straight line. When dried the putty should be covered with a coat of paint of approved quality and shade to match the existing. Clean the glass panes with an appropriate of all splashing or droppings.
e. With fillet: The existing fillets can be used if approved by the conservation architect. If new are specified, then the fillets should be of material to matching the existing. Fix the fillet either flushed or projected uniformly to match with the existing by means of nails (brads). Paint the fillet or finish otherwise to match with the existing. Clean the glass panes with an appropriate of all splashing or droppings.

5.5.5.4 Replacement of Frames and Shutters

- In case a door or window frame is missing or damaged beyond repair then a full replacement should be provided. A replacement may also be desirable when the original door or window frame has been replaced altering the design of the original changing the overall historic character and authenticity of the building and the context.
- Replacement doors or windows should match the original materials, type, shape, size, proportions, design configuration, profiles and details as the original. The new replacement should match the existing or in case of no evidence, it should be of appropriate design as approved by the conservation architect. The construction and installation details of the new door/windows should be as per design drawings issued by the conservation architect. Doors/windows from no other style or period should be installed.

Figure 5.11: Teak wood single and double paneled shutter doors.

- In case of interventions that alter the appearance of the door/window all non-original interventions should be removed taking care not to damage the remainder of the door, frame. All non-original elements should be replaced with new timber with appropriate details which matches the original timber and the detailing of the original work. All the new work should match the existing or as specified by the conservation architect.
- Care should be taken to remove deteriorated or damaged doors/windows to be replaced.
- Documentation of shape, size, and location with other details should be carried out before dismantling.
- During replacement, all the hardware should be removed and stored. New non-compatible hardware should be discarded and replaced with hardware matching the original.
- If absolutely no evidence is found or it is difficult to ascertain the design or the style then a simple design that reflects the period be installed to show honest interventions based on the decision of the conservation architect.

i. Teak Wood Panelled Shutters

Teak timber door shutters should generally conform to standard laid in IS: 1003-2003 or the latest revision for requirements of materials, construction workmanship and should be of specified thickness and of 1st class C.P. teak timber of approved design with stiles, top, bottom and lock rail generally as per consultant's drawing. Wherever shown, each panel should be in a single width piece, but when two or more pieces have to be used and are permitted, all of them should be of equal width or a combination of sizes as per availability and match the grains as much as possible during joining and should be jointed with a tongue and groove joint with chamfered edges glued together or by other timber joints and dowels using traditional techniques.

ii. Teak Wood Glazed Shutters

The specifications for teak timber paneled shutter should generally apply to glazed shutters for frame, stiles etc. The sash and beading required for glazing should be of the best teak timber and should be fixed as per the design shown in relevant drawing. Any mouldings, carvings shown should be worked out from the teak wood member of bigger size. The glazing is to be matched in size, thickness and color with glazing of existing windows in the building. New glazing to be used on approval of the by the conservation architect. .

5.5.6 Conservation of Decorative Timber Elements

The work should be carried out in accordance with the specified drawings or as directed by the conservation architect and art conservator. Specified timber should be used. It should have been sawn in the direction of the grain. Sawing should be truly straight and square and free from wanes. The grounds should be in second class teakwood or as specified. These should be painted with red lead and fixed to match the existing or with screws to wooden plugs buried in the walls. Wall panelling moulding wall panelling, skirting chair rail picture rail cornices and other mouldings should be made true and accurate to the dimensions shown on the working drawings. Before being fixed to the grounds, the back should be painted with red lead. The fixing should be done true to the lines and levels.

5.5.7 Application of Preservatives

- Preservatives should be applied as per IS code: 401-2001. Regional and local practices should be followed wherever applicable like neem oil. These should be prescribed by conservation architect based on individual case and the need, as per the site requirement and as per local climate.
- Preservatives should be applied to all bare surfaces of wood after repairs and cleaning have been carried out, and before finishes are applied.
- When used readymade mixes, manufacturer's written instructions and labeling with regard to substrate conditions, dilution, mixing, and application should be followed.
- Provide protection to adequately protect adjacent work and materials. Do not allow wood preservatives to drip, pool, or settle onto adjacent surfaces, including exposed sides of stain finished eave boards.
- Apply only to clean, dry, bare wood that has no remaining paint or water repellent present.
- Do not apply in the rain. Do not expose treated exterior wood surfaces to rain for at least 48 hours after treatment.
- Apply the first coat of wood preservative to the point of saturation. Allow to dry at least 20 minutes before applying a second coat, if necessary.
- Allow wood preservatives to dry for at least 48 hours before applying paint or stain finish. Preservatives can alter the colour of the timber in some cases.
- Strength of timber should not be affected by the preservative.
- Preservatives should not penetrate too much into the historic substrate. The depth of penetration of preservative in wood fibers should be minimal.

5.5.8 Finishing

Deteriorated old finishes should be removed before applying new finishes. It is important to ascertain the existing finish to be removed through appropriate testing before narrowing down to technique of removal and also for its reapplication.

5.5.8.1 Removal of Finishes from Timber

i. Removal of Shellac and Lacquer

Shellac can be removed with denatured alcohol. Lacquer can be removed with lacquer thinner and a 50-50 mixture of denatured alcohol and lacquer thinner can remove a combination of shellac and lacquer. Aggressive chemicals are not required for the removal of these finishes. Test the finish first with denatured alcohol. If the finish liquefies, then it is shellac. If it gets soft, then it might be a combination of shellac and lacquer. Apply lacquer thinner to the surface. If it liquefies, then it is lacquer.

ii. Removal of Paint

By Sanding: The old paint can then be scraped off. The main drawback of sanding is that it removes some of the timber surface underneath paint. Sanding can be done with sandpaper along the grains of the timber member using water paper/emery paper to get a perfectly smooth and uniform finish. It can be used on extremely rough jobs. No such process should be applied on decorative and carved timberwork.

By Applying Solvents: The exact method of applying the solvent may vary slightly, but broadly the following procedure may be adopted;

a. Apply the appropriate solvent to the section of the timber member. Do not brush, but rub on it gently with a piece of cloth.
b. Always work in one direction only.
c. Leave the chemical in the timber for a few seconds as specified depending on the surface and the type of solvent. This time may vary with the solvent and the coating. In the case of paint remover, it can be a few minutes.
d. Then wipe off with the rough cloth.
e. The speed is important because many of the solvents such as alcohol and lacquer thinner evaporate very quickly.
f. The work should proceed in sections and the cloth should be changed after a few sections or as required.
g. In the case of a vertical section, start at the top and work down. In the case of old doors and windows, there may be many coats of paint or varnish. Patience is required for the removal of the coating without damaging the timber pieces.

5.5.8.2 Applying New Finishes

Timber in heritage structures has a variety of finishes depending on their location in the building and local practices. New finishes of paint, varnish, wax should be applied as specified by the conservation architect to match the existing finishes. All surfaces to be finished should be dry. Several days should be allowed for the timber surfaces to dry after stripping procedures.

i. Surface Preparation

After stripping the older finishes as in section 5.5.8.1 or as specified by the conservation architect, the surfaces should be prepared to receive new specified finishes like paint, wax, or varnish. All surfaces should be cleaned of grime,

grease, dirt, loose material, and other substances that may interfere with the proper adhesion of the new surface finish. Then it should be prepared smooth with a carpenter's plane and by sanding. Cracks and holes should be cleaned of dust and provided with repairs to have a better bond with the new finishes, as per section 5.5.2

- Sealer coat : Sealer coats are to be applied after old finishes have been removed.
- Primer: Primer should be applied as required and as specified by the conservation architect. Primer should be applied on a clean surface. The primer should be applied with brushes, worked well into the surface and spread even and smooth. After the priming coat is applied, minor holes and indentation on the surface should be filled.

Some commonly used finishes are mentioned below and should be used to match the existing finishes. Alternatives should be provided by the conservation architect if original can't be used for some reasons.

ii. Paint

The Paint should be continuously stirred in the smaller containers before applying so that its consistency is uniform. The painting should be applied evenly and smoothly in the direction of the grains of timber. In this process, no brush marks should be left after the laying off is finished. The number of coats should be as specified. No hair marks from the brush or clogging of Paint puddles in the corners of panels, angles of dings etc. should be left on the work. In painting doors and windows, the putty round the glass panes must also be painted but care must be taken to see that no Paint stains, etc. are left on the glass. After work, the brushes should be completely cleaned of Paint and linseed oil by rinsing with turpentine.

iii. Varnishing

Varnish should be done if specified to match the original surface finish. Varnish is not easily removable and is considered irreversible.

Apply varnish of specified quality and number of coats as specified. In handling and applying varnish care should be taken to avoid forming froth or air bubbles. The undercoat should be with a flatting varnish. This dry hard and brittle and when cut and rubbed down to produce a smooth surface enhances the gloss of the finishing varnish. The varnish should be applied liberally with a full brush and spread evenly with short light strokes. If the work is vertical the varnish should be crossed and recrossed and then laid off, latter being finished on the upstrokes so that varnish, as it sets, flows down and eliminates brush marks, the above process will constitute one coat. If the surface is horizontal, varnish should be worked in every direction, with light quick strokes and finish in one definite direction so that it will set without showing brush marks. Rubbing down and flatting the surface should be done after each coat except the final coat with fines and paper. The work should be allowed to dry away from droughts and damp air. The finished surface should then present a uniform appearance and fine glossy surface free from streaks, blister etc.

Any varnish left over in the small container should not be poured back into the stock tin, as it will render the latter unfit for use. Special fine haired varnishing brushes should be used and not ordinary Paint brushes. Brushes should be well worn and perfectly clean.

iv. Waxing

The polishing should be done with bees wax prepared locally or with readymade wax polish of approved brand and manufacture, as specified. In this case one or two coats should be applied as necessary to get uniform gloss, instead of three coats in the case of new work. The polish should be applied evenly with a clean soft pad of cotton cloth in such a way that the surface is completely and fully covered. The surface is then rubbed continuously for half an hour. When the surface is quite dry, a second coat should be applied in the same manner and rubbed continuously for one hour or until the surface is dry. The final coat should then be applied and rubbed for two hours (more if necessary) until the surface has assumed a uniform gloss and is dry, showing no sign of stickiness.

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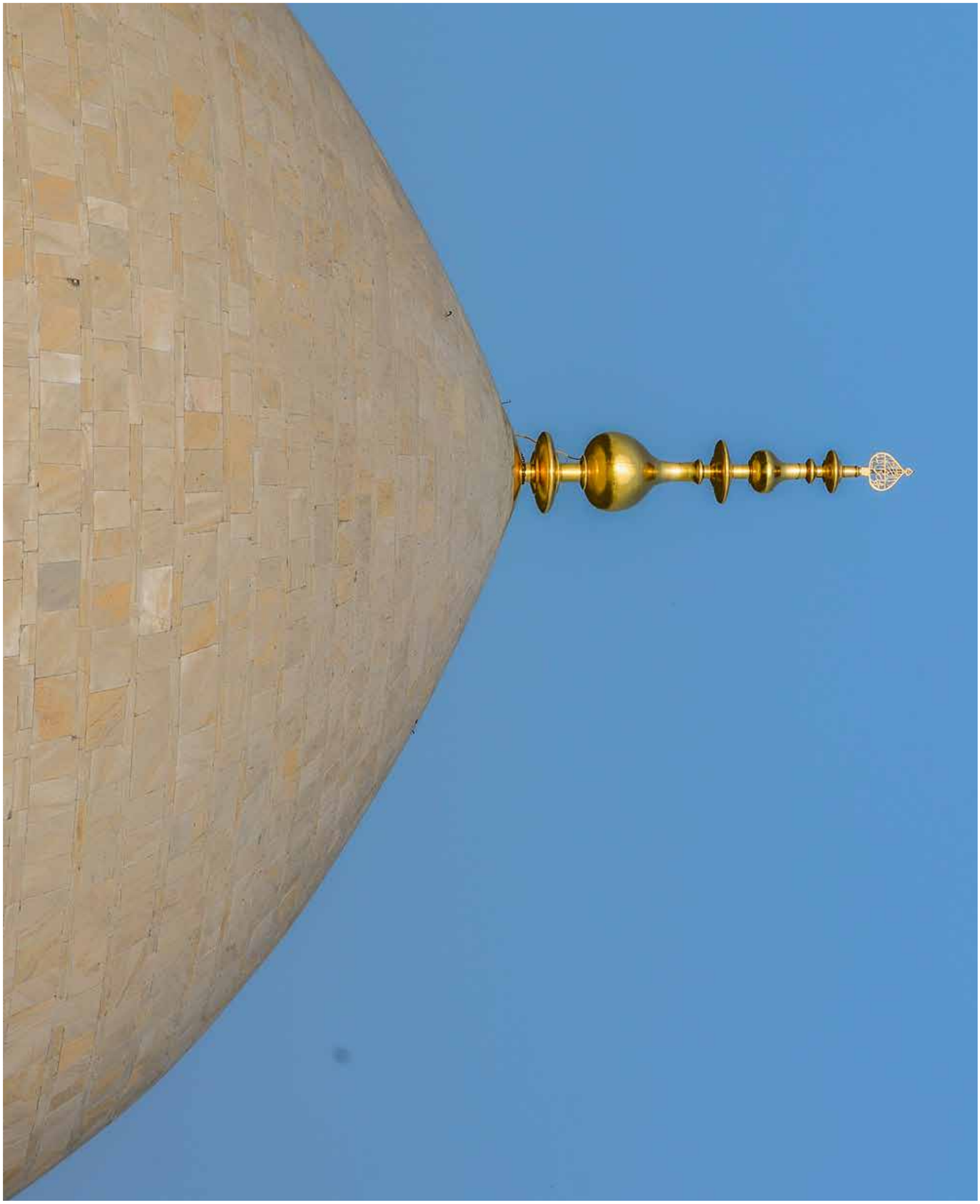

METAL WORK

CONTENTS

6. METAL WORK

This chapter describes and provides guidance on conservation treatments for metals in heritage structures. The conservation treatments should be carried out in consultation with a conservation architect and engineer-in-charge as per the requirement. Conservation of ornamental and decorative works should be undertaken in consultation with a metal or art conservator. Metals like wrought iron, cast iron, copper, brass, bronze and zinc, have been used in various forms in heritage buildings due to abundance of such metals and India's expertise in metallurgy. This chapter should not apply to gold, silver and 20 century metals like aluminum, tin and steel. Structural application of metals and its conservation is not discussed in this chapter.

6. 1 MATERIALS

6.1.1 Adhesives and Fillers

- Adhesives should be chosen carefully for each metal.
- All the fillers and adhesives should be specified and approved by the conservation architect. Usually, fillers are alloys or unalloyed metals which melt when heated, and fill the required area.
- These should be carefully chosen and applied through techniques such as welding, brazing or soldering joints

6.1.2 Hardwares

- Materials for new hardware should be of the same in shape, size, colour and finishing as existing or as specified by the conservation architect. The hardware should be well made and free from defects. They should be finished correct to shape and dimensions. All sharp edges and corners should be removed and finished smooth so as to facilitate easy handling.
- Original hardware such as bolts, nuts, and screws will only be replaced with or dissimilar or non-original (like stainless steel) when specified by the conservation architect.
- Nails and screws should be of sizes required to adequately secure the work.
- Concealed fasteners should be provided as specified for decorative metal items unless exposed fasteners are unavoidable.

6.1.3 Techniques

- **Brazing:** Brazing is a form of soldering that uses a bronze or brass filler metal.
- **Soldering:** The joining of metals by fusion using an alloy with a lead or tin base.
- **Welding:** The joining of metals by heating them with or without the use of filler metal.

6.1.4 Finishing Materials

Finishing materials should be to match the existing or as specified by the conservation architect. All the materials should be of approved brand and manufacture and brought to site in their original packing in sealed condition.

6.1.5 Metals

Salvaged metal should be used for the repair, wherever available, provided it is in good condition and should be approved by the conservation architect. If salvaged metal is not found, new should be procured and used to match the existing.

6.1.5.1 Occurrence of metals in India

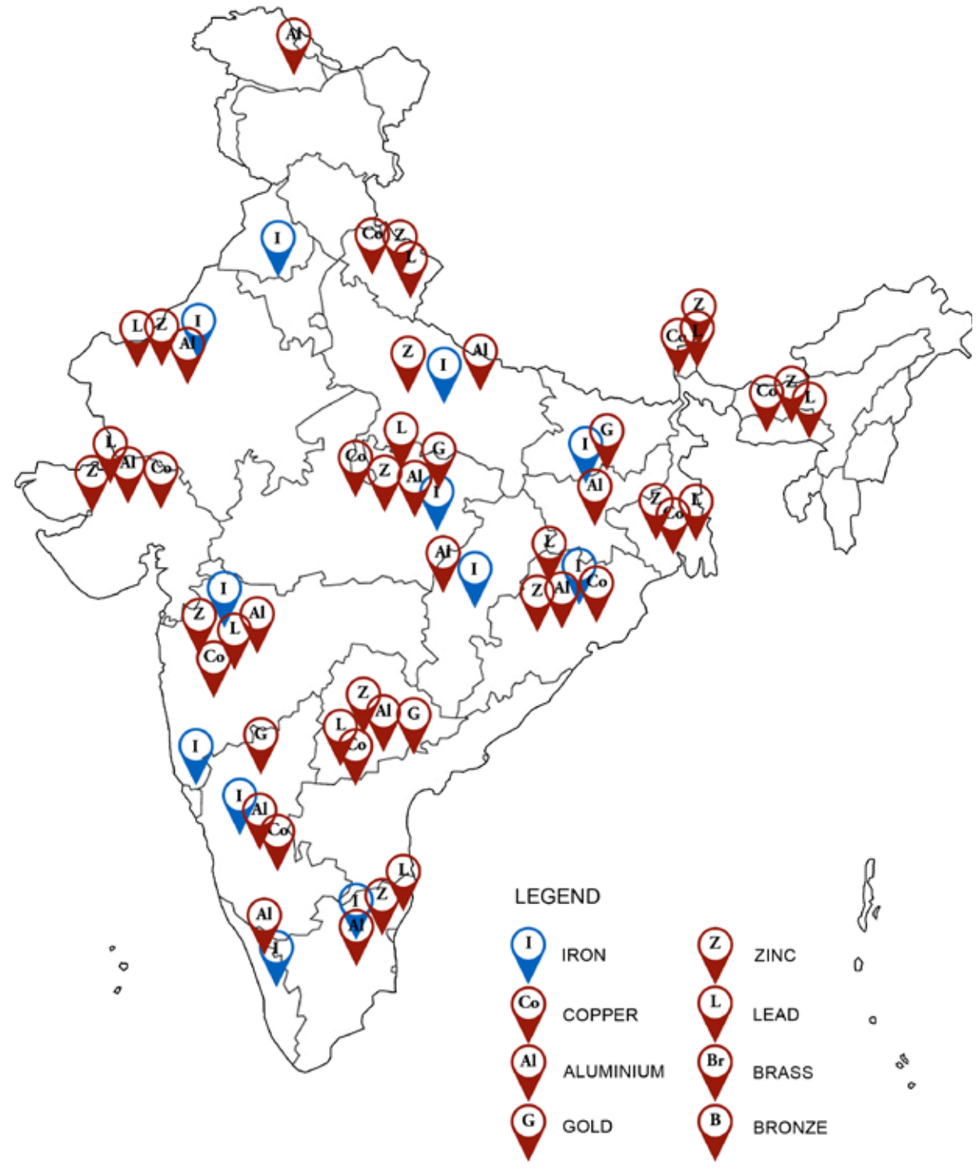

Figure 6.1: Map showing mineral distribution in India,
Source: Envis centre on Environmental problems of mining, Indian Institute of Technology (ISM), Dhanbad, Jharkhand

6.1.5.2 Types

Metals can be divided into two main groups: ferrous metals are those which contain iron and non-ferrous metals that are those which contain no iron.

Metallic minerals are the sources of metals and provide a strong base for the development of the metallurgical industry. Iron ore, bauxite etc. produces metal and are included in this category. Metallic minerals exhibit a metallic shine or lustre in their appearance.

Metallic minerals can be further divided into ferrous and non-ferrous metallic minerals. Ferrous Minerals: All those minerals which have iron content are called ferrous minerals. Iron ore, manganese and chromites are examples of ferrous minerals.

Ferrous Minerals account for about three-fourth of the total value of the production of metallic minerals. These minerals provide a strong base for the development of metallurgical industries, particularly iron, steel and alloys.

India is well-placed in respect of ferrous minerals both in reserves and production. Non-ferrous Minerals: Minerals which do not contain iron are known as non-ferrous minerals. Copper, bauxite, etc. are non-ferrous minerals. India is poorly endowed with non-ferrous metallic minerals, except bauxite.

6.1.5.3 Precaution and Care

- Extreme care should be taken while handling metals since they are prone to denting and being damaged.
- Care should be taken while undertaking processes like brazing, welding, and soldering and should be supervised.
- Appropriate safety gear should also be used while undertaking these procedures.
- Care should be taken in extreme hot and cold weather while working with metal members.

6.1.5.4 Delivery, Storage, and Handling

- Dismantled metals are susceptible to theft or loss, so insecure loose components should not be left unsupervised.
- The storage areas should be clean, secure and most importantly be as dry as possible.
- Metal elements should not be stacked and may require some support and protection from abrasion by providing cushioning.
- To reduce the stress dismantled metal elements should be stored in the plane from which they were taken out from the building. For example, window frames, doors and similar elements should be stored upright.
- The dismantled piece should be labeled systematically with tags and stored flat on wooden palettes.

6.2. USES OF METAL IN HERITAGE STRUCTURES

Metals are found in many heritage buildings in the form of structural, non structural and decorative elements. Some of the documented uses are illustrated below for better understanding of its applications

Table 6.1: Use of Metal in Heritage structures

Gates	
Brackets	
Railings	
Stairs	 
Water Disposal Pipes	 

Hardware		
Elements: Plaques and medallions		
Finials		

6.3. DEFECTS

Metals are very durable but are also prone to deterioration due to natural or inherent problems, exposure to the elements humans use causing wear and tear as well as vandalism and mechanical impacts. Maintenance also plays a vital role in longevity of metal elements. The defects should be assessed and diagnosed before applying corrective measures. Some most typical issues with stone are listed below but the list is not exhaustive. For each site the conservation architect and engineer-in-charge should prepare their own list/record of defects using the table below as a baseline with the help of a metals conservator as required , assess them and formulate the conservation treatments accordingly.

Table 6.2: Defects of Metal

DESCRIPTION	CONSERVATION
Deformation	Refer 6.5.1 Hammering and Chasing
Cracks and Holes	Refer 6.5.2 Filing Holes
Tear or Damage	Refer 6.5.3 Patching or 6.5.4 Replacement
Coating and Corrosion	Refer 6.5.5 Removal of Coatings and Corrosion
Connection Failure	Refer 6.5.6 New Connections

6.4. TESTS

As a first step, the metal should be correctly identified using tests as suggested by the conservation architect or metal conservator. Simple tests like identification of color of metal, density, magnetic properties should be performed. Docuevidence and construction techniques also aids in determining the types of metal.

- Tests also aid in ascertaining the issues with the existing metals and should be used to make informed assessments to ensure appropriate repairs.
- These tests should be done under the guidance of a conservation architect or a metals conservator and should be conducted either in the field or by laboratory analysis.
- The tests should be performed using current IS Codes provided in Bureau of Indian Standards.
- If the tests are not available in the IS Codes then international standards could be followed under conservation architect's guidance.

REFERENCES FOR TESTS

ASTM International (American Society for Testing and Materials)
ICCROM ARC: A Laboratory Manual for Architectural Conservators Methods
Built heritage Evaluation- Manual Using Simple Test Conservation of Historic Stone Buildings and Monuments

6.5. CONSERVATION

Conservation treatments for metals should be carefully selected on the basis of a thorough analysis of the causes of the deterioration. The interventions should be kept to minimum. The causes of the problems should be identified and addressed before carrying out any repairs. This section presents conservation techniques for metals and should be modified for individual instances and situations with the conservation architect and engineer-in-charge as required. For conservation of metal architectural elements, following should be considered during conservation procedures:

- avoiding contact between dissimilar metals,
- the selection of new metals that are compatible with the existing metals.
- the selection of suitable corrosion-resistant materials, when possible.
- provisions for the removal and prevention of trapped water.

6.5.1 Hammering and Chasing

Small dents should be treated using a technique called repousse or hammering if the backside is accessible and the metal is not too thick. In this technique, the dented piece is hammered from the backside to shape it to its original profile. However, if the metal has stretched, it should be difficult to hammer it back to its original profile. Chasing or embossing is a similar technique in which a piece is hammered from the front side to shape and remove the dents. Both hammering and chasing are often used in conjunction with each other. The process for hammering is outlined below.

a. **Flipping:** Carefully dismantle the element and turn over to receive the hammering if the element is inaccessible in its current or original location.
b. **Repousse or hammering:** Carefully hammer the element to remove dents and achieve the required to profile making sure that the surrounding surfaces don't get affected.
c. **Filling cavities:** Fill the cavities formed by hammering with appropriate filler material as specified.

d. **Chasing:** Refine the repair by chasing once the filler material is dry or hard. It should be performed with utmost care as to not deform the front of the piece. Repeat these procedures several times, alternating between hammering and chasing as instructed by the conservation architect to achieve desired result.
e. **Finishing:** Provide new finishing on the front and back side to match the existing.

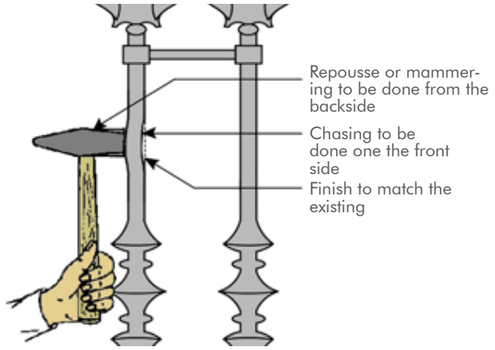

Figure 6.2: Repair with hammering

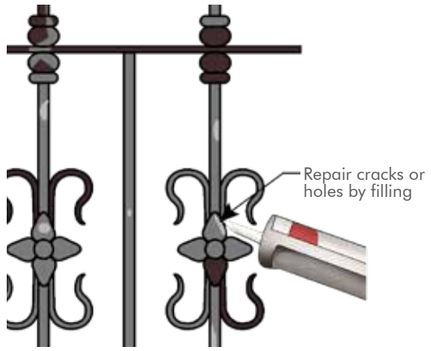

Figure 6.3: Repair with filling

6.5.2 Filling Holes

For nonstructural cracks and small holes filling should be used. Such defects should be treated and made weather-tight by using fillers, depending on the width of the cracks or holes. Filler compounds should be used as specified for each metal based on its properties, condition and its location in the structure.

In some cases, wide or deep cracks can be repaired by brazing or welding with special nickel-alloy welding rods. Brazing or welding of some metals is very difficult to carry out in the field and should be undertaken only by very experienced welders.

For filling cracks and small holes the following steps should be followed.

a. **Cleaning:** Clean the crack or hole and the surrounding area with sandpaper or other methods as specified, to remove dirt, corrosion, oil, and paint in small sections only.
b. **Priming:** prime the area immediately after cleaning to avoid contact with air.
c. **Filling the holes:** Carefully fill the cracks or holes using the specified material with appropriate tools and allow it to dry.
d. **Sanding:** Sand the filled area for a smooth surface and level to match the surrounding.
e. **Painting:** Apply a coat of paint over the patch and finish with paint to match existing surrounding surfaces.

6.5.3 Patching

For torn or damaged areas patching should be used. Patching involves mending and covering a damaged or deteriorated area with another piece of material that matches the existing. Depending on the type of metal and its location, the patch could be applied by welding, soldering, brazing. Mechanical repair connections, such as rivets can also be used. This is mostly used for non-structural elements and are not applicable to structural elements.

a. **Cleaning:** Clean the damaged surface and wipe it with specified cleaner and make sure that there is no residue.
b. **Abrasive cleaning:** Clean the surface with a wire brush or by sanding or any other appropriate method should be used as specified.
c. **Preparing patch:** Cut matching approved material to a suitable size to cover the area to be patched. The patch should be cut slightly larger than the area to be covered. File the corners and edges of the patch and make it made smooth.
d. **Providing the patch:** Apply sealant on the edges of the area to be patched. Apply the patch in place and press it over the damaged spot.
e. **Securing:** After pressing the patch into position, fix it with an appropriate method such as brazing, or fasteners or screws as specified around the patch.

f. **Cleaning:** Clean the areas around the patch of sealant or any other residual material.
g. **Finishing:** Finish the patch to match the adjacent surfaces.

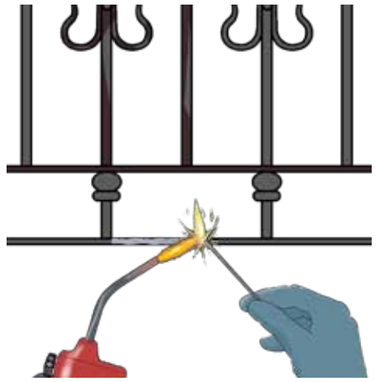
Figure 6.4: Patch repair with appropriate technique

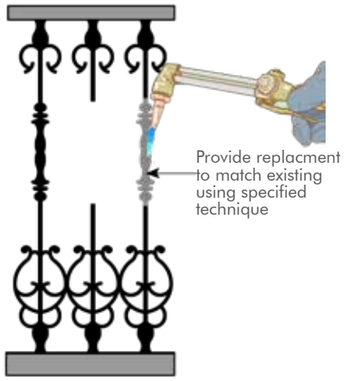

Figure 6.5 : Repair by replacing damaged sections

6.5.4 Replacement

Severely damaged or deteriorated sections that are beyond repair should be cut out, replicated by recasting, and reattached by methods specified by the conservation architect.

- Dismantling the deteriorated or damaged element should be done under the supervision of a conservation architect.
- All elements to be replaced should be well documented for its material, size and methods of attaching for accurate replication. These elements should then be dismantled and disposed at a location approved by the engineer in-charge.
- While undertaking replacement, the components should be laid out and pre assembled to make sure that the alignment and fit are proper.

For replacing metal elements the following procedure should be followed.

a. **Making a replica:** To replace an existing element, new element should be made to order by providing accurate details for the replication generated through documentation.
b. **Removal of damaged elements:** Carefully remove damaged or deteriorated elements from its original location.
c. **Providing replacement:** Install new element using the same details as the existing for fixing in the required location.
d. **Finishing:** Finish the replacement elements to match the existing, adjacent surfaces.

6.5.5 Removal of Coatings and Corrosion

Corrosion, patina or inappropriate previous coatings on metal elements may be required to be removed. A variety of methods are available and can be used to remove unwanted surface layers.

Mechanical methods include uses of abrasive materials or abrasive tools and equipment, such as hand scraping, chipping, sanding, wire brushing, wet or dry grit blasting and sandblasting. Metal wire brush or steel wool on nonferrous metals, which may cause galvanic corrosion or abrasion of the softer metal should be avoided. Coating it with a new protective coating is essential after the cleaning as it also help in avoiding future surface contact with air leading to corrosion. For coating removal and reapplication, the following steps should be followed.

a. **Removal of coatings or corrosion:** Remove all previous inappropriate coatings by a suitable method specby the conservation architect.
b. **Priming:** After the previous coatings have been removed, prime the cleaned surfaces with a corrosion-inhibiting primer as quickly as possible to avoid the reaction with air leading to corrosion.

c. **Painting:** Painting the metal surfaces is the most common treatment for controlling the surface deterioration or controlling corrosion to an even luster matching the original condition in each location. Apply paint wherever specified to match the existing.

d. **Other coatings:** When painting is not suitable, repatination, lacquer, polish, wax or clear coatings should be provided to resist corrosion and for a renewable surface, in consultation with the conservation architect.

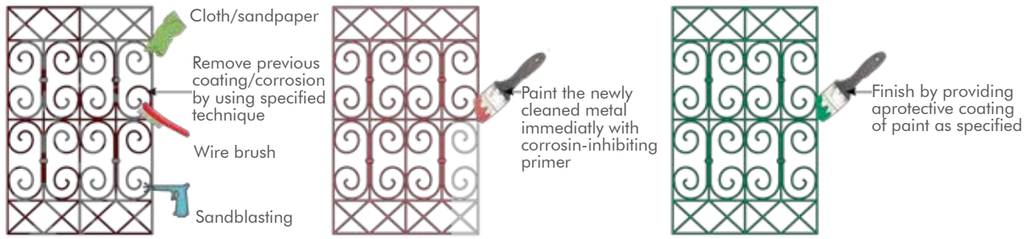

Figure 6.6: Repair by providing coating

6.5.6 New Connections

If the connection between different metal parts is broken or has failed, then it should be re-established by an appropriate technique to match the existing. Some frequently used techniques include brazing, soldering, welding or any other mechanical methods like screwing, riveting, nails and fasteners.

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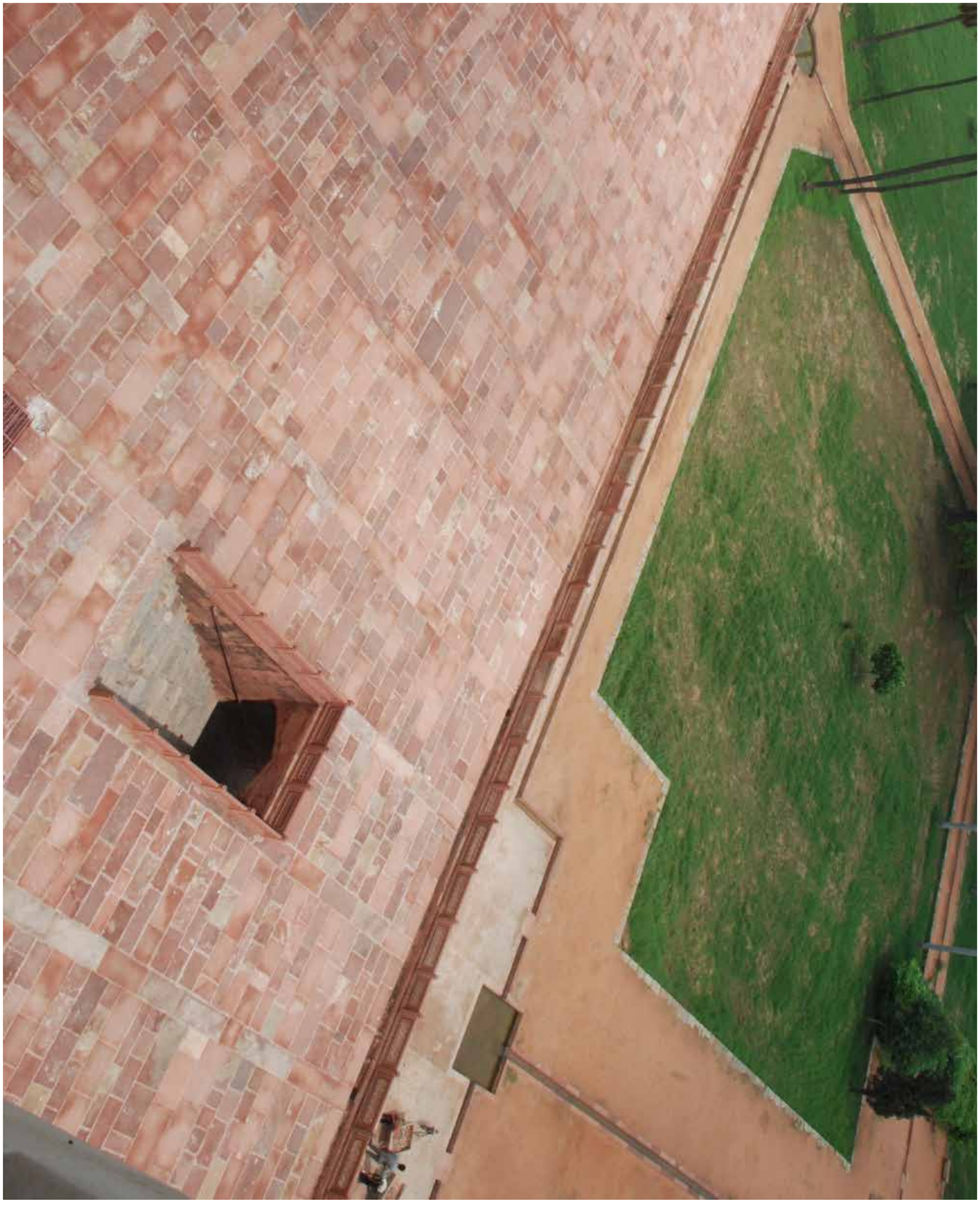

FLOORING

CONTENTS

7. FLOORING

Many types of floors have been used in heritage structures like stone, brick and timber based on their availability, climatic conditions as well as the significance of the spaces where the floor was to be installed. Towards the 19th and 20th century other new floors like terrazzo also started to be used as flooring material. Tiles as a flooring material have also been very effectively used.
This chapter provides information and guidance on conservation treatments for flooring in heritage structures. The conservation treatments should be carried out in consultation with a conservation architect and engineer-in-charge as per the requirement.

7.1. TYPES

Table 7.1: Types of Flooring

Brick on Edge		
Stone Sandstone, Marble, Kotah		
Timber		
Oxide		
Terrazzo		
Mosaic		
Inlay		

7.2. DEFECTS

Floors in heritage structures are exposed to everyday wear and tear, footwall and various types of loads. The areas of most use are localized and often show maximum signs of deterioration. The floors may be deteriorated in general as well due to subgrade issues or lack of maintenance. In all types of floors, cracks and small holes are present due to the prolonged use and weathering. The joints wherever present also become loose (timber) and become open (mortar). Surface finishes may come off and look weathered and may need renewal in a cyclical manner. Some sections may get severely damaged or deteriorated due to natural causes or mechanical impacts. The flooring should be assessed together with the subgrade and structural member below if possible.

7.3. Conservation

- Before undertaking any work to an old heritage floor, it is important to understand what are the values, age and condition, techniques and materials used as well as the original intent so decisions can be made to conserve these floors.
- Floors in Heritage structures should not be disturbed unless it is a safety and functionality issue and should be maintained and conserved in their original form. Original features and details which contribute to the value of the floors should be retained as far as possible.
- All floors should be conserved and treated rather than replaced as far as possible. The repairs should match the existing. When the floors are beyond repair, it should be dismantled and re-laid. The deviation from original should be exercised judicially as per the alternatives offered by the conservation architect. Local and traditional details should be followed wherever possible.
- Before making any repairs and replacements, the original details should be documented and record existing patterns. For efficient planning and execution of the work, it's better to be informed about the surface area to be covered and type of supporting systems and other fixing and installing details.
- If inappropriate replacements have been carried out then those should be restored back to the original and authentic floor finishes. Alternative techniques or materials should be considered where there is limitation to use the original type as well as for performance in consultation with the conservation architect.
- No work should be carried out without proper support, shoring and scaffolding as required and specified by the conservation architect and the engineer-in-charge.
- While dismantling damaged sections of the floors , sound material should be stored to be reused. Unusable material should be discarded as specified by Engineer-in-charge.
- When putting in new services care should be taken to minimize the intervention on floors with minimal impact on original work.

7.3.1 Subgrade or Subfloor

The structure for flooring is often constructed of lime concrete, mud concrete, bricks, timber, or any other local way of making subfloors over a structural system.

- If the floors are found to be settling, no work should be carried out without consulting the engineer-in-charge.
- The deficiencies and issues with structural systems and the subgrade must be addressed prior to the repair of the surface and its finishes.
- Existing subgrade should be used wherever possible.
- The existing subgrade should be repaired in case of minor damage before carrying our repairs to the floors.
- Where sub-grade does not exist, flooring is often laid directly over structural members. If a subgrade is required, as per the conditions, a new subgrade should be provided as per the specification of the conservation architect.
- New subgrade should be provided as per the specification of the conservation architect wherever the existing is deteriorated and not strong enough to support repairs or replacements. The sub-grade should be provided with the slope required for the flooring.

7.3.2 Brick on Edge

Most brick floors were laid directly on the earth or over a layer of sand earth or mud on a bed of well-compacted rubble. It is not uncommon to have lime concrete as a base too. Brick floors are mostly preferred in outdoor locations.

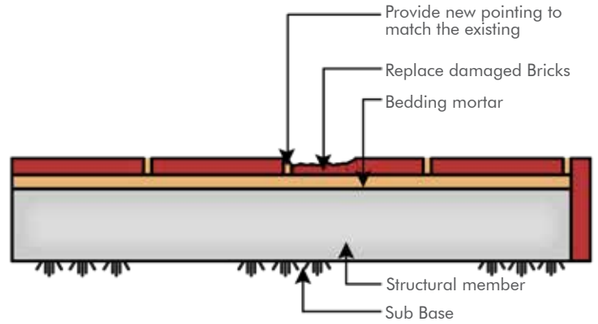

Figure 7.1: Detail of brick on edge flooring

7.3.2.1 Materials

Materials used for conservation of brick on edge floor are given below.

- Bricks: Bricks of the specified sizes, colour and strength should be used to match the existing. If a new floor is being installed then the bricks should match the existing, or context or period as recommended by the conservation architect. Broken bricks should not be used in flooring except for specified locations. The bricks should be laid on edge. Chapter 2 Brickwork should apply as far as possible. Salvaged material should be used as specified.
- Mortar: The mortar used should be as specified or to match the existing. In case of dry bricks flooring, fine sand should be filled in the joints. However, for durability mortared jointing will be preferable. Mortar should also be matched as closely as possible in colour and texture with the existing. Chapter 1 Lime Work should apply as far as possible.
- Water: Water should be clean and free from contaminants such as oil, acids, alkalis, salts, sugar and vegetable growth. It should meet the latest standards IS: 10500-2012 for drinking water. Only potable water should be used. Sea water or tidal estuary or brackish water should not be used for any conservation works.

7.3.2.2 Repairing Brick on Edge Floors

Deteriorated or damaged bricks should be replaced in small sections wherever possible as specified by the conservation architect to match the existing. Bricks may be replaced as per the following process given below. The same process may be used for a larger or a full scale replacement as well under the guidance of a conservation architect.

a Removing deteriorated bricks: Carefully remove deteriorated bricks in a small specified section or all bricks if the full floor is being replaced with hand tools. Sound bricks should be kept aside and cleaned of mortar and other debris.

b Laying: Compact and ensure that the floor below is sound. Lay the bricks on edge in plain, diagonal herringbone bond, or other pattern as specified on a bed of sand or mortar as specified or as existing, above a well compacted subfloor. Properly set each brick by gently tapping with a handle trowel or wooden mallet. Butter the inside faces with mortar before the next brick is laid and pressed against it. Frequent–ly check the surface of the flooring, with a straight edge, so as to obtain a true plain surface with the required slope.

c Joints: Lay the bricks so that all joints are full of mortar to match the existing or of specified thickness. The joints should be struck flush and finished at the time of laying if pointing is not required to be done. While if pointing is specified then all face joints should be raked to a specified depth by raking tool during the

prog¬ress of work when the mortar is still green so as to provide proper key for pointing to be done.

d **Pointing:** Pointing is usually preferred as it protects the arises of bricks that are vulnerable to damage by heavy traffic. Where existing pointing needs to be repaired this should be done with an appropriate mortar to match the existing.

e **Curing:** Protect the brick floor from rain by suitable covering when the mortar is green. Keep the floor moist for a minimum period of seven days.

f **Cleaning:** Clean the face of brick flooring should be cleaned on the same day of all mortar droppings.

Dry Brick:

Dry brick flooring should be laid on a bed existing or new subgrade laid to required slope. All the above provisions will be applicable except those bricks need not be soaked. Bricks will be laid on a bed of mud mortar of specified thickness, laid to the required slope. The joints should be as thin as possible but will also depend on the irregularities in the brick surfaces which will be filled with fine sand. In case of dry brick flooring no curing should be done.

7.3.3 Marble Chips or Terrazzo Flooring

Marble chips or Terrazzo flooring is made by mixing small pieces of marble or coloured stone in mortar, laying and then polishing the surface. Terrazzo flooring is mostly found in patterns with both coloured mortar and stones making it one of the most beautiful floor finishes.

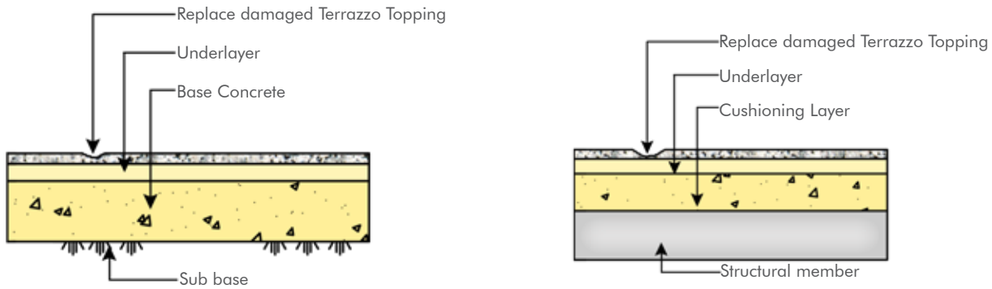

Figure 7.2: Detail of terrazzo flooring, Source: IS: 2114- 2018

7.3.3.1 Materials

Materials used for conservation of Marble Chips or Terrazzo Flooring are given below.

- **Mortar:** The mortar used should be as specified or to match the existing. In case of dry bricks flooring, fine sand should be filled in the joints. However, for durability mortared jointing will be preferable. Mortar should also be matched as closely as possible in colour and texture with the existing. Chapter 1 Lime Work should apply as far as possible.
- **Water:** Water should be clean and free from contaminants such as oil, acids, alkalis, salts, sugar and vegetable growth. It should meet the latest standards IS: 10500-2012 for Drinking Water. Only potable water should be used. Sea water or tidal estuary or brackish water should not be used for any conservation works.
- **Stone chips:** Marble chips should be of uniform size and color to match the existing or as specified. Colors and gradation of chips should match original materials and patterns. The color of chips should be matched after cleaning or of core samples. They should be of approved quality and free from foreign matters.
- **Pigments:** Pigments should match the existing or pure mineral or synthetic pigments should be used as specified. Colour matching should be accurately achieved.
- **Wax or sealer:** Colorless sealer that does not affect color or physical properties of terrazzo surface may be used.

7.3.3.2 Repairing Marble Chip or Terrazzo Flooring

Deteriorated and damaged terrazzo should be repaired in small sections wherever possible or replaced as specified to match the existing. Small cracks and holes should be filled with matching mortar with marble chips after cleaning. For repairing in small sections the following process given below.
The same process may be used for a larger or a full scale replacement as well under the guidance of a conservation architect.

a. **Removal of deteriorated sections:** With appropriate tools, cut a perimeter around the area to be repaired.
b. **Cleaning:** Clean all debris from the surface. Wet with water and prevent quick surface drying.
c. **Providing patch:** Apply cement/lime paste as specified to the surface. Do not allow cement/lime paste to dry before placing terrazzo matching material. Prepare the matching mix with specified stones chips and cement/lime to match the existing and add enough water to make the mixture plastic. Place mixture over the cavity and level with a trowel. Add additional stone chips of the same blend over the patch, as required to establish uniform coverage. Compact the patch, removing all excess materials from the surface.
d. **Protecting the repairs:** Cover the patch with paper or polyethylene sheeting to prevent quick drying until the patch develops sufficient strength and doesn't come off during grinding.
e. **Grinding/sanding:** After an interval of specified number of days or after setting of the patch, grind and polish the patch using hand tools to match the adjacent floor to produce a clean, smooth, and uniform finish. Caution should be ex¬ercised when grinding near the divider strips. For small areas like skirtings, sand surface with a hand sander or small grinding tool, using fine stones to achieve the desired finish. For larger areas of replacement, a circular buffing machine could be used with grinding and polishing pads as specified. Use a finer grit stone for the initial grinding, exposing the stone chips followed by another.
f. **Cleaning:** Rinse the floor thoroughly with clean, clear water.
g. **Protection:** Cover the surface with paper or polyethylene for at least 72 hours.
h. **Final polishing:** A final polish may be specified with a finer grit stone.
i. **Curing:** The floor should be kept covered with thoroughly damped empty gunny bags, for a period of 7 days or as specified.
j. **Finishing:** Allow the surface to thoroughly dry and polish or seal flooring as spec¬ified.

7.3.4 Oxide Flooring

Oxide flooring is an old practice of using oxide colours as a finishing layer over a base floor of lime or cement.

7.3.4.1 Materials

Materials used for conservation of oxide Flooring are given below.

- **Mortar:** The mortar used should be lime or cement as specified or to match the existing. Chapter 1 Lime Work should apply as far as possible.
- **Oxide powder:** Oxide Powder should be used to achieve the desired colour to match the existing.
- **Wax or sealer:** Colorless, slip and stain resistant sealer that does not affect color or physical properties of oxide surface can be used.

Preparation of the Oxide Mix:

- Oxide mix should be prepared to match the existing or as per the local practices.
- Dry Mix: 1 kg of oxide powder per 5 sq mt of floor area should be added to mortar of 1:3 mix and well incorporated during mixing. Some variations in the mix may have to be carried out in situ in order to arrive at the matching colour shade.
- One-unit quantity of marble powder should be added to this mix by running it through the sieving tray. Marble powder is used to give a stronger grip to the materials and also to increase the volume of the mix. In cement mixes. Lime is also added which retards the setting process of the mix, helping achieve a better blend

without developing cracks.

- This mixture is then ready to be mixed proportionately with water.

7.3.4.2 Repairing damaged sections

Cracks and small holes present in the oxide floor should be repaired using a similar matching mortar or grout after cleaning and routing the cracks. Repair steps from chapter 1 Lime work should apply. Before considering full scale floor replacements, small deteriorated sections may be considered to be repaired without replacing the entire floor if possible. For deteriorated floor beyond repairs, replacement may be carried out using the steps below.

a. Removal of deteriorated section: Carefully remove deteriorated floor along with the parts to be replaced.
b. Cleaning: Clean the surface to remove any debris and get a plain, clear base.
c. Laying of cement mix: Prepare a mix with cement or lime as specified and sand to match the existing or in the ratio 1:3 or 1:4. Spread this uniformly in the location of replacement with the quantity of water that makes the slurry be easily poured, up to the specified height to match the existing floor level. Level the surface with a straight-edge trowel, called *chunardu* '*karni*' after a second layer of the mix which is in thick lump consistency is to be firmly applied and pressed. This layer will provide the final floor level for the thin oxide layer to come on top. The edges of the panel strips are cleared with an appropriate tool to get sharp ends and clean depth of 2-3 mm.
d. Pouring and curing of the oxide layer: TApply the oxide layer in two stages. First, add the oxide composition prepared to water, to get a slurry-like mix and pour over the base. The second layer should have the quantity of water in proportion to keep the application thick so that it can be levelled with the help of a flat trowel. Remove any lump formations while any minor undulations are addressed during polishing.
e. Curing: Fill the floor space with water up to one inch by cor¬doning off the premise and curing is done over a time of 24 hours for attaining the reactive strength.
f. Cleaning: After the surface gets dried properly, and in case the white patches show up on top, wipe off the area with a cloth and cured again to dry out the residual mineral deposit.
g. Preparation for polishing: FFor achieving a smooth and anti-acid stain finish for replaced sections or the entire floor, rub the surface with specified grade sandpaper to smoothen and level the base for polish application.
h. Polishing: Wax based polish should be used in a mixed in 1 part to 2-3 drops of turpentine or any other way specified. Apply this mix with a soft cloth on the floor and scrubbed with rice husk or co¬conut pith twice in a circular fashion till the wax disappears and does not show visible seams and to cross it off from possible pores. Organic additives may be used as per local practices - Egg-white, coconut oil and rice bran are commonly used. It should be ensured that the space is not be used for 2-3 days so that the wax is absorbed fully and until the floor achieves a radiant sheen.

7.3.5 Tile Flooring (Tiles)

Tiles may include Terrazzo Tiles, Chettinad Athangudi, Heritage Tiles (Bombay, Gujarat), and other hand-crafted tiles. Many such tiles were made by an exclusive processes using local materials, such as sand, along with other components like cement and oxide pigments. A very meticulous process was followed to create intricate designs and patterns. Tiles may have to be custom produced if specialized design and patterns needs to be conserved.

7.3.5.1 Materials

Materials used for conservation of tile Flooring are given below.

- Tiles: The tile should be of approved quality, true in shape and free from cracks. Where full tiles or half tiles cannot be fixed, tiles should be cut from full tiles to the required size and their edges rubbed smooth to ensure a straight and true joint.
- Water: Water should be clean and free from contaminants such as oil, acids, alkalis, salts, sugar and vegetable growth. It should meet the latest standards IS: 10500-2012 for Drinking Water. Only potable water should be used. Sea water or tidal estuary or brackish water should not be used for any conservation works
- Mortar: The mortar should be as specified and should match the existing. Mortar should be matched as closely as possible in colour and texture with the existing. Chapter 1 Lime Work should apply as far as possible.

7.3.5.2 Replacing Tiles

Damaged or missing tiles may be replaced as specified to match the existing color, shape, size, pattern and the existing adjacent floor tiles, so that the tiles are not in contrast to the overall view of the floors. For replacing damaged or missing tiles the following process given below.

a. Removal of cracked or damaged tile: Carefully remove damaged tiles with appropriate tools, with¬out disturbing the surrounding intact tiles.
b. Wetting the tiles: Wash and wet the tiles before laying.
c. Cleaning: Clean the base slab on which the tiles are to be laid.
d. Bedding: The bedding for the tiles should be done with mortar as specified with an appropriate slope. Average thickness of the bedding mortar should match the existing.
e. Laying: Spread and tamp the mortar for bedding and lay the tiles immedi¬ately. Lay the following tiles one after the other over the prepared bed, each tile being gently tapped with a wooden mallet till it is in proper line and in level with the adjoining tiles.
f. Joint patterns: Lay tile joints in patterns to match the original and existing tile pattern. Provide uniform joint widths to match existing widths. The joints should be kept as thin as possible and in straight lines or to suit the required pattern. The joints should be properly cleaned before filling with specified material of matching colour. Neatly finish the junction between wall plaster and tile work.
g. Cleaning: The floor should be thoroughly washed and cleaned after all the damaged tiles have been replaced.
h. Curing: The floor should then be kept wet for a minimum period of 7 days or as specified.

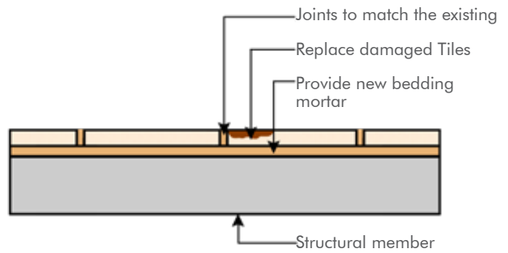

Figure 7.3: Detail of tile flooring

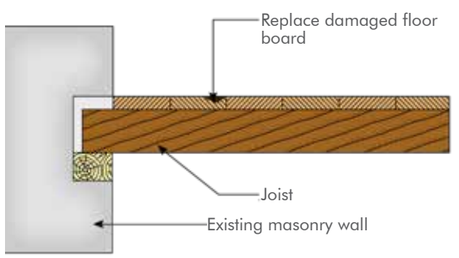

Figure 7.4: Detail of wooden flooring, Source: IS: 3670- 1989

7.3.6 Timber Flooring

A timber floor surface can be either a series of connected planks or parquets (small timber pieces arranged in decorative patterns). The timber used is either plain sawn or quarter sawn. Plank flooring, is a more common type, is assembled by joining: butt joint, tongue and groove, doweled or spline. Timber floors are usually secured to the under structure by countersinking nails, blind-nailing, or screwing and plugging.

7.3.6.1 Materials

Materials used for conservation of timber flooring are given below.

- Timber: The timber should be of the same species as the original wherever possible or of specified alternates. The grain direction and figure or pattern have similar characteristics of grain where it will be visible; Tool

marks, be worked using similar craft methods and tools as the original, color and finishes and similar moisture content as specified. Chapter 5 Timber Work should apply as far as possible.

- Hardware and Nails: To match the existing

7.3.6.2 Replacing Sections

Deteriorated and timber planks/boards may be repaired wherever possible or replaced as specified to match the existing.
Small repairs and holes should be filled using plastic repairs described in chapter 5 Timber Work.
Dutchman repairs should be installed as described in chapter 5 Timber Work.
For replacing damaged sections the following process given below..

a. Removing damaged boards: Carefully remove the deteriorated boards using appropriate tools. Make sure the adjacent boards are not disturbed during removal.
b. Preparing replacement: Measure the new board to exactly fit the void. The replacement timber should match the existing and approved by the conservation architect.
c. Providing a new board: TThe edges of the void where the board has been removed should be neatly squared up. Provide the new prepared board by placing it into the void. Use existing joinery wherever possible.
d. Securing: Nail the board to the subfloor or into joists as per the site conditions. Fill the nail holes with timber filler stained to match floor.
e. Finishing: Finish the boards to match the existing surrounding floor boards.

7.3.7 Stone Flooring

Stone flooring is usually laid on lime mortar bedding and fixed with the same. Stone floors have been used in interiors as well as exteriors and the choice of stone as well the dressing and finishing is decided accordingly.

7.3.7.1 Materials

Materials used for conservation of stone flooring are given below.

- Stone: Stone should be of the specified sizes, colour range, length, thickness, and widths, dressed to match the adjoining. Stones with a round surface should not be used. The slabs should be hard even, sound and durable Chapter 3 Stone should apply as far as possible.
- Mortar: The mortar used should be as specified or to match the existing. In case of dry bricks flooring, fine sand should be filled in the joints. However, for durability mortared jointing will be preferable. Mortar should also be matched as closely as possible in colour and texture with the existing.Chapter 1 Lime Work should apply as far as possible.
- Water: Water should be clean and free from contaminants such as oil, acids, alkalis, salts, sugar and vegetable growth. It should meet the latest standards IS: 10500-2012 for Drinking Water. Only potable water should be used. Sea water or tidal estuary or brackish water should not be used for any conservation works.

7.3.7.2 Replacing Stone Flooring

Small holes cracks and voids should be filled with patch repairs as described in chapter 3 Stone Work. Dutchman repair should be installed as described in chapter 3 Stone Work.
When there is no alternative and the damaged or deteriorated floor must be re-laid whether either in small sections or the entire floor, it should match the existing. For selectively replacing damaged stone flooring, following process given below .

a. Removal of deteriorated stone: Carefully remove deteriorated stones with appropriate hands tools as specified without disturbing the adjacent sound stones. Removed stones should be kept aside and cleaned of mortar and other debris.
b. Dressing of stones: Dress the replacement stone slabs to match the existing. The exposed faces may be chisel dressed or rough tooled as specified to match the existing. It should be ensured that all angles and edges of the stone slabs are true, square and free from chippings and the surface is true and plane.
c. Laying: Clean and wet the subgrade before providing the bedding mortar. Spread the specified mortar to match the existing on the subgrade as per the existing thickness. Lay the slabs and gently tap down with a wooden mallet till it is properly bedded in level with the adjoining slabs. Make sure to match the grains of slabs while laying. Wherever required, lay the subsequent slabs in the same manner. The surface of the flooring as laid should be true to levels and slopes.
d. Pointing: Pointing may be provided as specified. Where point¬ing is not required to be done, the joints should be levelled flush at the time of laying
e. Cleaning: After each slab has been laid, clean the surplus cement from the surface of the slabs.
f. Curing: Cure the flooring for a minimum period for specified number of days.
g. Finishing: Slight unevenness at the meeting edges of slabs may be removed by fine chiseling. Finish the slab to match the existing adjacent floor.

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ROOFING

CONTENTS

8. ROOFING

Roofing in India varies according to climatic conditions and availability of materials. Many types of roofing materials have been used in heritage structures like earth, stone, brick, lime concrete, tiles and many more, laid over a variety of support systems. All roofing systems provide weather protection to the structures from sun, rain and other climatic conditions. This chapter provides information and guidance on conservation treatments for roofing materials in heritage structures. The conservation treatments should be carried out in consultation with a conservation architect and engineer-in-charge as per the requirement.

8.1. TYPES

Table 8.1: Types of Roofing

Stone/Brick Roofing over Wood or Metal		
Lime Concrete Flat		
Lime Concrete Domes and Vaults		
Jack Arched Roofing		
Mud Phuska Terracing with Tile		
Earth Roofing		
Wooden Shingles		
Slate Roofing		

8.2. DEFECTS

Roofing coverings are exposed to the elements such as wind and rain and hence suffer damage. Often the areas with maximum exposure are most deteriorated therefore the damage may be in sections or localized. In some cases the entire covering may be deteriorated due to exposure and lack of maintenance. Water is typically the most detrimental to roofing, therefore its correct disposal can also lead to issues in the roofing as well the structure below. Structural members, fixings and their supporting members usually deteriorate along with the roof coverings so the entire roof assembly should be assessed together. Roof coverings like tiles and shingles get selectively damaged due to corroded nails and mechanical impact. Cracks and deterioration of the surface finish leads to water penetration and vegetation growth. Sometime the supporting systems also fail leading to the failing of entire assembly.

8.3. CONSERVATION

- All roofs should be conserved and repaired rather than replaced as far as possible. The repairs should match the existing. When the roof is beyond repair and maintenance, it should be dismantled and re-laid. The deviation from original should be exercised judicially keeping regard to structural and durability conditions as per the alternatives offered by the conservation architect. Local and traditional details should be followed wherever possible.
- Prior to undertaking any repair work the historic value of the materials used for the roof and system should be assessed. Thereafter, a complete inspection of the roof should be carried out to understand all the causes of failure and to eventually identify the repair methods, or alternatives for repair or replacement of the roofing.
- Before making any repairs and replacements, the original details should be documented and recorded existing patterns. For efficient planning and execution of the work, it's important to be informed about the surface area to be covered, type of supporting systems, drainage details etc.
- No work should be carried out without proper support, shoring and scaffolding as required and specified by the conservation architect and the engineer-in-charge.
- When dismantling, usable material should be salvaged and reused wherever possible.
- Roofs should be repaired immediately to prevent water damage.
- If inappropriate replacements have been carried out then those should be restored back to the original and authentic roofing systems and materials. Alternative techniques or materials should be considered where there is limitation to use the original type as well as for performance in consultation with the conservation architect.
- A structural engineer should be involved when undertaking structural repairs to the roof.
- During repairs drainage should be planned since it is crucial for maintaining the roof.
- Insertion of appropriate water proofing layer can be recommended as per the conservation architect.

8.3.1 Support Systems for Roofing

Roofing supports are of many types like timber, steel, slabs cast in lime concrete etc. It is important to check the structural adequacy of roofing structure before taking up any repairs to the roofing In case of any issues, in supporting structure, the same should be addressed before stone undertaking the roofing repairs to avoid future complications under the supervision of conservation architect and the engineer-in-charge.

- Wherever possible the roof supports should be repaired in place and the removal and restoration be only performed when repair is not possible.
- Propping and bracing as directed should be done adequately and members required to be replaced should be removed carefully including nails/bolts etc.
- The dismantled members should not be thrown or dropped but lowered with ropes carefully and stacked properly. All roofing and flooring timber members are to be documented and dismantled and to be stacked for later use. Members, which are not fit to be re-used are to be disposed away from the site as approved.
- All replacements are to be done with another sections of sufficient cross-sectional area. Keep as much of the original material as possible.
- The support system should be laid back in a similar manner to match the original under the supervision of conservation architect and structural engineer.
- Adequate slope be maintained for proper drainage.

8.3.2 Stone or Brick Rroofing

Stone roofing or Kadi/kari roof is a very popular type of roofing systems that uses wooden or metal understructure to support stone slabs above it. Stone slabs are laid in patterns ensuring they are well supported on the beams. When there is no alternative the roof must be re-laid either in small sections or the entire following procedure outlined below.

Same process should also apply to brick roofing.

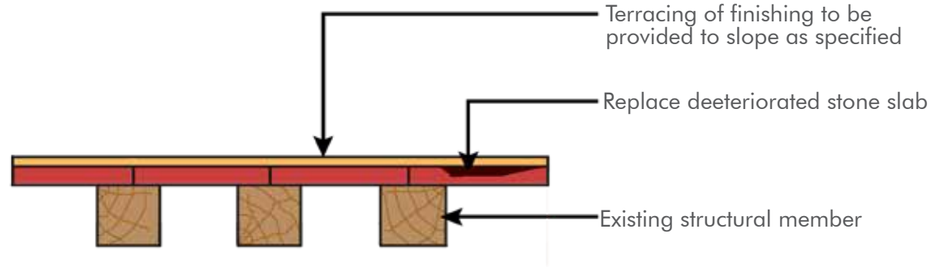

Figure 8.1: Detail of stone/ brick roofing

8.3.2.1 Materials

Materials used for conservation of stone or brick flooring are given below.

- **Stone:** Stone should be of the specified sizes, colour range, length, thickness, and widths, dressed to match the adjoining. Stone slabs should be hard, even sound and durable. Slabs should be sawn or chiselled in a plane parallel to the natural bed of the stone. The slabs should be dressed as specified for exposed faces and sides. The width of the slabs should be uniform and kept equal to the spacing of the 'Karis' centre to centre to match the existing layout. The width of the slabs may vary unless otherwise stipulated but it should not be less than 40 cm. Chapter 3 Stone Work should apply as far as possible.
- **Brick:** Bricks of the specified sizes, colour and strength should be used to match the existing. If no evidence is found then the bricks should match the existing, or context or period as suggested by the conservation architect. Broken bricks should not be used. Chapter 2 Brick Work should apply as far as possible.
- **Water:** Water should be clean and free from contaminants such as oil, acids, alkalis, salts, sugar and vegetable growth. It should meet the latest standards IS CODE IS: 10500-2012 for Drinking Water. Only potable water should be used. Sea water or tidal estuary or brackish water should not be used for any conservation works
- **Mortar:** The mortar should be as specified and should match the existing. Mortar should be matched as closely as possible in colour and texture with the existing. Chapter 1 Lime Work should apply as far as possible.

8.3.2.2 Replacement of Stone or Brick roofing

Cracked, broken or damaged stone slabs should be replaced to match the existing. No other material should be acceptable. The roofing should be documented before dismantling including all fixing details. Any useful material to be stacked for later use and cleaned before reusing. Damaged stones that are not fit to be re-used, are to be disposed as approved by Engineer-in-charge. The slabs should be fixed and re-laid using the steps below.

a **Removing deteriorated slabs:** Carefully remove deteriorated stone slabs by clearing of mortar in joints and around the slab. If the slabs are missing, clean the area around to receive new replacement slabs.

b **Laying:** Lay the stone slabs with lime or cement mortar as specified for bedding and jointing. Set the slab properly by gentle tapping with a handle trowel or wooden mallet over the bedding mortar. Finish the joints to match the existing adjoining surfaces. Level or slope the finished surface as specified or as directed by the conservation architect or the engineer-in-charge. Lay other slabs in a similar manner following the first. Clean off all mortar droppings and markings from all the surfaces.

c **Finishing:** A layer of finishing materials (lime, mud, cement) may be applied if deemed suitable be specified by the conservation architect.

d **Curing:** The mortar in the joints should be cured for at least 7 days or as specified.

8.3.3 Mud Phuska Terracing with Tile Brick Flooring

Mud phuska is a roofing system that is provided above the main structural slab and consists of many layers including mud phuska, mud plasters, gobar plaster and tiles in many cases. This type of multi layered roofing also provides thermal comfort to the interior spaces.

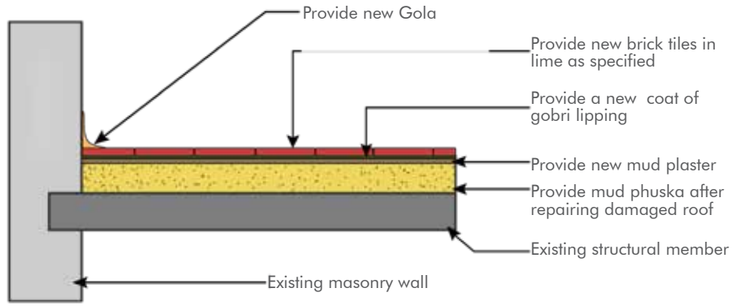

Figure 8.2: Detail of mud pushka roofing

8.3.3.1 Materials

Materials used for conservation of mud phuska terracing with tile brick roofing are given below.

- Mud phuska: For mud phuska, soil should be a good quality earth suitable for making bricks not containing excessive clay or sand, free from stones, kankar, vegetable matter and other foreign matter, to be collected and stacked at site. The soil should not be collected from a locality infested with white ants.
- Mud mortar: Puddled clay or stiff mud mortar should be mixed with bhusa as per IS: 2115-1980 of mortar and allowed to mature for 3 to 4 days. During this period it should be worked up at intervals with appropriate tools with men's feet and phawras so as to become a homogeneous mass free from lumps, clods, etc. A small quantity of sand, if necessary, should also be added to avoid subsequent shrinkage cracks.
- Mud gobar plaster: Mortar for gobri leaping should be prepared by mixing equal quantities of fresh gobar and finely sieved clay adding sufficient water to form a thin paste. The quantity of gobar used in gobri leaping should not be less than 0.03 cum per 100 sqm of plaster area. Five percent of cut back bitumen by mass of dry clay may be added to improve upon the water proofing qualities.
- Flat tiles: Flat tile bricks to match the existing, conforming to the specifications of 1 (first class) bricks

8.3.3.2 Replacing Mud Phuska roofing

Deteriorated Mud phuska roof should be replaced as specified below and should match the existing materials and techniques as far as possible. The roofing should be documented before dismantling and any useful material should be stored to be reused. Unusable material should be discarded as specified by Engineer-in-charge. The following steps should be followed to repair sections or to relay new roofing it as a whole but does not include the structural members.

a Removal of deteriorated roofing: Carefully remove the existing deteriorated roofing in layers without disturbing the structural members.

b Waterproofing treatment over the roof before mud phuska: If required appropriate water proofing systems may be provided before laying mud phuska, to prevent any chance of dampness and leakage from the roof.

c Laying mud phuska: Laying mud phuska: Before laying on the roof, make the soil damp by adding water about 12 hours earlier. Turn it over with *phawaras* so as to break clods and to pulverize the same. Be careful to regulate the quantity of water to be added to the soil so that the soil should have optimum moisture content at the time of laying and compaction on the roof. Lay the damp soil on the roof to required thickness and slope, well compacted with wooden rammers and *thappies*, to obtain an even surface.

d Applying mud plaster: Applying mud plaster: After laying the mud phuska, coat the surface with mud plaster 25 mm thick or as specified and allow it to be dry

e Gobari liping – lipai: Provide a coat with mud gobri mortar 3:1 (3mud and 1 cow dung) with an average thickness of the lipping to be ½" or as specified.

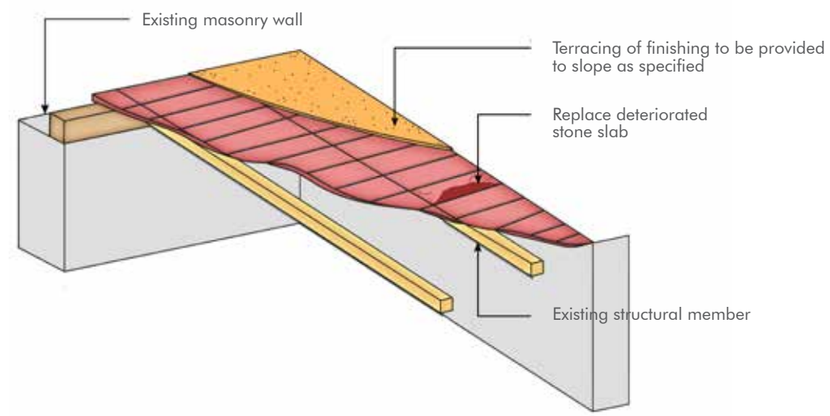

Figure 8.3: Pictorial view of stone/ brick roofing

f Laying Tiles and Grouting: Lay the flat tile bricks to the required slope on the mud gobri plaster, before it dries up completely. Grout the joints of the tiles with appropriate specified mortar mix taking care that no joint remains unfilled. Care should be exercised to see that mud mortar does not rise into the vertical joints of the tiles more than specified or 12 mm.

g Curing: As soon as cement grouting obtains initial set, protect the surface of the brick tile with wet gunny bags, hessian cloth or wet sand to prevent quick drying. After 8- 12 hours, cure the brick tiles cured by frequent sprinkling of water on the surface for a period of 7 days or other specified period. Clean the surface after curing has been done. The tile surface as completed should be even and true to slopes as specified and should be leak proof. During this period, protect the surfaces suitably from sun, rain and other damages.

8.3.4 Lime Concrete Roofs

Lime concrete roof is a commonly used roof composed of lime concrete laid over wooden substrates as a flat roof or in form of domes and vaults over bricks/stones.

8.3.4.1 Materials

Materials used for conservation of lime concrete roofing are given below.

- Lime concrete: Lime concrete should be provided as specified to match the proportions and properties of the existing. Chapter 1 Lime Work should apply as far as possible.
- Water: Water should be clean and free from contaminants such as oil, acids, alkalis, salts, sugar and vegetable growth. It should meet the latest standards IS: 10500-2012 for Drinking Water. Only potable water should be used. Sea water or tidal estuary or brackish water should not be used for any conservation works.
- Mortar: The mortar should be specified and match the existing. Mortar should also be matched as closely as possible in colour and texture with the existing. Chapter 1 Lime Work should apply as far as possible.

8.3.4.2 Replacing Lime Concrete Rooff

Repairs can be for used for small areas but for larger areas sometimes full replacement may be required. For small holes and cracks in the terraces can be filled with matching new matching mix. After cleaning to a depth sufficient to provide a good key, dampen the surfaces to control suction. Fill and compact the new matching lime concrete mix followed by curing for a duration specified by the conservation architect. For larger areas of deteriorated lime concrete, a full replacement is usually suggested and following steps should be followed for the same.

a. **Removing deteriorated lime concrete:** For large deteriorated/eroded areas, carefully cut back sections of defective material completely.
b. **Cleaning:** Dampen the area to be provided with mew lime concrete.
c. **Laying lime concrete:** Lay the concrete terracing sloping towards the gutter or water outlets. The slopes should not be less than 2" in 10' preferably 3" in 10' for a flat terrace or as specified to match the existing parameters. Carefully prepare and plaster the surface near the gutter and through the wall to avoid any chances of leakage.

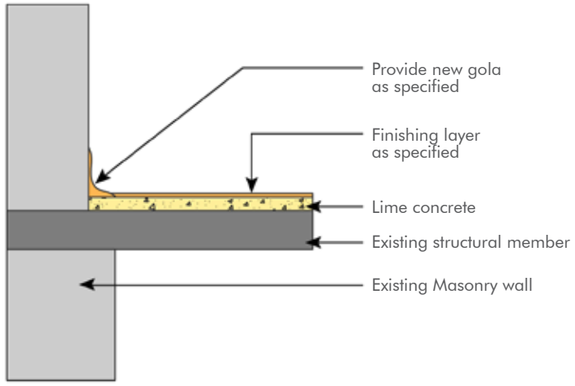

Figure 8.4: Detail of lime concrete roofing, Source: Modified from IS: 3036-1992

d. **Consolidation through ramming:** After laying, the beat the terracing with wooden thapies until thoroughly consolidated by systematic lengthwise movement. Continue this beating for 3-4 days or until the mix is almost set and the wooden thapies rebound from the surface when struck on it and clear ringing sound is heard. During the beating the surfaces, liberally sprinkle with a mixture of 3.5 seers of gur and 2 seers of bel fruit (pulp or juice?) and 25 gallons of water. Make sure the joints are properly sealed and there is adequate slope. Provide gola as per the conservation architects instructions wherever required.
e. **Finishing:** After the beating is complete, moisten the surface by sprinkling with water. The mortar which had been brought to the surface by beating should be smoothened and worked to a fine finish with trowels. No plastering should be done.
f. **Curing:** Cover the surface with fine wet sand or kept thoroughly saturated with water by any other method as specified for at least 10 days.

8.3.5 Earth roof

Earthen roof is popular roofing in areas with negligible rainfall. It is laid over the structural wood beams and joists followed by grass, twigs, and thick compacted local earth.

8.3.5.1 Materials

Materials used for conservation of earth roofing are given below.

- **Willow twigs:** locally available tallu or willow twigs of small cross sections of diameter 3.8 cm or to match the existing. These should be dry and stored in a dry area.
- **Yagzee grass:** Local grass easily procured in mountains.
- **Water:** Water should be clean and free from contaminants such as oil, acids, alkalis, salts, sugar and vegetable growth. It should meet the latest standards IS: 10500-2012 for Drinking Water. Only potable water should be used. Sea water or tidal estuary or brackish water should not be used for any conservation works.
- **Earth:** Earth should be good quality not containing excessive clay or sand, free from stones, and vegetable matter and other foreign matter, to be collected and stacked at site.

- **Markala:** This multilayered roof is then finished with a fine, locally available clay called markala that acts as a water-proofing layer.

8.3.5.2 Replacing Earth Roof

Deteriorated and damaged earthen roof should be repaired in sections wherever possible or replaced as specified to match the existing materials and technique. The roofing should be documented before dismantling and useful material should be stored to be reused. Unusable material should be discarded as specified by Engineer-in-charge. The following steps should be followed to repair sections or to relay new roofing it as a whole but does not include the structural members.

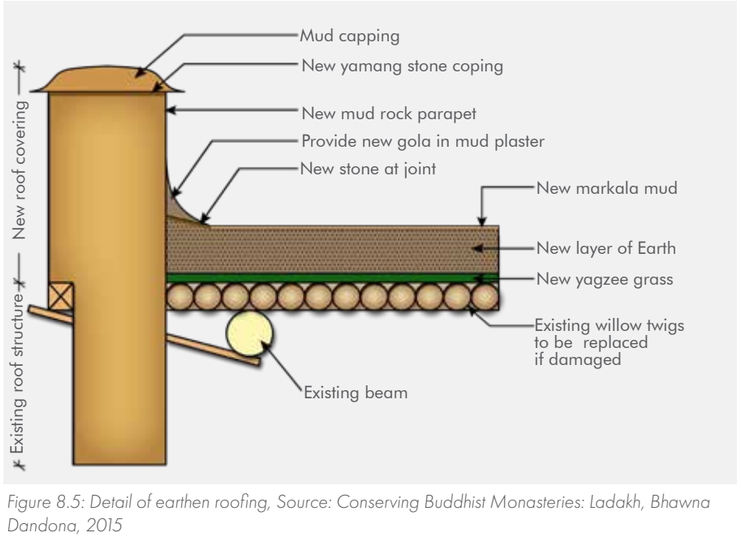

Figure 8.5: Detail of earthen roofing, Source: Conserving Buddhist Monasteries: Ladakh, Bhawna Dandona, 2015

a **Removal of deteriorated roofing:** Remove the deteriorated earth layer carefully after supporting the roof from inside as well as outside as specified.
b **Replacing willows sticks:** Remove damaged willow sticks, or tallu, along with the yakzee grass. Install and lay new willows or tallu, close together in rows, creating patterns as per local practices, covering the whole roof followed by a layer of grass or yakzee laid out evenly.
c **Providing earth and markala layers:** Prepare specified soil is in a manner similar to the mud bricks (with phugma or hay). Provide the new mix above the yakzee with an appropriate slope in two layers or as specified. Each layer should be compressed manually using wooden tools. First layer is usually 7.5 cm or should match the existing. Once compressed, a 5 cm layer of markala is to be laid over it. It is crucial that the markala is sandwiched between two layers of earth. On top of markala add another 10-12 cm of mud mortar evenly and compress it. On top of this compressed mud mortar add another five cm markala layer evenly. Finally, spread a thin layer of dry soil on top of markala. This dry soil prevents removal of markala when one walks on top.
d **Slopes and golas:** While laying all the layers, make sure to provide gola at the junction of walls and roof, to ensure that no water penetrates down into the interiors. Provide proper slopes and other water disposal systems like, pipes for water disposal where deemed necessary and as specified.

8.3.6 Roofing Tiles

Sloping roofs have been covered and finished with a variety of tiles over the structural system of wood, metal or any other materials. The tiles that are commonly used include Single Allahabad Tile Roofing, Mangalore Tile Roof, and terracotta tiles. These are mostly flat or patterned with suitable projections.

8.3.6.1 Materials

Materials used for conservation of tile roofing are given below.

- Tiles: All replacement tiles should match the existing. Tiles should be of approved quality, well and uniformly burnt, free from cracks, twists and flaws and other deformations. They should be of uniform colour and must give a ringing sound when struck.
- Nails for Fixing Reepers: Nails used for fixing reepers or rafters should match the existing nails or should conform to IS : 723-1972
- Wire: Wherever applicable use the wire for tying down to conform to IS: 280-2006 or as per local practices..

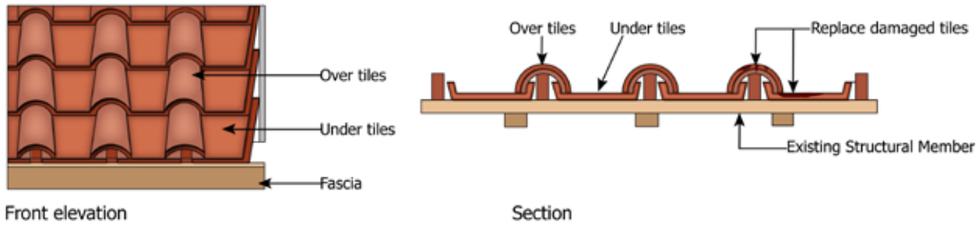

Figure 8.6: Detail of Allahabad tiles, Source: Civil Engineering Blog, Sanjay Sharma, 2017

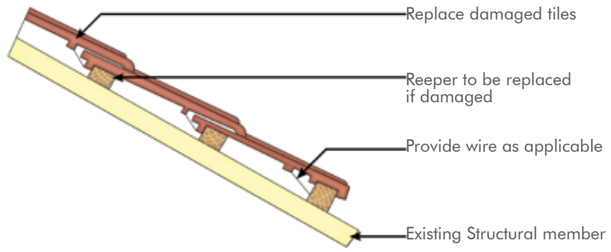

Figure 8.7: Detail of mangalore tiles, Source: IS: 2858-1984

8.3.6.2 Replacing Tiles

Cracked, broken or damaged tiles should be replaced to match the existing. No other material should be acceptable. All roof tiles should be documented before dismantling including all details of ridges and valleys. When full scale replacement is being carried out, tiles in good condition should be salvaged, by carefully removing with appropriate tools. All salvaged tiles should be stored for later use and should be cleaned by using a wire brush and water. Tiles, which are not to be re-used, are to be disposed as approved by Engineer-in-charge. Once tiles are ready to be used they are to be relaid conforming to IS 654:1992.

a Removal of tiles: arefully remove damaged or cracked roof tiles by lifting up the neighboring tile by using a wedge and gently sliding the roof tile out. Care should be taken to not disturb the adjacent tiles if only a section is being replaced. Carefully remove the nails and other hardware as well.

b Laying tiles: Lay the tiles either directly over the reepers or over an undercover. Adjust and slide the replacement tile into position by lifting the adjacent tiles slightly. Lay the tiles so that they fit properly with one to another, resting fully against battens. Cover the hips and ridges of the roof with ridge tiles which should be edge-bedded in mortar. At eaves the lowermost course of the tiles should overhang the tilting fillet by a distance sufficient to ensure that the water drained off from the roof discharges clear off the eaves into the gutter.

Note : In heavy rainfall areas there are chances of leakage through such tile systems, to avoid such damage it is better to provide plain GI sheets underneath over which tiles can be fixed with suitable fixing arrangement. The tile pattern and GI sheets are also available in a variety of colours which can also be considered as an alternative if deemed appropriate.

8.3.7 Wooden Shingles

In hilly regions, planks or shingles of hardwood like Deodar have been used as the main roofing material. The replacement of wood shingles in historical buildings should be continued with shingles, following original pattern unless it is justified otherwise.

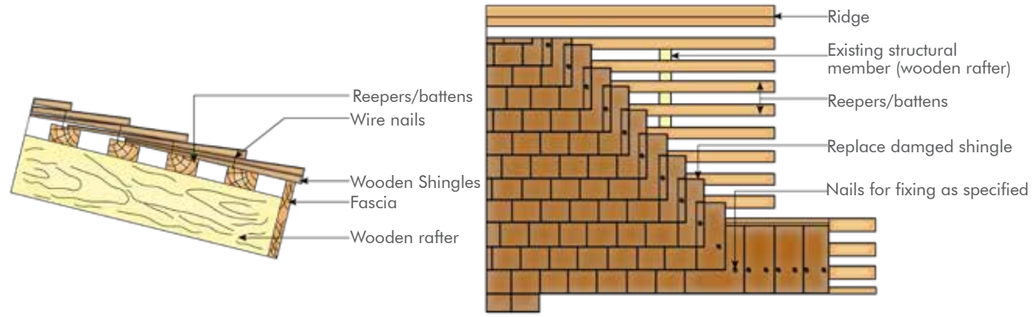

Figure 8.8: Detail of Wooden Shingles, Source: IS:2700-1987

8.3.7.1 Materials

Materials used for conservation of wood shingles roofing are given below.

- Wooden Shingles: The wooden shingles should match the existing. Size and Shape of Shingles depend upon the spacing of the battens. Wooden shingle sizes may be chosen from 300 to 400 mm for length and 120 to 150 mm for width. Well-seasoned timber should be used. Shingles should be given appropriate wood preservative coating.
- Nails: Nails should conform to IS : 723-1972. Preferably rust-resistant or hot-dipped galvanized nails should be used. For fixing wooden shingles, nails should be 2.00 or 2.24 mm shank diameter and length 40 mm depending upon the species.

8.3.7.2 Replacing Shingles

Damaged or missing shingles tiles should be replaced to match the existing. No other material should be acceptable. All shingles should be documented before dismantling with details. During full replacement, any shingles in good condition should be salvaged by careful removal using appropriate tools. All salvaged shingles should be stored, cleaned and reused. Shingles, which are not to be re-used, are to be disposed of as approved by Engineer-in-charge. If no evidence is found, new shingles can be installed to match the , or context or period as recommended by the conservation architect or conform to IS 2700: 1987.

a Remove damaged shingles: Carefully remove damaged shingles to be replaced by taking off all hardware and slightly lifting up the neighboring shingles. Care should be taken to not disturb the adjacent shingles if only a section is being replaced.

b Laying new: Fasten each wooden shingle to the battens by two nails where the distance of the nails should be kept the same as the original roofing. The nail should be driven flush, but not so hard that may crush or split the wood. Overlap each course of wooden shingles follow existing design and patterns, by another course or such that only one-third of the length of the shingle in the lower course is left uncovered; the remaining two-third length to be overlapped. Except for the bottom two courses, the wooden shingle is mostly three course deep throughout the roof area. Each horizontal course of wooden shingles should break joints with two courses above and two courses below it. Make sure that the gap between wooden shingles in each

course is offset at least 40 mm centre-to-centre from the corresponding gaps between the shingles in the course above. The two courses of shingles at the eaves should break joints or follows the existing pattern. The first shingle course laid in double should extend 50 to 60 mm beyond fascia member, to prevent the water from backing up underneath the shingles.

8.3.8 Slate roofing

Slate roofing has been commonly used in hills where it is easily available.

8.3.8.1 Materials

Materials used for conservation of slate roofing are given below.

- Slate: The slates should be of uniform size, colour and texture, free from white patches and be hard but not tough and should match the existing. When struck, it should give ringing sound and should not break when it is let fall flat on hard ground from a height of I.25 metres. The slates should be of reasonably straight cleavage and the grains should be longitudinal and not transverse. The slates should be- impervious to moisture.
- Nails and screws: Nails used for fixing should be plain head nails of size to match the existing or 2.50 mm or 2.25 mm conforming to IS: 723-1972. If not otherwise specified the nails should be galvanized. The length of the nails should be long enough such that they are able to penetrate through the rafters when they are driven through without coming off. If the nails are of copper, they should conform to IS : 725-1961. Screws may also be used in place of nails to match the existing or to conform to IS: 451-1999. Nails made of copper or aluminum alloy and screws may also be used.
- Wire: Wherever applicable use the wire which should conform to IS : 280-2006 or as per local practices.

8.3.8.2 Replacing Slates

Cracked, broken or damaged slates should be replaced to match the existing. No other material should be acceptable. All roof tiles should be documented before dismantling with all details. When full scale replacement is being carried out, slates in good condition should be salvaged, by carefully removing with appropriate tools. Any broken slates can be stored for re-dressing and reuse elsewhere on the roof in the future. All salvaged slates should be stored for later use and should be cleaned. Slates, which are not to be re-used, are to be disposed of as approved by Engineer-in-charge. Relay conforming to IS 654:1992. Slipped, or missing slates simply need re-securing using wires. Old slates should not be reversed while reinstalling. Larger sections can be replaced by single or double slating to match the existing as described below.

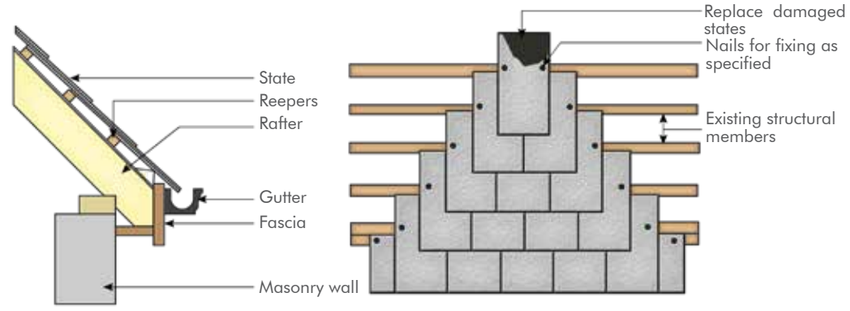

Figure 8.10: Detail of slate roofing, Source: Modified from IS: 51196(part-1)-1968

a Removal of damaged slates: Carefully remove damaged slates by removing the nails and by lifting up the neighboring slate and gently sliding the damaged slate out. After this process, safely dispose the nails away. Care should be taken to not disturb the adjacent slates if only a section is being replaced. Often when slate tiles are damaged, there are usually remnants of the tile left behind, including nails and the same should be removed.

b Laying: Carefully lay the slates timber reepers as specified. Slide the slates into place under the existing slate directly above the location where the slate is to be installed. Slide the slate to a point where the bottom of the slate is flush to the bottom of the slates on either side. The bottom course of the slates near the eaves should be laid so that they project outside the planking or to match the existing layout. Other subsequent slates are to be laid over the bottom course. Each slate should be laid with a specified lap over the bottom layer as well as on the sides.

c Fixing: Once positioned, fix the slates to the reepers with flat headed galvanized wire nails of specified diameter, and length. It is preferable to dip the nails in the anti-corrosive paint and to dry them before use. All slates should be head-nailed with two nails each or to follow the existing system. Holes for the nails should be made preferably by drilling or other specified method. It should be ensured that the nail is driven into the reeper by at least 2 cm or two thirds of the depth of the reepers, whichever is less. Fix the nails on two holes, 3.75 cm from top edge and 5 cm from side edges or to match the existing. The heads of the nails should not be driven firmly against the slates, but close enough to prevent any appreciable movement.

NOTE: For double slating over the bottom course, other courses should be laid. Slates should be laid with a minimum lap of 5 cm at each side and should have an overlap of slightly more than half the slate length over the bottom layer.

8.3.9 Jack arched roofing

Jack Arch roofing is a composite roofing system composed of vaults laid in series. It is constructed using of Rolled Steel Joists(RSJ), bricks and lime concrete.

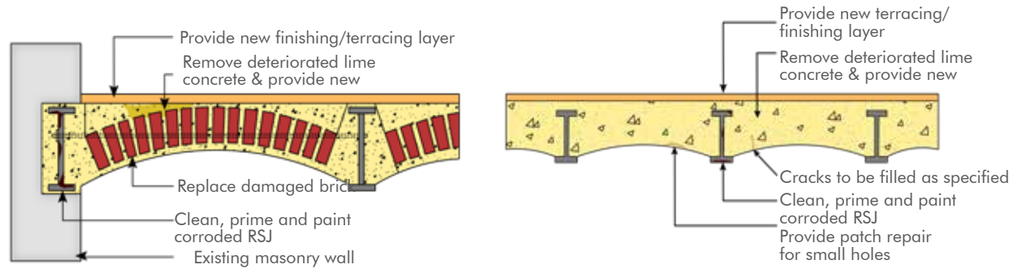

Figure 8.11: Detail of jack arch roofing with brick and without bricks. Source: IS: 2118-1980

8.3.9.1 Materials

Materials used for conservation of jack acrhed roofing are given below.

- Lime concrete: Lime concrete should be provided as specified to match the proportions and properties of the existing. Chapter 1 Lime Work should apply as far as possible.
- Brick: Bricks of the specified sizes, colour and strength should be used to match the existing. If no evidence is found then the bricks should match the existing, or context or period as suggested by the conservation architect. Broken bricks should not be used. Chapter 2 Brick Work should apply as far as possible.
- Water: Water should be clean and free from contaminants such as oil, acids, alkalis, salts, sugar and vegetable growth. It should meet the latest standards IS: 10500-2012 for Drinking Water. Only potable water should be used. Sea water or tidal estuary or brackish water should not be used for any conservation works
- Mortar: The mortar should be as specified and match the existing. Mortar should also be matched as closely as possible in colour and texture with the existing. Chapter1 Lime Work should apply as far as possible.
- Primer and Paint: Paint and primer should match the existing and of specified approved make.

8.3.9.2 Repairing Jack Arches

Deteriorated Lime concrete with cracks and material issues should be removed and repaired in situ. When carrying our repairs to jack arched roofing, opening of the complete roofing system is not suggested. It is also advisable not to work on both sides of jack arched roofing at the same time. Corrosion of metal rolled steel joists should be addressed from ceiling side.

a. Remove deteriorated lime concrete: Carefully remove deteriorated sections of lime concrete. Dismantling works at the roof should be done carefully without disturbing the members below.
b. Provide new lime concrete: Provide new lime concrete as specified to match the existing. After lime concrete the finishing of the terrace should be done to match the adjacent details.

i. Ceiling Side

a. Cracks: If there are cracks in the roofing from ceiling side then these should repaired by supporting and providing patch repair or grouting if it has structural issues as described in Chapter 1 Lime Work.
b. Bricks: Check the bricks if accessible or by a method suggested by the conservation architect. Install new bricks if decayed by supporting from below under the supervision of the engineer-in-charge.
c. RSJ: In case the RSJ is corroded, then clean, prime and paint as specified from the ceiling side. RSJ s should be provided with protective coatings as per specified to avoid future deterioration.

8.3.10 Water Disposal Systems for Roofs

Water disposal is an important function of the roof therefore roof drainage should be carefully inspected and addressed if found deficit. Water pipes, gutters, their location, slopes, alignment and water-tightness to be given utmost priority. Slopes, sizes of all drainage elements should be adequately provided and should match the existing as far as possible. Wood, copper, sheet metal and cast Iron and other metals have been used for pipes and gutters in the past but suitable replacements should be offered if the original is unavailable or has other limitations. Local design details should be followed as far as possible. Galvanized iron, stainless steel and aluminum and its alloys could be used as replacements.

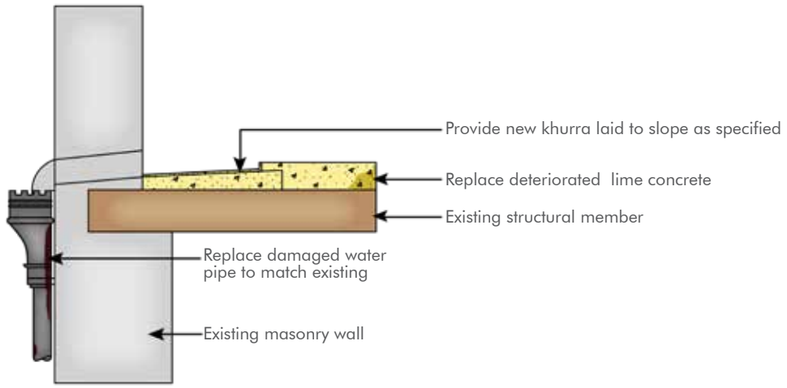

Figure 8.12 Detail of water disposal system for roofs, Source: Modified from IS: 2527-1984 & IS:3036-1992

8.3.10.1 Gola

When providing new roofing or terracing, gola should be provided at the edge of the roof, at the junction of parapet and the terrace to protect water from the terrace to enter at the junction. The gola details should match the existing or as specified. The specifications for the concrete should be the same as the Lime concrete terracing on roofs and the mortar for finishing should be as specified or a mix of lime surkhi mortar 1:2 (1 lime putty: 2 surkhi). The height of the gola at the wall face should be to match the existing but not less than 7.5cm. The profile of the gola should be quadrant of a circle 7.5 cm radius at top and sloping 9 to 10 cm at the base. The brick face of the parapet and terrace where the gola will be formed should be scrubbed clean of all dirt, dust and other foreign matter and well wetted. Lime concrete will then be laid along the junction of the terrace and the parapet under the brick drip course and well compacted and formed to shape with wooden thappies until the mortar cream comes to the surface. The gola should then be rounded and finished smooth with the lime plaster of specified mix. The top edge of the finished gola should end exactly at the junction of underside of the drip course with the parapet.

8.3.10.2 Khurras

When laying a new roof or terracing, khurras should be provided on the terrace near the water outlets as specified in the drawings. Khurras should match the existing or as specified. It should be made as per existing dimensions or specifications or be 45 x 45 cm size, unless otherwise specified. It should be formed by the use of lime concrete or other mix as specified. The concrete should be laid to an average minimum thickness of 5 cm with its top surface lower than the level of the adjoining roof surfaced by not less than: -

a. 20 mm in case of roof surface finished with lime concrete terracing.
b. 70 mm in case of roof surface finished with lime concrete terracing covered with brick tiles.
c. 50 mm in case of roof surface finished with mud phuska with brick tile covering.

The concrete should be laid to a size greater than the stipulated size of the khurra in such a way that the adjoining terracing whether of lime concrete or of the tile bricks should overlap the concrete on its three edges by not less than 7.5 cm. The concrete will slope uniformly from the edges to the outlet, the slope being as much as possible and in no case less than 10 mm thus leaving a minimum thickness of 4.5 cm at the outlet. The khurras and the sides of the outlet should then be rendered with appropriate mortar. This should be done when the concrete is still green, and should be finished with a floating coat of rich mortar. The sides of the khurras and the sides of the outlet should be well rounded. The size of the finished outlet opening should be 10 cm X10 cm or as specified by the conservation architect. In cases where rain water is to be disposed of through rain water pipes, cast iron grating should be provided at the outlet, as a safe guard against choking, as specified by the conservation architect.

8.3.10.3 Water Disposal Pipes

Deteriorated rain water disposal pipes, should be replaced to match the existing unless otherwise specified. The pipes should be free from cracks and other flaws. The pipes should be fixed perfectly vertical or as specified. The pipes should be secured to wall to match the existing details. Wooden cleats should be inserted between the pipe and the walls to avoid direct contact with the wall. IS: 2527-1984

Figure 8.13: Detail of water disposal system for roofs

8.3.10.4 Gutters

Damaged and deteriorated gutters should be replaced in sections or the entire length to match the existing or as specified. These should be free of flaws and cracks. The gutters should have appropriate slopes. The joints should be properly sealed without any leaks. IS: 2527-1984

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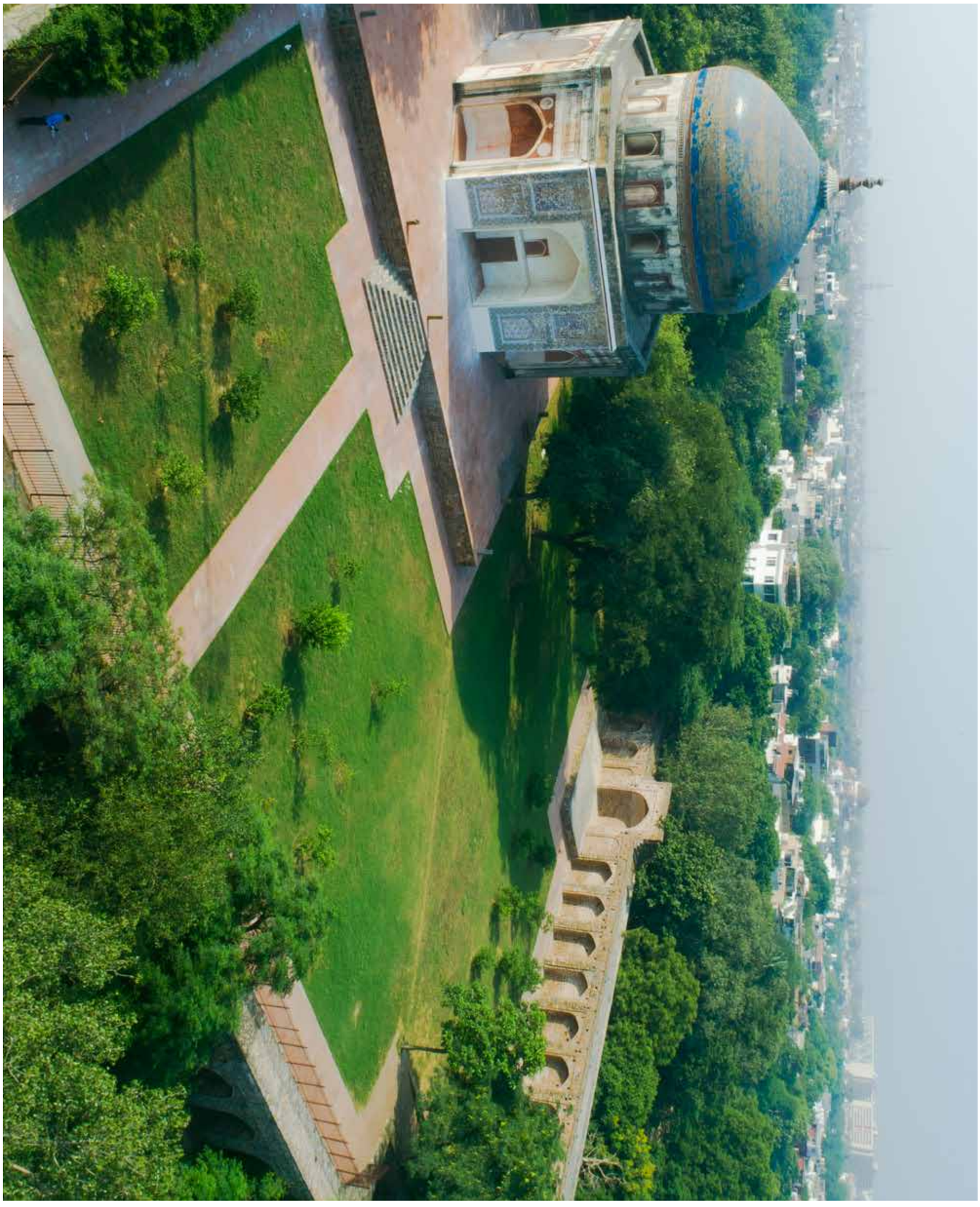


LANDSCAPE

CONTENTS

9. LANDSCAPE

This chapter provides guidance and approach for the conservation of historic gardens, landscapes and sites. The landscape plan for the site should be developed in consultation with a landscape architect and conservation architect, in keeping with the significance of the site and its historic value. Landscape restoration and development should be carried out in a congruous manner with the built heritage of the site and should be governed by the Principles of the Florence Charter 1982, outlined below.

9.1. PRINCIPALS FOR CONSERVATION: FLORENCE CHARTER

9.1.1 Definitions and Objectives

Article 4

Architectural composition of Historic Gardens include:

- Its plan and its topography.
- Its vegetation, including its species, proportions, colour schemes, spacing and respective heights.
- Its structural and decorative features.
- Its water, running or still, reflecting the sky.

Figure 9.1: Historic Gardens will include its built elements, vegetation, water features

9.1.2 Florence Charter - Maintenance and Conservation

Article 11.

Continuous maintenance of historic gardens is of paramount importance. Since the principal material is vegetal, the preservation of the garden in an unchanged condition requires both prompt replacements when required and a long-term programme of periodic renewal (clear felling and replanting with mature specimens).

Article 12.

Those species of trees, shrubs, plants and flowers to be replaced periodically must be selected with regard for established and recognised practice in each botanical and horticultural region, and with the aim to determine the species initially grown and to preserve them.

Article 13.

The permanent or movable architectural, sculptural or decorative features which form an integral part of the historic garden must be removed or displaced only insofar as this is essential for their conservation or restoration. The replacement or restoration of any such jeopardised features must be effected in accordance with the principles of the Venice Charter, and the date of any complete replacement must be indicated.

Article 14.

The historic garden must be preserved in appropriate surroundings. Any alteration to the physical environment which will endanger the ecological equilibrium must be prohibited. These applications are applicable to all aspects of the infrastructure, whether internal or external (drainage works, irrigation systems, roads, car parks, fences, caretaking facilities, visitors' amenities, etc.).

9.1.3 Florence Charter - Restoration and Reconstruction

Article 15.

No restoration work and, above all, no reconstruction work on a historic garden should be undertaken without thorough prior research to ensure that such work is scientifically executed and which will involve everything from excavation to the assembling of records relating to the garden in question and to similar gardens. Before any practical work starts, a project must be prepared on the basis of said research and must be submitted to a group of experts for joint examination and approval.

Article 16.

Restoration work must respect the successive stages of evolution of the garden concerned. In principle, no one period should be given precedence over any other, except in exceptional cases where the degree of damage or destruction affecting certain parts of a garden may be such that it is decided to reconstruct it on the basis of the traces that survive or of unimpeachable documentary evidence. Such reconstruction work might be undertaken more particularly on the parts of the garden nearest to the building it contains in order to bring out their significance in the design.

Figure 9.2: The interface between the garden and its built heritage is crucial to the historic character of the site

Article 17.

Where a garden has completely disappeared or there exists no more than conjectural evidence of its successive stages a reconstruction could not be considered a historic garden.

9.2. CONSERVATION OF LANDSCAPE

At the outset a landscape master plan should be prepared with the aim to preserve traces or restore key elements of the landscape, while taking into account subsequent developments which may have transformed the site. The plan should also make due reference to its historical origins and safeguard the key historic structures and elements within the garden.

To ensure the sustainability of the site, the plan may also propose new developments for the upgradation and maintenance of the site. However, these proposals should be in keeping with existing norms and policies governing the conservation of historic buildings, landscapes and sites. New developments should employ the use of materials that are compatible with the existing historic character of the site.

An operational guide for the management and maintenance of the site would also be a beneficial addition to the landscape master plan.

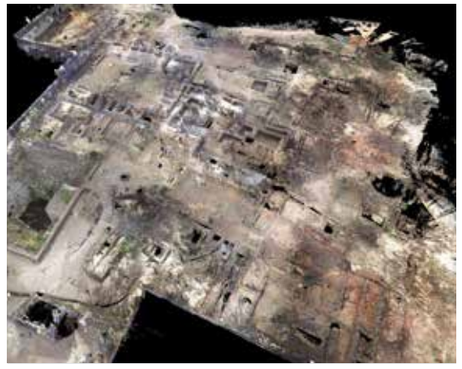


Figure 9.3: Laser scanning of archaeological remains of historic precinct

Some key aspects for the development of a landscape master plan are as follows

9.2.1 Data Collection

To define the approach towards the restoration of the gardens and to identify areas of priorities for immediate action, it is necessary to undertake surveys to record and document the site and its conditions. This should be crucial in ascertaining existing levels, flora and fauna, water bodies, slopes, drainage, services, among others.

This should be combined with historical research to understand the original extents of the gardens and its elements, and to understand the evolution of the garden and its environs.

Various digital or analogue techniques are available to record various components and should be used as suggested by the conservation architect and landscape architect.

Figure 9.4: Site investigations uncover water features buried under earth

9.2.2 Site Investigations

Site investigations should be carried out with the focus on exploring the original levels of the site and could include original irrigation systems, garden remains, and other key aspects of the landscape. Together with a topographic survey, the outcomes of the investigations should guide the restoration of the landscape and any design developments proposed at the site. These investigations could be through scientific excavation of trenches or areas, site clearance and other manual means carried out carefully under the supervision and guidance of the engineer in charge, conservation architect and landscape architect.

All excavated material should be carefully sorted and deposited at a location specified by the engineer in charge and serviceable material re-used wherever required. The site investigations could also be guided by GPRS surveys and other suitable methods.

9.2.3 Selection of Materials

The selection of materials for the site should be governed by the existing materials found during the site investigations and data collection exercise carried out at the onset of the project. The use of materials can be categorised according to their use based on the following

- Materials used for pathways, plinths and paving abutting the historic buildings and elements within the site
- Materials used for the restoration of existing pathways and elements of the historic landscape
- Materials used for new interventions in the historic landscape such as pathways, paving, walls, retaining walls
- Materials used for street furniture, new visitor infrastructure, boundary walls, among others.
- Any material should be sensitive to the historic character of the site and be selected in consultation with the conservation architect and landscape architect.

Figure 9.5: New elements introduced to a historic garden should use materials compatible with its historic character

9.2.4 Landscape Development

New interventions at the site could include street furniture, signage, dustbins, visitor infrastructure such as toilets, drinking water points, changing rooms, boundary walls, security stations, etc. These should be designed in consultation with the conservation architect and should be such that they do not harm the historic character of the site or disturb visual connections or require the removal of existing historic elements of the site.

Materials for these interventions should be as specified in 2.3

Figure 9.6: Landscape development will include features for the sustainability of the site

9.2.5 Horticulture Works

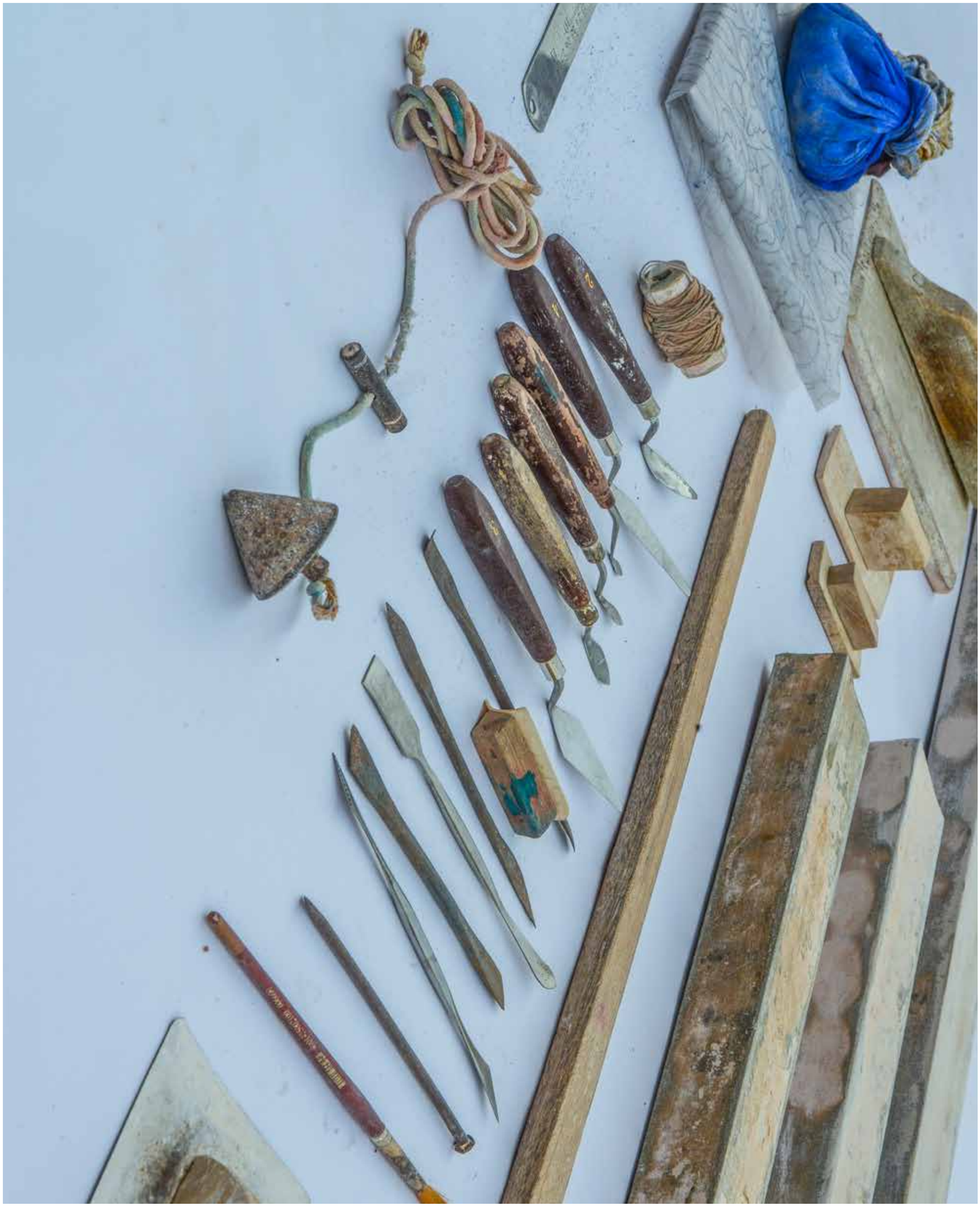
Proposed planting and landscape for the site should take into account existing surveys and the bio-diversity of the site. All existing vegetation at the site should be recorded and retained.

These should be coupled with a drainage and irrigation plan.

9.2.6 Illumination

Sensitively deigned illumination for the landscape and historic sites and elements should be carried out in consultation with the conservation architect. Proposed illumination for the site should not damage the historic elements of the site and should be employed to highlight the historic character and significance of the historic landscape and its elements.

Figure 9.7: Sensitively designed illumination can be used to highlight the historic character of the site



APPENDIX 1 TOOLS & EQUPMENT


Tracing Paper


Potli


Plumb Bob


Bada Manjhola


Badi Cheni


Basooli


Chota Manjhola


Choti Cheni


Moulding Tool


Plaster Fanti


Soot


Naherni 6 or brush


Fuhara


Gurmala


Gutka or Roosa


Patti


Tape


Gutki


Hathodi


Moulding Fanti


Moulding Tool 2


Moulding Tool 3


Moulding Tool 4


Moulding Tool 5


Moulding Tool 6


Moulding Tool 7


Moulding Tool 8


Naherni 1


Naherni 2


Naherni 3


Naherni 4


Naherni 5


Bada Takla


Bada Thalak


Chota Takla


Compass


Gague


Scale

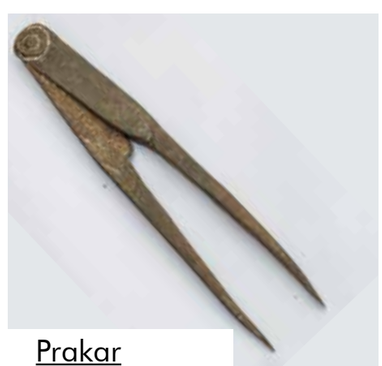

Choti Thalak


Cheni


Thalak 1 inch


Chota Manjhola


Pakad


Prakar


Nazzi 0.5 inch


Badi Sabwal


Sabwal


Gunja 1


Gunja 2


Gunja 3


Bit


Nazza


Cheni peetne ka pankha


Pichad


Sandasi

APPENDIX 2 IS CODES TESTS

LIME

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STONE

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