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ROYAL GOVERNMENT OF BHUTAN

MINISTRY OF HOME AFFAIRS

DEPARTMENT OF CULTURE AND DZONGKHA DEVELOPMENT

SPECIFICATION FOR CONSERVATION WORKS IN HERITAGE SITES 2025

FORWARD

It is with great pleasure and a deep sense of responsibility that I present the Specification for Conservation of Heritage Sites in Bhutan, a document meticulously crafted to uphold Bhutan's rich cultural legacy and ensure the preservation of our heritage sites. In Bhutan, our heritage sites are not mere structures but embodiments of our collective identity, encapsulating centuries of history, spirituality, and tradition. With over 261 registered heritage sites and the number expected to double with potential for registration sites listed, our nation's commitment to preserving this legacy is resolute.

The Royal Government of Bhutan has demonstrated unwavering commitment to the conservation of heritage sites, investing over Nu. 22 billion across four successive Five-Year Plans starting from 9th FYP. Recognizing the transformative potential of heritage preservation, there is a growing call for private sector engagement to leverage cultural heritage as a driver of economic development, particularly emphasized in the upcoming 13th Five-Year Plan. In line with this vision, a comprehensive specification and coefficient have been developed for the conservation of heritage sites.

Distinguished from routine civil work, conservation efforts carry the weighty responsibility of preserving the cultural heritage value while safeguarding the authenticity and integrity of the site. This requires a delicate balance between retaining historical attributes and reinforcing structural integrity, necessitating a specialized approach to conservation work. Drawing from two decades of data maintained and collaboration with conservation experts and Schedule of Rates specialists from Ministry of Infrastructure and Transport, this standardized document forms an integral part of the Bhutan Schedule of Rates. Through iterative workshops and consultations, the specification has been refined to incorporate diverse conservation approaches and principles, laying a robust foundation for outsourcing conservation works while ensuring the preservation of Bhutan's rich cultural heritage.

In conclusion, the Specification for Conservation of Heritage Sites represents a significant milestone in our ongoing efforts to preserve and protect Bhutan's cultural heritage. It is my sincere hope that this document will serve as a guiding beacon for all stakeholders involved in the noble endeavour of heritage conservation.

(Nagtsho Dorji)
Director
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INTRODUCTION

In Bhutan, heritage sites are intricately classified into three principal categories: heritage buildings, cultural sites, and archaeological sites, each bestowed with significance based on their cultural heritage value (CHV). As of now, the Department of Culture and Dzongkha Development has registered 261 heritage sites, with an additional four sites designated, signaling the nation's commitment to preserving its rich cultural legacy. There are expectations of uncovering over 250 more sites with the potential for registration, underscoring Bhutan's deep-rooted reverence for its historical and cultural heritage.

The notion of CHV in Bhutan encompasses a multifaceted tapestry, including aesthetic, architectural, archaeological, historical, scientific, religious, and spiritual elements. These facets not only contribute to the nation's identity but also serve as tangible links to its illustrious past. From bearing witness to significant historical events to exemplifying Bhutan's spiritual evolution, each heritage site holds a unique narrative, deeply ingrained in the fabric of the nation's heritage. Conservation endeavors emerge as imperative for heritage sites, driven by the pressing needs of addressing disrepair, enhancing living conditions, and restoring sites post-damage. Distinguished from routine civil work, conservation efforts carry the weighty responsibility of preserving the cultural heritage value while safeguarding the authenticity and integrity of the site. This entails a delicate balance between retaining historical attributes and reinforcing structural integrity, necessitating a specialized approach to conservation work.

The Royal Government of Bhutan has provided unwavering commitment to conservation of heritage sites, investing over Nu. 22 billion from the central government across four successive Five-Year Plans, starting from the 9th Plan. Acknowledging the transformative potential of heritage preservation, there is a growing call for private sector engagement to harness cultural heritage as a driver of economic development, particularly emphasized in the upcoming 13th Five-Year Plan. As a pivotal step towards facilitating private sector involvement, a comprehensive specification and coefficient have been developed for the conservation of heritage sites. Drawing from two decades of meticulously maintained data and collaboration with conservation experts and Schedule of Rates specialists from the Ministry of Infrastructure and Transport, this standardized document forms an integral part of the Bhutan Schedule of Rates. Through iterative workshops and consultations with private sector specialists, the specification has been refined to incorporate diverse conservation approaches and principles, laying a robust foundation for outsourcing conservation works while ensuring the preservation of Bhutan's rich cultural heritage.

The fundamental prerequisite for utilizing the Schedule of Rates and specifications for the conservation of heritage sites is that the site must hold at least a registered heritage site status. Before engaging the Schedule of Rates, a comprehensive conservation plan must be prepared, delineating the elements slated for preservation and those earmarked for alteration within the heritage sites. Should the scope of work undergo modifications during the execution of the conservation plan, it is imperative to revise the plan accordingly, necessitating a recalibration of the estimated costs prior to commencing work on the site. For adjacent areas or newly identified sites in the vicinity of heritage sites, it's crucial to apply the Schedule of Rates outlined in the Bhutan Schedule of Rates (BSR), rather than adhering to the specific conservation specifications tailored for heritage sites. This ensures that construction and maintenance activities in these surrounding areas align with standard procedures and pricing structures, distinct from the specialized requirements governing heritage conservation.

DEFINITIONS

1. **Demolishing:** Careful dismantling or removal of part or whole of structures, buildings, or architectural elements that are no longer deemed suitable for preservation or are hindering the conservation efforts. It involves protection of historically significant features, salvage of reusable materials, and adherence to preservation guidelines and regulations. It may involve the use of specialized techniques and equipment to minimize damage to surrounding areas of heritage structures and to facilitate the safe removal and disposal of demolished materials.

2. **Salvage:** Salvage involves rescuing valuable materials, artifacts, or architectural elements from buildings undergoing demolition or renovation. This process includes careful dismantling, documentation, and storage to ensure integrity and future usability.

3. **Repair:** Repair involves the process of fixing or restoring damaged or deteriorated materials, structures, or architectural features.

4. **Traditional Techniques:** A traditional technique refers to a method or practice that has been passed down through generations and is deeply rooted in the cultural or historical context. These techniques often involve craftsmanship, materials, and processes that have been used for centuries and are characteristic of a Bhutanese cultural tradition.

5. **Wood preservatives:** Wood preservatives are substances or treatments applied to wood to protect it from decay, fungal growth, insect damage, and other forms of deterioration. These preservatives help extend the lifespan of wood products and structures, particularly in outdoor environments or in areas with high moisture levels where wood is prone to rotting. Common type of wood preservatives used in heritage sites is persimmon which is applied to the embedded part of the timber.

6. **Refurbishing:** Refurbishing refers to the process of renovating, repairing, or restoring structures, buildings, or artifacts to improve their condition, functionality, or appearance while preserving their historical or cultural significance.

7. **Restoring:** Restoring refers to the process of returning structures, buildings, or artifacts to their original or historically accurate condition. This often includes repairing, rebuilding, or reconstructing elements that have been damaged, decayed, or lost over time, using historical evidence, documentation, and traditional craftsmanship techniques.

CHAPTER 1: DISMANTLING WORKS

Rammed earth wall

- *Demolishing rammed earth wall including disposal of unusable materials within 200m lead*

DD2001 - Ground floor level

DD2002 - First floor level and above

Description:

Rammed earth walls are typically load-bearing and integral to the structure of a building. However, in many cases, it becomes necessary to dismantle a part of the wall for the following reasons:

1. If substantial structural alterations are required, such as changing the building layout, or extensions, a part of the rammed earth wall needs to be dismantled to accommodate these modifications.
2. Over time, rammed earth walls can sustain damage from various factors such as the development of cracks, surface erosion, settling, or other environmental influences. In such cases, a section of the wall needs to be dismantled to undertake the repair work, such as patching cracks, reinforcing weakened areas, or replacing damaged sections.
3. To incorporate modern utilities like plumbing, electrical wiring, or HVAC systems, a section of the wall needs to be dismantled for installing, repairing, or upgrading these systems.
4. To conduct a thorough inspection or assessment of its condition, a section of wall needs to be dismantled. This could be done to evaluate its structural stability, identify underlying issues such as moisture infiltration or pest damage, or determine its suitability for future renovations or adaptations.

The demolishing process involves careful disassembly of the section of the wall to minimize damage to the existing structure. In cases of total demolition, reusable materials need to be salvaged, and the site needs to be cleared for new construction or development.

Figure 1: Demolishing of Rammed earth wall

Measurement: The length, breadth, and thickness of the rammed earth wall to be dismantled shall be measured correctly to 10mm and the cubical contents shall be worked out correctly to two places of decimal.

Rate: The rate shall include the cost of all labor involved and tools used in dismantling excluding scaffolding and propping works. The rate also includes the charges for separating and stacking the reusable material properly and disposal of unusable material within a distance of 200 metres.

DD2003 - Cutting, trimming, shaping, leveling etc. of rammed earth wall to insert timber components like Chams (Joists), doors/ windows, Dhung, etc. including disposal of unusable materials within 200m lead (all floor levels)

Description:

Due to its compact and solid structure, rammed earth walls do not allow for piece-by-piece removal like stone masonry walls. This characteristic necessitates cutting the wall when inserting timber elements such as *Chams*, doors/windows, *Dhungs*, etc. These cut sections need to be trimmed, shaped, and leveled to create a suitable opening space for the insertion of timber components. These adjustments are mainly made to ensure that the timber elements fit seamlessly into the structure, maintaining both functionality and aesthetic coherence across all floor levels of the building. Cutting involves carefully removing sections of the rammed earth wall, while trimming and shaping ensures that the edges are smooth and uniform. Leveling ensures that the surface of the wall is flat and even, providing a solid foundation.

Throughout this process, paying close attention to detail is vital to ensure precision and accuracy, preventing any structural issues or gaps that could compromise the integrity of the wall or the stability of the building. Skilled craftsmanship and specialized tools may be necessary to achieve the desired results effectively.

During these processes, any unusable materials generated from the cutting, trimming, and shaping activities must be disposed properly at a safe distance. Furthermore, adhering to environmental regulations and best practices for waste management is essential to minimize the impact on the surrounding area and maintain a clean and safe work environment.

The scope of work covers all floor levels of the building. Taking this comprehensive approach ensures that the installation of timber components goes smoothly and seamlessly, which adds to the overall quality and functionality of the building.

Figure 2: Cutting, trimming, shaping and leveling of rammed earth wall

Measurement: The length, breadth, and thickness of the rammed earth wall to be dismantled shall be measured correctly to 10mm and the cubical contents shall be worked out correctly to two places of decimal.

Rate: The rate shall include the cost of all labor involved and tools used in dismantling excluding scaffolding and propping works. The rate shall also include the charges for separating and stacking the reusable material properly and disposal of unusable material within a distance of 200 metres.

Stone masonry

- *Dismantling stone masonry walls without any features such as Depri (mural paintings) including salvaging of usable materials and disposal of unusable materials within 200m lead*

DD2004 - Ground floor level

DD2005 - First floor level and above

Description:

After conducting a structural assessment, walls that are deemed unstable and beyond consolidation may need to be dismantled. Dismantling is a complex and time-consuming process, requiring careful attention to ensure the safety of workers and their environment. Additionally, qualified heritage professionals with experience in this type of work must supervise the process. The dismantling process includes propping and scaffolding; however, scaffolding and propping work in the heritage conservation field are treated separately and can be found in the scaffolding and propping chapter.

When dismantling stone masonry walls, the following process should be considered:

1. Secure the area where you need to dismantle the stone walls.
2. Observe the failure mechanism of stone walls based on the structural assessment report.
3. Carefully remove the stones and mud mortar using appropriate tools such as hammers, chisels, crowbars, etc.
4. Place the stones on the scaffolding platforms and move the usable stones to a safe place.
5. Dispose of the unserviceable stones at a designated location.

Important consideration:

Stone masonry walls, constructed using two stone wythes filled with mud mortar, are generally considered vulnerable to damage during seismic activities. Several factors contribute to their vulnerability, including the type of stone used, the quality of mortar, and construction method, among others. Therefore, when dismantling these walls, it's crucial to have a proper propping system in place to prevent partial or complete collapse due to delamination.

If the wall contains bonding stones, the risk of delamination is reduced. In such cases, the area can be secured with scaffolding to serve as a platform for dismantling work. Since the width of walls in heritage structures is often greater than 600 mm, it's important to identify the mortar joint alignment both horizontally and vertically to ensure that scaffolding and propping works are mounted properly.

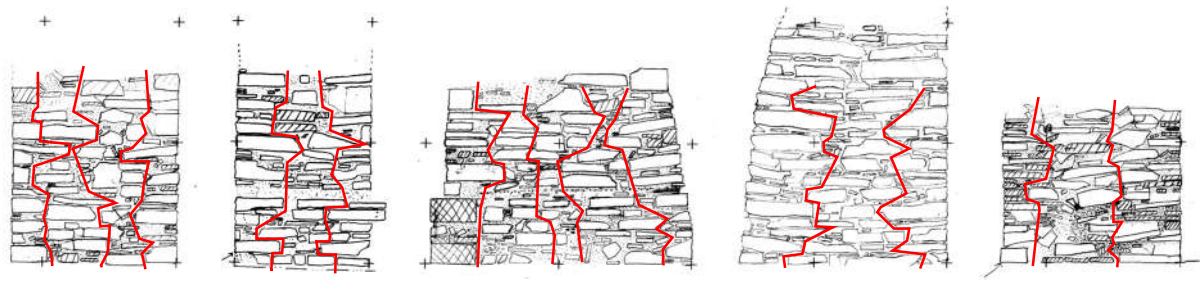


Figure 3: Stone masonry wall with vertical mortar joints

Measurement: The length, breadth, and thickness of the stone masonry wall to be dismantled shall be measured correctly to 10mm and the cubical contents shall be worked out correctly to two places of decimal.

Rate: The rate shall include the cost of all labor involved and tools used in dismantling excluding scaffolding and propping works. The rate shall also include the charges for separating and stacking the reusable material properly and disposing of unusable material within a distance of 200 metres.

- *Dismantling stone masonry walls with special features such as Depri (mural paintings) painted directly on mud-plaster along with detaching of Depri (mural paintings) including salvaging of usable materials and disposal of unusable materials within 200m lead*

DD2006 - Ground floor level

DD2007 - First floor level and above

Description:

The task at hand requires special attention to mural painting, particularly those directly painted on the stone masonry wall. Removing such paintings is a specialized process that demands precision and knowledge of mural paints. These *Depri* (mural paintings) are generally categorized into three types:

1. **Fresco mural painting:** This technique involves creating murals on freshly laid wet lime plaster. The paint is applied directly onto the wet surface, bonding with the plaster as it dries.
2. **Secco mural painting:** In contrast to fresco painting, this technique involves executing murals on dry plaster. To ensure pigment adhesion, a binding medium such as egg (tempera), glue, or oil is used.
3. **Marouflage:** This technique also involves executing murals on dry plaster, with a binding medium used for pigment adhesion, similar to secco painting.

For the current task, the focus is on secco *Depri* (mural paintings), which needs to be detached before dismantling the wall. Detaching such paintings requires careful handling and preservation of the artwork during the removal process. The detachment technique used for secco *Depri* (mural paintings) is known as STACCO.

STACCO is a method used to carefully remove *Depri* (mural paintings) from walls, along with the render or plaster that serves as their support base. It's a specialized process designed to separate the mural artwork from its underlying surface while minimizing the risk of damage or loss. By delicately detaching the render or plaster along with the mural, we can preserve the artwork intact. This allows for the possibility of reinstalling it elsewhere or storing it for future display. STACCO requires meticulous and precise handling to ensure the preservation of both the *Depri* (mural paintings) and their support base.

The process for detaching such mural paints involves the following steps:

1. The painting is first strengthened by applying acrylic resin Paraloid B-72 to the paint layer. Then, lens tissue paper and another layer of cotton gauze are applied to support the painting.

Figure 4: Conservator applying Paraloid B-72 to mural painting (Left) and Japanese len tissue applied to the Depri (mural paintings) (Right)

2. To properly preserve the detached murals, it's crucial to prepare a suitable panel frame. This frame can be constructed using either timber or steel, depending on the desired strength and durability. The backdrop support of the frame should consist of 12mm thick plywood, providing a stable surface for attaching the murals. Then, polyethylene foam is placed to act as a cushion and a layer of white cloth is also added for extra protection. It is important to ensure that the panel frame is portable for transportation to the designated laboratory for further treatment.

Figure 5: Conservator applying Paraloid B-72 to mural painting (Left) and Japanese len tissue applied to the Depri (mural paintings) (Right)

3. It is recommended to cut the edges of the plastered and treated murals on the walls using cutter machines to ensure a clean and precise detachment process. To ensure a proper fit, the size of the murals and the prepared panels should be identical. This ensures that the detached murals fit perfectly onto the panels.

Figure 6: Clearing of the edges of murals on the stone wall

4. To ensure the proper dismantling of the walls without disturbing the murals, it is essential to remove any floor beams or structural members while providing adequate bracing. Once cleared, the prepared panels are erected in their designated positions to accommodate the mural panels. Additional support is provided to ensure stability. It is followed by careful dismantling of the stone masonry wall by ensuring the preservation of the base plaster support for the murals. The walls are manually dismantled, layer by layer, by removing the mud mortar and stones. Finally, the murals are securely placed on the panel frame.

Figure 7: Erection of panel (left), Additional support to the frame and mural (middle) and detached mural with the panel (right)

5. Once the detachment process is complete, additional foam is placed directly on top of the murals to provide an extra layer of protection. A 12mm plywood sheet is then placed on the foam to further secure and shield the murals. To ensure that the panel set remains intact during transportation, it is securely fastened using nylon rope. The entire panel set, including the murals, foam, and plywood, is then transported to a designated storage facility or laboratory for further handling and preservation.

Figure 8: Foam on detached mural (Left), Plywood sheet added (Middle), Completed form (Right)

Measurement: The length, breadth, and thickness of the stone masonry wall to be dismantled shall be measured correctly to 10mm and the cubical contents shall be worked out correctly to two places of decimal.

Rate: The rate shall include the cost of all labor involved and tools utilized for dismantling the walls and detaching the murals. It shall also cover the expenses associated with preparing the panel frames. Additionally, the rate shall include charges for properly separating and stacking reusable materials, as well as disposal of any unusable material within a 200-meter distance.

Wood work

- *Removal of doors, windows, and timber frame components from the existing stone masonry wall, while preserving the Salen (lintel), salvaging usable materials, and disposing of unusable materials within 200m lead*

DD2008 - Ground floor level (<3.0 sq.m surface area)

DD2009 - Ground floor level (3.0 sq.m to 6.0 sq.m surface area)

DD2010 - Ground floor level (> 6.0 sq.m surface area)

DD2011 - First floor level and above (<3.0 sq.m surface area)

DD2012 - First floor level and above (3.0 sq.m to 6.0 sq.m surface area)

DD2013 - First floor level and above (> 6.0 sq.m surface area)

Description:

The work involves careful removal of all timber frame components such as doors and windows, while retaining the *Salen*, a crucial structural element responsible for load transfer to the adjacent walls. The *Salen* plays a pivotal role in preventing the collapse of the upper portion of the wall, making it imperative to ensure its position while removing other timber members.

To achieve this, the task requires the implementation of necessary propping techniques to support the weight of the upper wall section during the removal of timber components. This propping ensures that the *Salen* remains structurally sound and capable of bearing its designated load, even as the surrounding elements are dismantled. By carefully executing the removal process and providing adequate propping, we can successfully salvage the timber materials for potential reuse. It is crucial to properly segregate and dispose of any unusable materials within 200-meter lead.

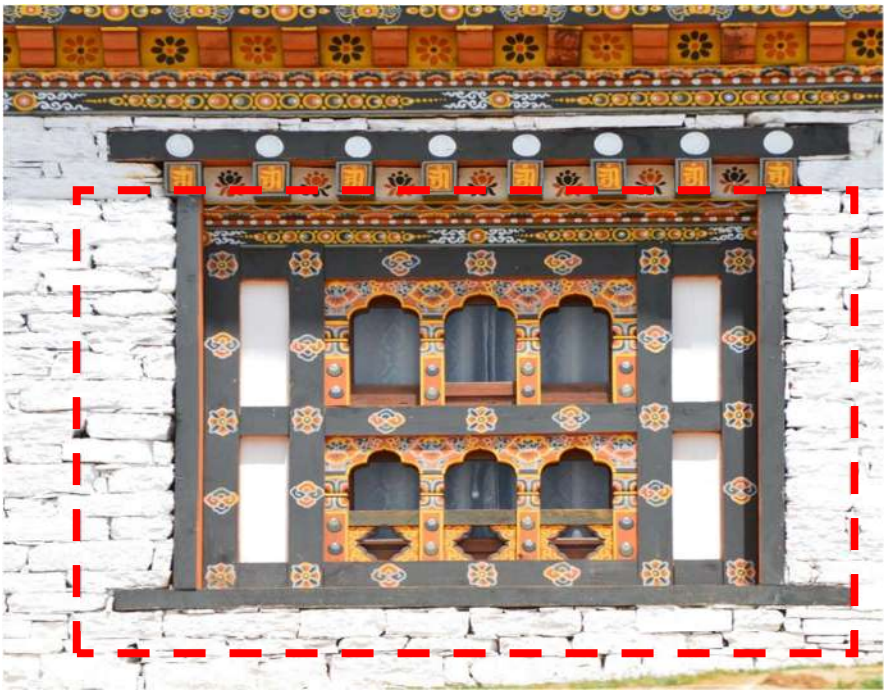


Figure 9: Timber window in stone masonry wall excluding Salen

Measurement: The removal of doors, windows, and timber frame components from the existing stone masonry wall shall be measured in numbers depending on size/area of the openings. The length and breadth of the opening must be measured correctly, allowing for a tolerance of 10mm. It is important to note that the measurement should include the opening size, incorporating any windows or doors within the wall, as shown in figure below.

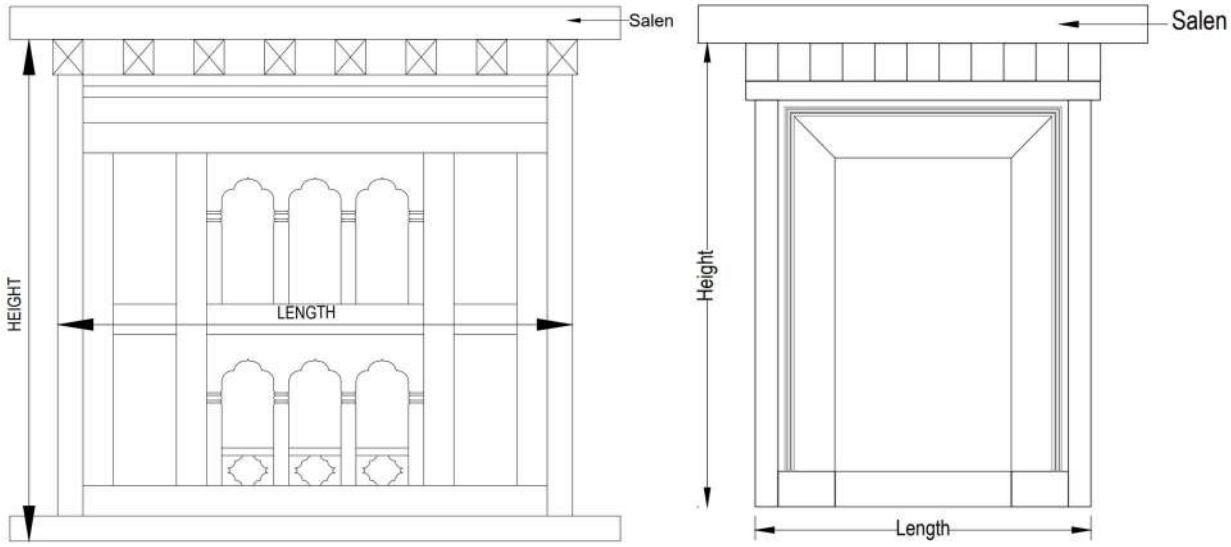


Figure 10: Measurement system

Rate: The rate for this task covers the cost of labor, tools and equipment, material separation and stacking, and disposal.

- *Removal of doors, windows, and timber frame components along with the Salen (lintel) from the existing stone masonry wall, salvaging usable materials, and disposing of unusable materials within 200m lead*

DD2014 - Ground floor level (<3.0 sqm surface area)

DD2015 - Ground floor level (3.0 sq.m to 6.0 sq.m surface area)

DD2016 - Ground floor level (> 6.0 sqm surface area)

DD2017 - First floor level and above (<3.0 sqm surface area)

DD2018 - First floor level and above (3.0 sq.m to 6.0 sq.m surface area)

DD2019 - First floor level and above (> 6.0 sqm surface area)

Description:

The work entails the removal of all timber components, particularly windows and doors, from the stone masonry walls. This must be done while minimizing disruption to the structural integrity of the building. Special attention must be given to the removal of the *Salen*, which is a crucial load-bearing element supporting the weight from above. In heritage buildings, the

main load-bearing walls are thicker, and the *Salen* is often composed of multiple wooden beams that are laid across the width of the wall.

Removing the *Salen* presents a challenge as it can result in an A-shaped (cone-shaped) collapse of the upper wall portion. If the stone walls have been properly bonded together, only a few layers may detach along with the *Salen*. In such cases, it is necessary to remove and relay certain layers of stones after inserting a new *Salen*. However, if the walls lack proper bonding and have weak mud mortar, a significant portion of the walls may collapse upon *Salen* removal. It is crucial to understand the specific stone bonding technique used in the structure and to take appropriate preventive measures before removing the *Salen*.

It is important to note that localized collapses of walls may occur, but efforts should be made to ensure the overall structural integrity of the wall remains intact. To achieve this, a careful approach is needed, removing each component of the *Salen* one by one. Propping techniques should be implemented to redistribute the weight of the upper wall section to other parts of the *Salen*, ensuring its structural stability while surrounding elements are dismantled. This allows for the salvage of timber materials for potential reuse, maximizing resource utilization and preserving the stability of the wall structure. Additionally, it is essential to properly segregate and dispose of any unusable materials within a 200-meter radius.

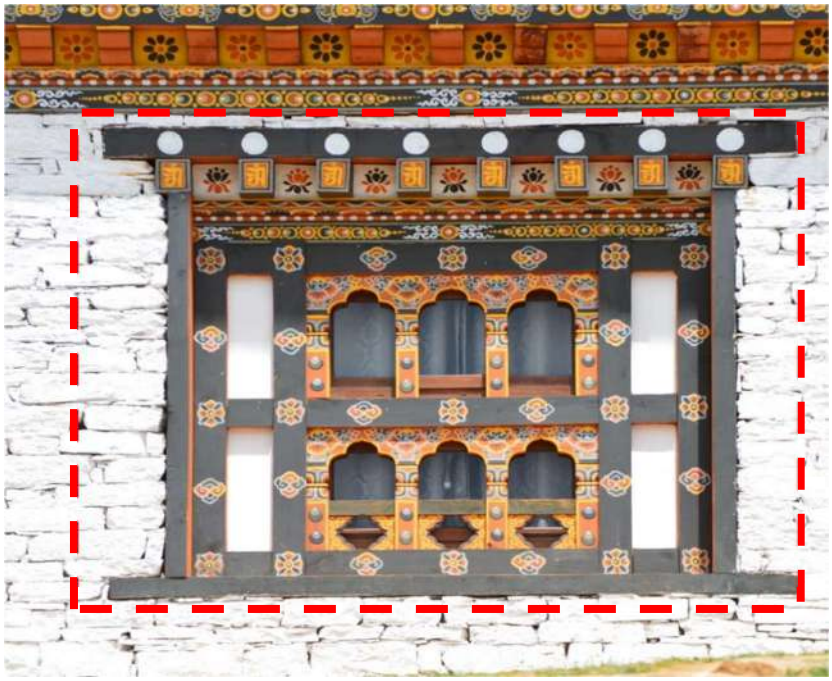


Figure 11: Timber window in stone masonry including Salen

Measurement: The removal of doors, windows, and timber frame components from the existing stone masonry wall shall be measured in numbers depending on size/area of the openings. The length and breadth of the opening must be measured correctly, allowing for a

tolerance of 10mm. It is important to note that the measurement should include the opening size, incorporating any windows or doors within the wall.

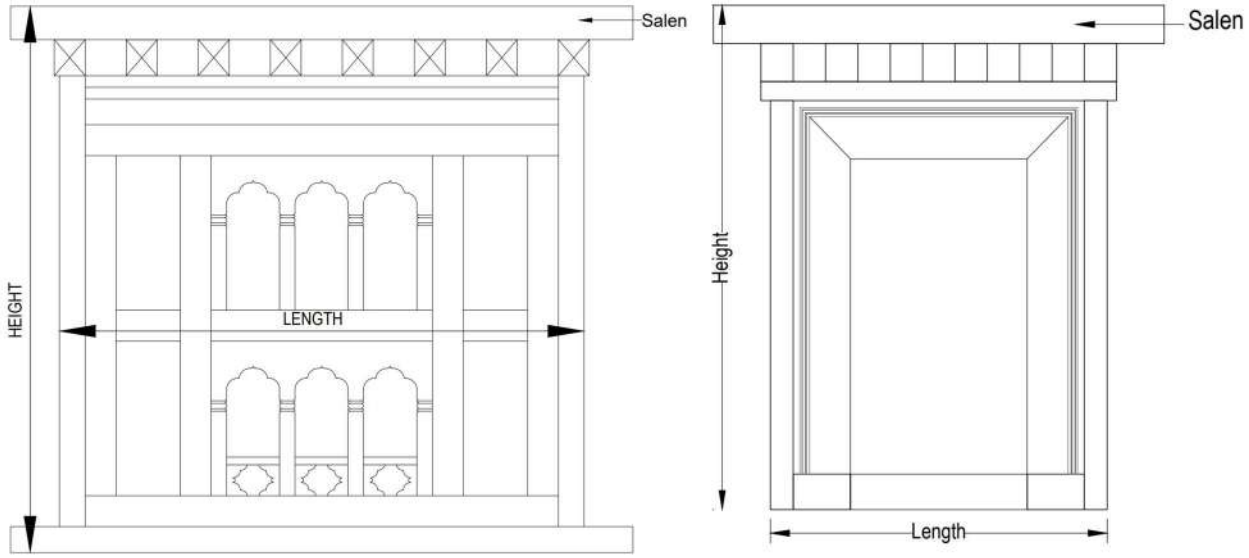


Figure 12: Measurement system

Rate: The rate for this task covers the cost of labor, tools and equipment, material separation and stacking, and disposal.

- *Removal of Chams (joists)/Dhungs and its components from the existing stone masonry wall, salvaging usable materials and disposing of unusable materials within 200m lead*

DD2020 - Ground floor level

DD2021 - First floor level and above

Description:

The flooring of traditional houses is structurally considered a flexible diaphragm, which facilitates one-way load distribution. The floor *Chams* bear the dead and live loads, transferring them to timber *Kachens* (columns) or directly onto walls, depending on the architectural layout. Therefore, it is crucial to conduct regular maintenance and monitoring to ensure the durability and integrity of the *Chams*. While the exposed parts of the *Chams* are generally structurally sound, the embedded ends in masonry walls tend to deteriorate over time. Hence, thorough inspections are essential to assess the stability of the structure.

Considering these factors, it may be necessary to remove and replace the floor *Chams* based on their usage and results of the structural assessment. However, this should be done without compromising the overall and local behavior of the structure. Furthermore, if the entire flooring requires replacement, there is an opportunity to enhance the stiffness of the flooring system.

Generally, the following process is crucial in establishing the soundness of a flooring system:

- **Assessment:** Begin by assessing the condition of the existing floor *Chams*. Look for any signs of deterioration or damage, particularly at the embedded ends in the masonry walls. This evaluation will help you determine the extent of replacement that is needed.
- **Planning:** Based on the assessment, create a detailed plan for the replacement process. Consider factors such as the type and dimensions of the new *Chams*, the materials required, and the impact on the overall structure.
- **Removal:** Carefully dismantle the existing floor *Chams*, taking precautions to minimize disturbance to the surrounding structure. This may involve removing sections of the flooring, such as wooden planks, to access the *Chams*.
- **Replacement:** Install the new floor *Chams*, ensuring they are compatible with the structural requirements and provide adequate support for the floor loads. Use seasoned timber that can withstand the anticipated stresses and maintain the architectural integrity.
- **Stiffening (optional):** If the entire flooring system needs replacement, consider incorporating additional elements to enhance stiffness and improve structural performance. This could involve adding reinforcing elements or modifying the layout to optimize load distribution.
- **Integration:** Integrate the new floor *Chams* with the existing timber columns or walls, ensuring proper connections and load transfer. Pay attention to maintaining the continuity and stability of the overall structure.
- **Testing and verification:** Once the replacement is complete, conduct thorough testing and verification to ensure the new floor *Chams* meet the required standards for durability and load-bearing capacity. This may involve performing deflection tests or seeking the expertise of structural engineers.
- **Maintenance:** Establish a maintenance plan to regularly inspect and monitor the condition of the replaced floor *Chams*. Implement necessary measures to mitigate any potential issues and ensure their long-term durability.

Figure 13: (a) Removal of Cham from stone wall (b) Removal of Dhung along with Zhu (capital) from stone masonry

For the particular task, the following steps are necessary:

1. **Planning:** Based on the assessment, identify the areas of the wall that need to be dismantled to facilitate the replacement of the floor *Chams*. It is important to note that only a small portion, typically around 1 foot in height where the *Chams* are located, needs to be dismantled to minimize disruption to the overall structure.
2. **Propping:** Before beginning the dismantling process, ensure proper support is in place to prevent any unexpected shifting or collapse of the wall. This involves propping the upper sections of the wall securely, using appropriate bracing and supports.
3. **Dismantling:** Carefully dismantle the identified portion of the wall, using appropriate tools and techniques. Take great care to avoid any damages to the adjacent areas and ensure the stability of the remaining structure. This may involve removing stones and mud mortar, gradually working from the top downward.
4. **Floor *Cham* Replacement:** With the wall section dismantled, proceed with the replacement of the floor *Chams*. Install the new *Chams* according to the predetermined plan, ensuring they align properly with the existing structure. Securely fasten the *Chams*, using appropriate techniques such as nailing, depending on the construction style.
5. **Wall Reconstruction:** Once the new floor *Chams* are in place, carefully reconstruct the dismantled portion of the wall using the same wall construction technique. Pay attention to maintaining the structural integrity and aesthetic harmony of the wall.
6. **Finishing Touches:** After the wall reconstruction is complete, perform any necessary finishing touches, such as plastering, to ensure a seamless integration of the repaired section with the surrounding wall.

The step 1 to Step 3 are the activities involved in this section for applying rates.

Measurement: The length, breadth, and thickness of *Cham* shall be measured correctly to 10mm and the cubical contents shall be worked out correctly to two places of decimal.

Rate: The rate shall include the cost of all labor involved and tools used in removal of *Cham/Dhung* and its components excluding scaffolding and propping works. The rate shall also include the charges for separating and stacking the reusable material properly and disposal of unusable material within a distance of 200 meters.

Timber flooring

DD2022 - Dismantling Thinzhi enta (Timber flooring) / Nampa enta (Ceiling plank) including stacking useful materials and disposal of rubbish within 200m lead (thickness > 50mm)

Description:

Traditional flooring systems typically consist of two layers of timber planks or boards with compacted mud in between, except for the attic floor. The attic floor, located beneath the roof, only consists of ceiling timber boards with thick mud layers. Timber *Chams* (joists) are used to support the flooring boards, which are inserted into the wall. In case of longer span, additional timber *Kachens* (columns) are added to support the timber *Chams*.

To replace or repair the flooring system, necessary supports are provided, and the timber floors and mud filling are removed. All materials, both serviceable and unserviceable, are separated and stacked or disposed of as specified by the procuring agency.

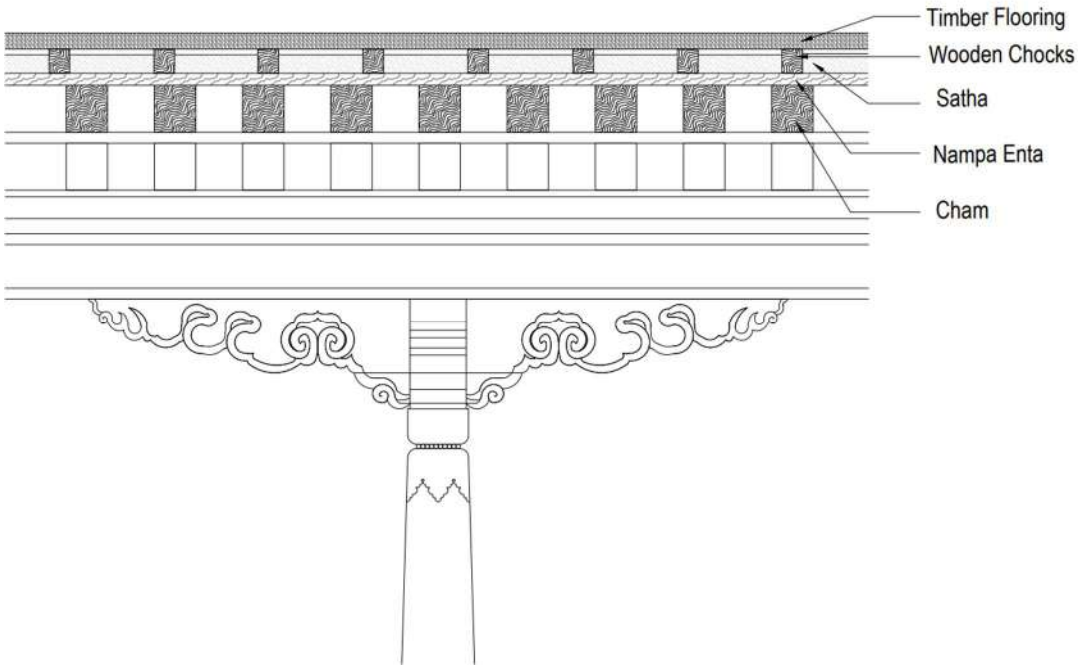


Figure 14: Cross-section of a timber floor –1st and 2nd floor (wooden chock should be right above nampang)

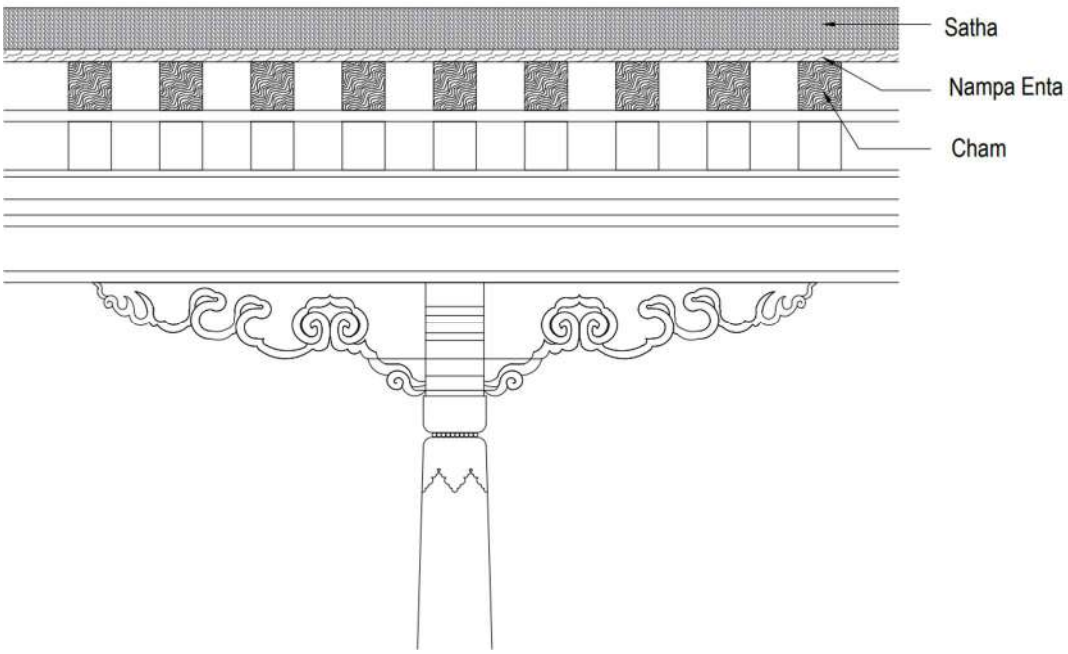


Figure 15: Cross-section of a timber floor –Attic floor

Measurement: Dismantling of a floor shall be measured in square meters. The length and width shall be measured to the nearest 10 millimeters, and the area shall be calculated to two decimal places.

Rate: The rate shall include the cost of all labor involved, as well as the cost of tools used in dismantling. The rate shall also include the charges for separating and stacking serviceable materials properly, and for disposal of unserviceable material within a distance of 200 meters.

Satha (Mud insulation)

- *Removal of Satha (mud insulation) including disposal of rubbish within 200m lead*

DD2023 - Ground floor level

DD2024 - First floor level and above

Description:

Satha acts as a layer of mud insulation between the Nampa enta (ceiling plank) and Thinzhi enta (timber flooring). It comprises mud and natural bonding materials, which are compacted to a minimum thickness of 100 mm by intermittently sprinkling water. It's primary objectives are to provide insulation, fire resistance, and soundproofing.

During the removal process, the Thinzhi enta is first removed, followed by the removal of compacted mud fillings. All materials, whether serviceable or unserviceable, are then segregated and either stacked or disposed of in accordance with the specifications provided by the procuring agency.

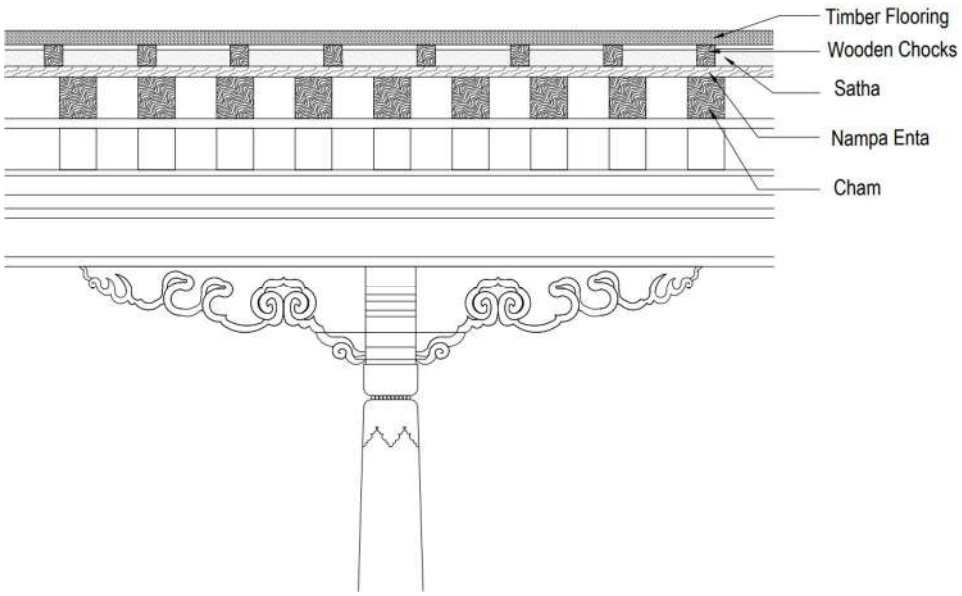


Figure 16: Cross-section of a timber floor showing *Satha*

Measurement: The removal of *Satha* is measured in cubic meters. The length, breadth and thickness shall be measured to the nearest 10 millimeters and the volume shall be calculated to two decimal places.

Rate: The rate shall include the cost of all labor involved, as well as the cost of tools used in removing compacted mud fillings. The rate shall also include the charges for separating out and stacking serviceable material properly, and for disposal of unserviceable material within a distance of 200 meters.

CHAPTER 2: SCAFFOLDING and PROPPING WORKS

A. Scaffolding works

Description:

Scaffolding is an essential part of infrastructure development. It is a temporary structure that allows workers to safely access and work on high areas. It consists of a number of components such as:

- Standards/ Upright: These are the vertical posts that support the scaffolding.
- Ledgers: These are the horizontal beams that connect the standards.
- Putlogs: These are the short pieces of timber that support the ledgers.
- Transoms: These are the horizontal beams that support the platforms.
- Braces: These are the diagonal pieces that provide stability to the scaffolding.
- Bridle: This is the horizontal beam that connects the standards at the top of the scaffolding.
- Guardrail: This is the barrier that prevents workers from falling off the scaffolding.
- Tee board: This is the platform that workers stand on.

Commonly used scaffolding materials include timber, bamboo, and steel. Timber scaffolding is typically favored for smaller projects, while steel and bamboo scaffolding are preferred for larger and more complex endeavors. Although timber and bamboo scaffolding are more cost-effective, steel scaffolding offers greater durability and can support heavier loads.

In Bhutan, timber and bamboo are the predominant scaffolding materials. At heritage sites, timber and bamboo scaffolding is commonly utilized due to their local availability and to avoid potential damage to historic structures that steel scaffolding may cause. However, certain projects at heritage sites may necessitate the use of steel scaffolding materials due to their complexity and scale.

To ensure safety of the workers, the distance between two uprights of the scaffold should be no less than 1.2.

Types of scaffolding used in heritage sites of Bhutan:

- **Timber scaffolding:** It is the most common type of scaffolding and is made from wood. It is relatively inexpensive and easy to assemble and disassemble. Timber scaffolding is typically used for smaller projects, but it can also be used for larger projects if it is properly reinforced.
- **Bamboo scaffolding:** It is a type of scaffolding that is made from bamboo. It is a sustainable material that is strong and lightweight. Bamboo scaffolding is typically

used in developing countries, but it is also becoming more popular in developed countries.

- **Steel scaffolding:** It is the most durable type of scaffolding and is made from steel. It is more expensive than timber or bamboo scaffolding, but it can support heavier loads and is more resistant to weather damage. Steel scaffolding is typically used for large and complex projects.

The use of timber and bamboo scaffoldings in heritage sites comes from the extensive experience of the craftsmen that was practiced over generations. The benefits of timber scaffolding are as follows:

- Reuse of serviceable timbers
- Easily customized to fit the specific needs of a project.
- Lightweight and easy to dismantle
- Relatively inexpensive
- Can be made from variety of woods
- Skill available

Process for erection of scaffoldings:

The process for erection of scaffolding in heritage buildings is a complex and specialized task that should only be carried out by experienced and qualified professionals. The process for erection of scaffoldings are as follows:

1. **Planning and design:** The first step is to carefully plan and design the scaffolding system. This will involve taking into account the specific requirements of the project, such as the height and width of the building, the weight of the materials that will be used, and the number of workers who will be using the scaffolding. The design should also take into account the need to protect the building from damage.
2. **Erection:** The next step is to erect the scaffolding system. This will involve assembling the individual components of the system, such as the ledgers, standards, braces, and planks. The scaffolding must be erected in a safe and secure manner, and it must be properly anchored to the ground. Generally, the timber putlog is inserted to the main wall or at times two standards or upright are erected at a spacing of 1.2metres to have a comfortable platform for workers with the materials.
3. **Inspection:** Once the scaffolding is erected, it must be inspected by the technical personnel to ensure that it is safe to use. The erected scaffold must be checked for any defects or damage, and should be corrected before work begins.
4. **Use:** Once the scaffolding is erected, it must be inspected by a qualified professional to ensure that it is safe to use.

5. **Dismantling:** Once the work on the building is complete, the scaffolding must be dismantled. This should be done in a safe and orderly manner, and all components of the system should be properly disposed of.

Figure 17: Timber scaffolding (Right) and Bamboo scaffolding (Left)

- *Providing, preparing and installation of timber scaffoldings*

SF2001 - Ground floor level

SF2002 - First floor level and above

- *Providing, preparing and installation of bamboo scaffoldings*

SF2003 - Up to second floor level (Dia > 50mm)

SF2004 - Above second floor level (Dia > 50mm)

Measurement: The measurement shall be taken as elevation area. The length and height shall be measured to the nearest 10 millimeters, and the area shall be calculated to two decimal places.

Rate: The rate for the erection of scaffolding is calculated by adding up the cost of all the materials, the cost of any tools that are used and labor involved.

- *Providing, hoisting/installation of double (two rows of vertical steel tubes or pipes) steel scaffoldings including all necessary steel fittings (clamps, brackets, nuts and bolts, etc.), working platform complete (>48mm dia, >2.5mm thickness)*

SF2005 - Up to first floor level

SF2006 - First floor level and above

- *Providing, hoisting/installation of single (single row of vertical steel tubes or pipes) steel scaffoldings including all necessary steel fittings (clamps, brackets, nuts and bolts, etc.), working platform complete (>48mm dia, >2.5mm thickness)*

SF2007 - Up to first floor level

SF2008 - First floor level and above

Description:

Steel scaffolding is a type of scaffolding constructed from steel tubes that are securely connected by steel couplers or fittings. Steel scaffolding offers greater strength, durability, fire resistance, and safety for workers.

Types of steel scaffolding

1. **Single:** Often referred to as bricklayer's scaffolding, single scaffolding is set parallel to a wall and typically used for brickwork on homes.
2. **Double:** Double scaffolding is commonly employed in stonemasonry, where making holes to support scaffolding is challenging. This method utilizes two rows of scaffolding: the first row is positioned between 20cm and 30cm from the wall, while the second row is placed 1-2m further away. The two rows are connected with cross beams and braces to ensure a sturdy structure.

Main parts of scaffolding

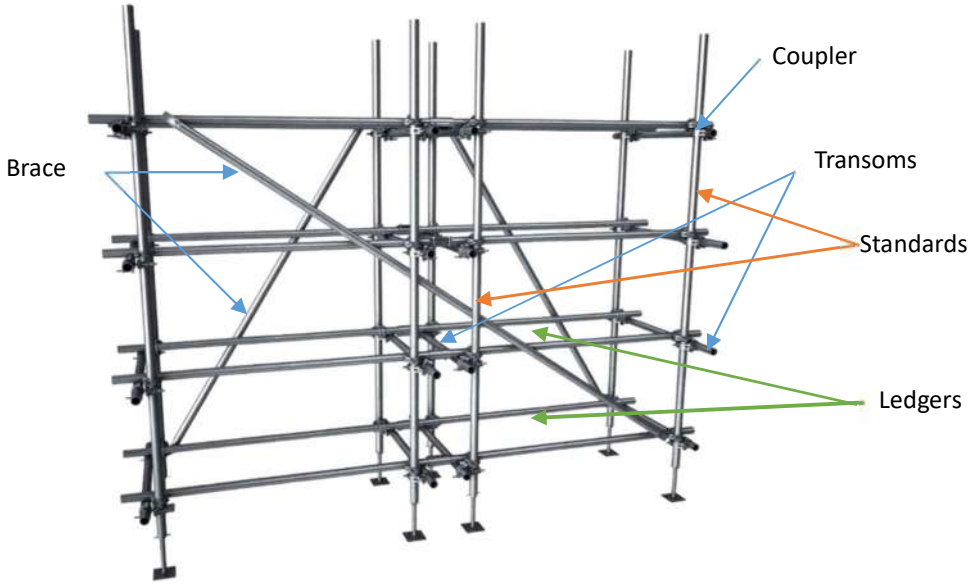


Figure 18: Typical example of double steel scaffolding

Scaffolding can take many different forms, so there are lots of different parts involved, but the main components involved in common tube and coupling scaffolding are standards, ledgers and transoms.

Standards:

A standard is the long pipe or tube running vertically which connects the mass of the scaffold directly to the ground. The base of each standard is connected to a base plate, which helps distribute the weight each standard bears. Standards typically come in a set height of 21ft, so taller structures would require multiple sets of standards connected on top of one another.

Ledgers:

In between each standard is a ledger (also known as a runner) that runs horizontally along the length of the scaffold, which adds further support and weight distribution. Each bay is fixed with ledgers at the front and back of the scaffolding framework. The placement of ledgers defines the height at which the worker platforms are staged.

Transoms:

Transoms (or bearers) are placed on top of ledgers and at right angles to them, they run horizontally and define the bay width. Transoms provide support for standards by holding them in position, as well as support the placement of boards (or planks) which the workers can walk on.

The distance between two uprights and horizontals should not exceed more than 2 meters. Additionally, for every fifth frame, there should be a minimum of one diagonal bracing. These measures are in place to ensure the safety of workers using the scaffolding.

It's also important to note that the scaffolding material belongs to the contractor at the end of the project.

Figure 19: Steel scaffolding used in conservation project

Measurement: The measurement shall be taken as elevation area. In the elevation area, the length and height of the scaffolding need to be measured. The length and height shall be measured to the nearest 10 millimeters, and the area shall be calculated to two decimal places.

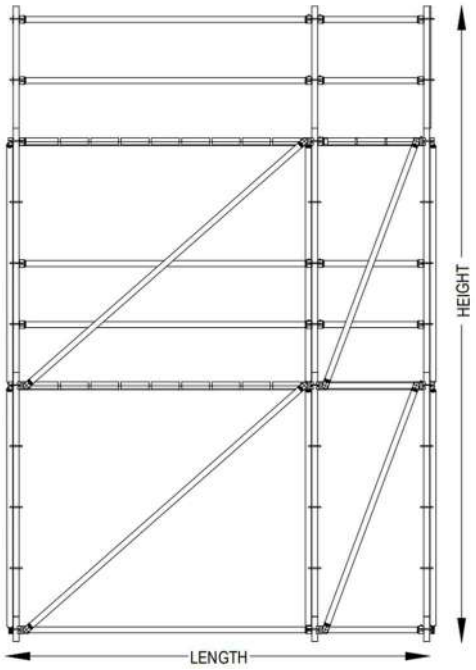


Figure 20: Measurement of steel scaffolding

Rate: The rate shall include the materials and labor for installation and removal of scaffolding.

B. Propping works

Description:

Scaffolding and propping are two distinct yet crucial methods used to provide temporary support for heritage buildings during different types of work such as conservation, renovation and other stabilization work. They play a significant role in ensuring the structural integrity and preservation of these valuable heritage structures.

Propping is employed to support and shore up specific areas or structures within the heritage building that require stabilization work. It is commonly used when existing load-bearing elements are weakened or compromised. Propping provides temporary reinforcement, minimizing the risk of further damage and ensuring the structural stability of the building during conservation efforts.

Propping in heritage conservation demands a deep understanding of the building's vernacular construction techniques, which is crucial for implementing the appropriate methods and materials that respect the building's cultural heritage values. It involves careful consideration of the building's original design, materials, and structural system to ensure that the support systems align with the heritage building's specific requirements.

To successfully undertake propping in heritage conservation, it is essential to recognize and implement the proper techniques. Failure to do so can result in unintended consequences, such as damage to the structural integrity. Heritage professional and experienced craftsmen are instrumental in ensuring that these support methods are executed in a well-intended manner.

Types of propping used in heritage sites of Bhutan:

Timber propping work involves the use of wooden props or supports in construction projects, particularly in heritage structures. Owing to the availability of timber as a traditional building material and expertise in working with wood, timber propping is commonly employed in heritage conservation efforts.

Timber props, typically made from strong and durable hardwoods, provide temporary support and stabilization to identified vulnerable areas of the building during conservation work. The adjustable nature of timber propping allows for customization to fit specific structural requirements. Skilled craftsmen can shape and modify the timber props on-site to ensure a precise fit, providing support to delicate or weakened elements of the heritage structure.

The use of timber propping offers several advantages. Firstly, timber is a lightweight material, making it easier to handle and install in confined or hard-to-reach areas of the building. It also has inherent flexibility, allowing it to distribute loads evenly and adapt to slight movements or settling of the structure. Additionally, timber propping is relatively cost-effective, utilizing locally sourced materials and traditional woodworking techniques often available within the heritage conservation context.

Figure 21: Timber propping

However, with advancements in construction technology and the increasing availability of steel adjustable propping systems, steel propping has become a viable alternative in modern practice. Steel propping offers distinct advantages over timber, particularly in terms of load-bearing capacity and adjustability. Steel props are manufactured to specific load ratings and can support heavier loads compared to timber. Furthermore, steel props are adjustable in height, allowing for precise and efficient leveling and support in different areas of the building.

The adjustable nature of both timber and steel propping work is crucial in heritage conservation projects. As heritage structures often have unique architectural features and irregularities, the ability to adjust and fine-tune the props ensures a tailored and secure support system. Adjustability allows conservation experts to account for variations in the building's conditions, such as uneven settling or shifting, and make necessary adjustments to maintain stability during the conservation process.

Figure 22: Steel propping

The choice between timber and steel propping work depends on several factors, including the specific requirements of the heritage structure, load-bearing needs, project budget, and the availability of materials and expertise. While timber propping work aligns with the historical context of heritage buildings and can be an appropriate choice for certain projects, steel propping offers enhanced load-bearing capabilities and adjustability, making it suitable for more demanding or complex conservation scenarios.

Process for erection of scaffoldings:

The process of propping involves the following steps:

- **Inspect the structure:** The first step is to inspect the structure to be propped. This will involve assessing the condition of the structure in accordance with the structural assessment report and the nature of the work.

- **Design the propping system:** Once the structure has been inspected, a propping system can be designed. The type of propping system used will depend on the size and weight of the structure, the duration of the works amongst other requirements.
- **Install the propping system:** The propping system is then installed. This involves placing the props in the correct position and securing them in place. Installation of propping is a delicate process, as it can damage the structure, especially when shoring the horizontal structural members that are embedded into the walls. Shoring works are carried out discreetly, allowing only slight movement of the structural members under consideration.
- **Monitor the propping system:** Once the propping system is in place, it is important to monitor it regularly to ensure that it is still providing adequate support.
- **Remove the propping system:** When the propping works are no longer needed, the propping system can be removed. This should be done carefully to avoid damaging the structure.

- *Providing, preparing and hoisting of timber props with bracing as per drawing and specification*

SF2009 - Up to first floor level

SF2010 - First floor level and above single

Measurement: The measurement shall be taken in cubic meters. The length, breadth and height of each timber prop shall be measured to the nearest 10 millimeters, and the volume shall be calculated to two decimal places.

Rate: The rate for the erection of timber props is calculated by adding up the cost of all the materials, the cost of any tools that are used and labor involved.

- *Providing, preparing and hoisting of steel props with bracing/struts, etc. as per drawing and specification*

SF2011 - Up to first floor level

SF2012 - First floor level and above

Measurement: The measurement shall be taken as length of each prop measured to the nearest 10 millimeters, and the total length shall be calculated to two decimal places.

Rate: The rate for the erection of steel props is calculated by adding up the cost of all the materials, the cost of any tools that are used and labor involved.

CHAPTER 3: *SHAMIG-DAKCHA* (EKRA WALL)

General:

The *Shamig-dakcha*, commonly known as the Ekra wall, is a type of wall construction that involves weaving bamboo splits within a frame and applying *Bji* (Mud plaster) on both sides. These walls serve as both structural load-bearing elements and partitions. The primary components of *Shamig-Dakcha* consists of wooden framing and mud-plastered bamboo splits. Compared to other wall construction methods, it offers several advantages. One notable advantage is their lightweight nature, which makes them resilient against earthquakes. Additionally, *Shamig-Dakcha* are highly energy-efficient due to the temperature-regulating properties of the *Bji*. These walls are also cost-effective as they utilize locally available materials.

In the context of heritage buildings, *Shamig-Dakcha* are often used for partitioning within structures made of rammed earth or stone masonry. However, in ancillary structures, it serves as both primary load-bearing walls and partitions, meaning the entire structure relies on them for support. Removing such walls can lead to structural issues. Conversely, if the *Shamig-Dakcha* is solely serving as a partition, its removal may not impact the overall structural integrity. Nevertheless, it is crucial to conduct a thorough structural assessment before performing any maintenance or interventions.

The work herein entails the repair of a *Shamig-dakcha*. The process is as follows:

1. **Removal of *Bji*:** Remove the existing *Bji* and check the condition of the bamboo splits.
2. **Repair of bamboo splits:** If the bamboo splits are damaged, it needs to be repaired by removing the damaged portion and replacing it using the same technique. If the damage is extensive, the bamboo splits are glued together or replaced with new bamboo strips.
3. **Application of *Bji*:** To prepare the *Bji*, mix 1 part mud, 2 parts sand, and water. Using a trowel, apply the *Bji* evenly over the bamboo splits, to a thickness of 20mm on both sides.
4. **Painting:** Once the *Bji* has dried, it can be painted with the desired color.

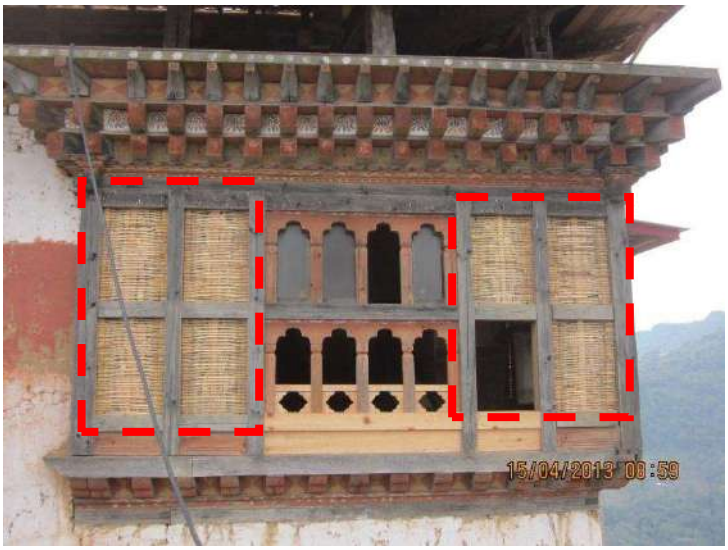


Figure 23: Repairing *Shamig-Dakcha*

SD2001 - *Repair and maintenance of Shamig-Dakcha (ekra wall) by removing and replacing damaged bamboo splits including grooving frames and applying 20mm Bji (Mud plaster) on both sides excluding the cost of frames*

Measurement: The length and height of the repaired *Shamig-Dakcha* shall be measured to the nearest 10 mm. The area should be calculated to two decimal places.

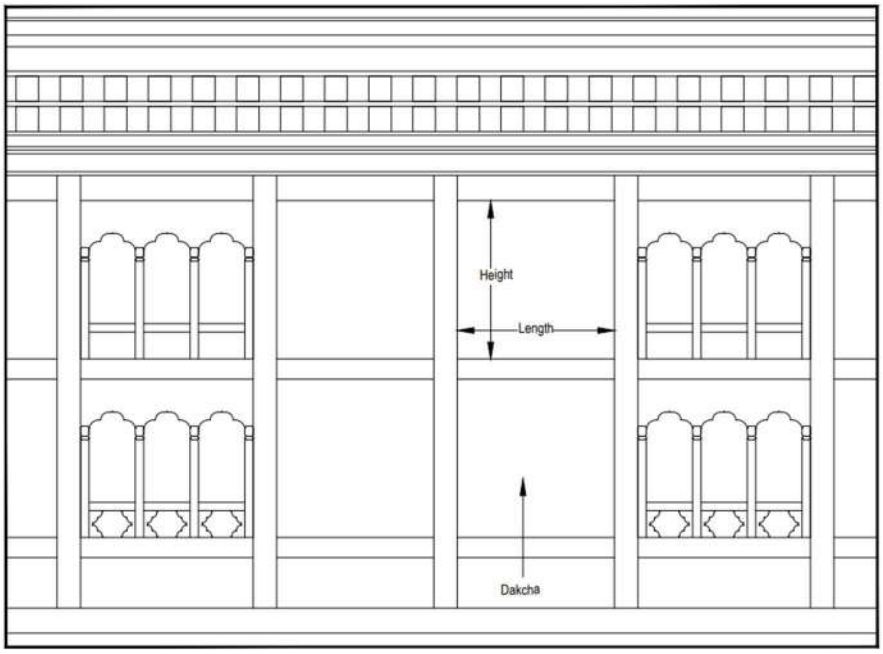


Figure 24: Measurement of work

Rate: The rate for repairing and maintaining a *Shamig-Dakcha* shall include the cost of all materials, labor, and tools used in the process including plastering on both faces.

CHAPTER 4: STONE/MUD MASONRY

Description:

Masonry is a composite material made up of units, such as bricks or stones, and mortar. The properties of masonry depend on the properties of the units and mortar. Mortar joints are weak and can act as planes of weakness. Traditional masonry houses are built by stacking units and bonding them with cementitious materials (soil, lime, and cement).

Stone masonry is a prominent construction technique that has been used throughout history in Bhutan, and it is found in a variety of structures, from small *choetens* (stupas) to majestic *Dzongs* (fortresses). Stone masonry is the most preferred construction material for construction of *Dzongs*, monasteries, *Lhakhangs* (temples), and traditional houses. This was mainly due to availability of material and local expertise on its construction. The use of these materials, combined with traditional construction techniques, contributes to the sustainable nature of the buildings. Simple tools and methods are employed, requiring minimal energy consumption and reducing the ecological footprint.

The traditional knowledge system of masonry in Bhutan is passed down through generations of skilled craftsmen. The expertise in stone selection, cutting, shaping, and laying techniques is transmitted through oral traditions and hands-on practice. This system ensures the preservation of cultural heritage and craftsmanship, while also maintaining the authenticity of Bhutanese architecture.

Coursed rubble masonry

- *Providing and laying of Course Rubble Masonry (CRM) in mud mortar*

SM2001 - Below plinth level wall thickness <600 mm

SM2002 - Below plinth level wall thickness >600 mm

SM2003 - Above plinth and up to 1st floor level (wall thickness <600 mm)

SM2004 - Above plinth and up to 1st floor level (wall thickness > 600 mm)

SM2005 - First floor and above (wall thickness <600 mm)

SM2006 - First floor and above (wall thickness >600 mm)

Construction technique: To construct high-quality masonry, it is important to follow the following conditions:

- Preparation of stones: Before use, all stones should be thoroughly soaked. Soaking the stones before using them in mortar ensures that the stones have the appropriate moisture content. This helps to improve the bond strength between the stones and the mortar, and it also prevents the formation of cracks. The water helps to keep the mortar from drying out too quickly.

- There are three types of stones used in stone masonry:
  1) *Zur-do (cornerstone)*: Literally, the translation of the Dzongkha term means "corner-stone". The minimum dimension for the corner-stone is:
     a. *Length= 16" (400mm)*
     b. *Width= 5" to 7" (130 ~ 180 mm)*
     c. *Height= 8" (200 mm)*

  2) *Lap-do* (Regular sized stones): The stones that are used for wall construction aside from the corner-stones are referred to as *Lap-do*. The minimum dimension for the corner-stone is:
     a. *Length= 12" (300mm)*
     b. *Width= 5" to 7" (130 ~ 180 mm)*
     c. *Height= 8" (200 mm)*

  3) *Nang-do* (Inner stones): these are smaller stones that are used to fill the gaps in the walls.

- Dressing: The stones must be dressed, or shaped, on the face, sides, and bed to enable proper bonding, aesthetic and in maintaining proper tapering during placement. A taper is a slight inclination or slope in the masonry.
- Façade: The external façade of heritage structures is diversified and unique as compared to other conventional stone masonry facades in the contemporary era. The construction technique of stone masonry walls is unique to heritage buildings. Some of the different types of stone masonry façade are shown in Figure 14.

Figure 25: Stone masonry techniques found in Bhutan

- Plumb or Taper: In heritage sites, it is common to have a truly plumb (vertical) wall or a wall with taper. It is highly recommended to have a tapering, as this can help to improve the stability of the wall.
- Construction height limit: To prevent excessive load on fresh mortar and ensure proper curing, the height of masonry constructed in a day should not exceed 1 meter. This limitation allows for adequate time for the mortar to set and gain strength before additional weight is added.
- Proper mortar mix: The selection and preparation of mortar should be done carefully. Mortar plays a vital role in the structural performance of masonry. The mortar mix should be appropriate for the specific masonry application, ensuring workability and durability. The mortar should be prepared with minimal shrinkage properties.

Figure 26: (a) Proper laying of stones (b) The mud mortar with undesirable shrinkage

- Bonding and jointing: The stones should be laid with a tight fit, ensuring proper bonding between the masonry units. The mortar joints should be uniform in thickness and completely filled. The stone courses should be well-defined with no vertical construction joints or voids.
- Quality control: Regular inspection and quality control measures should be implemented during the construction process. This includes checking for proper alignment, plumbness, and levelness of the masonry. Any defects or deviations should be addressed promptly to maintain the integrity of the structure.

Measurement: The measurement shall be in cubicle meters and the length, breadth and height shall be measured to the nearest 10mm.

Rate: The rate shall include the cost of all labor and materials required for the construction of CRM walls, excluding scaffolding.

Consolidation

- *Providing and Consolidation of Coursed Rubble Masonry (CRM) walls in mud mortar*

SM2007 - Up to first floor level

SM2008 - Above first floor level

- *Providing and Consolidation of Random Rubble Masonry (RRM) walls in mud mortar*

SM2009 - Up to first floor level

SM2010 - Above first floor level

Identifying and addressing failure mechanism in stone masonry walls:

When stone masonry walls suffer major damage that requires extensive repair work, it is crucial to identify and address the specific failure mechanisms that have occurred. The 2009 Narang earthquake is a good example of this, as it highlighted some common failure mechanisms that can result from seismic events. These failure mechanisms include:

a) **Corner cracks at both wall ends:** These cracks are often observed at the corners of walls, and they can indicate stress concentrations and potential instability.
b) **Delamination of outer walls:** This is the separation or detachment of the outer layers of walls, and it is often caused by inadequate bonding or structural deficiencies
c) **Collapse of the wall at gable ends:** This is the complete or partial collapse of the wall at the gable ends, and it can be caused by weak connections or inadequate support.
d) **Racking shear failure:** This is a failure that occurs when horizontal forces cause walls to tilt or shift, resulting in shear cracks and instability.
e) **Out-of-plane collapse:** This is when walls collapse or tilt out of their intended vertical plane, indicating significant structural damage and lack of stability.
f) **Partial collapse at the wall corner:** This is a partial failure that is often observed at the corners of walls, and it is typically caused by stress concentration and inadequate reinforcement.

Figure 27: Common failure mechanism of stone masonry structures

In addition to these failure mechanisms, there are a number of other common damages that can be observed in stone masonry walls. These include:

- Thorough vertical cracks: These cracks extend from the top to the bottom of the wall, and they can be caused by a number of factors, such as poor workmanship, inadequate foundations, or seismic activity.
- See-through cracks: These cracks are large enough to see through, and they can be caused by severe structural damage or weathering.
- Horizontal shear cracks: These cracks run horizontally across the wall, and they can be caused by racking shear failure or seismic activity.
- Vertical joints between transverse walls: These joints are often weak points in the wall, and they can be a source of damage if they are not properly filled or sealed.
- Long slender walls: These walls are more susceptible to racking shear failure than shorter walls, and they should be carefully inspected for signs of damage.
- Absence of transverse walls: Transverse walls can help to distribute the load in a wall, and their absence can increase the risk of failure.
- Small stones used in construction: Small stones are less strong than larger stones, and they can be a source of weakness in a wall.

By clearly identifying and documenting these failure mechanisms and damages in the assessment report, the extent of the damage can be better understood. This information can then be used to determine the appropriate repair strategies and interventions necessary to address the underlying structural issues and prevent future failures.

Repair and consolidation methods

The specific repair and consolidation measures that are required will depend on the specific failure mechanisms and damages that have occurred. However, some general recommendations include:

1. **Use of mud mortar:** The mud mortar used to repair the wall should be of a high quality and should be compatible with the existing mortar. The mortar should be laid out properly to ensure that the wall is properly sealed and that there are no voids.
2. **Proper connection of old and new walls:** The existing wall and consolidated walls should be properly connected and overlapped to ensure that the wall is structurally sound. The stone's size and its properties should be compatible with the existing wall.
3. **Increase of wall thickness:** In some cases, it may be necessary to increase the thickness of the wall to improve its structural integrity. This can be done by adding new layers of stone wall.
4. **Introduction of transverse walls:** Transverse walls can help to distribute the load in a wall and prevent it from collapsing. In some cases, it may be necessary to introduce transverse walls to improve the structural integrity of the wall.
5. **Documentation:** Further, the photographic documentation shall be taken to document the work, both before and after the consolidation. This documentation shall be used to verify the quality of the work and to ensure that the work is in accordance with the contract specification and scope of work.

The walls must be consolidated with proper techniques and methods employing good construction practices. Wherein necessary, modern interventions may be introduced. Else, it is important to make proper connections during laying of stones.

Measurement: The measurement shall be in cubic meters (cum) and the length, width, and depth should be measured to the nearest 10mm.

Rate: The rate shall include the cost of all labor and materials required for the consolidation of walls, excluding scaffolding.

Stitching of existing stone masonry walls

Description:

Repairing and stitching of stone masonry walls are essential in historical construction to ensure the preservation, stability, and longevity of these valuable structures. Over time, natural forces, environmental factors, and human activities can cause deterioration, cracks, and damage to the masonry walls.

Here are several important aspects and technicalities related to the repairing and stitching of stone masonry in historical construction:

1. **Structural Stability:**
   Repairing and stitching of stone masonry walls aim to restore and reinforce the structural stability of the building, which is the most important consideration. Repair and stitching works should ensure that the structural stability is not compromised. Cracks, loose stones, or weakened mortar joints can compromise the load-bearing capacity of the walls, potentially leading to partial collapse. If left untreated, this can lead to complete collapse and further deterioration. Repair techniques help to address these issues and maintain the overall stability of the structure.

2. **Preservation of Historical Integrity:**
   Historical buildings possess unique architectural and cultural significance: Repairing and stitching of stone masonry walls allow for the preservation of the original materials, architectural details, and craftsmanship. It ensures that the historical integrity of the structure is maintained, and its heritage value is preserved for future generations.

3. **Prevention of Water Infiltration**:
   Damaged or deteriorated masonry can allow water infiltration, leading to moisture-related issues such as decay, mold growth, and structural damage. Repairing techniques, such as repointing mortar joints, sealing cracks, or replacing damaged stones, help to create a watertight barrier, preventing further water ingress and protecting the masonry from long-term deterioration.

4. **Strengthening and Reinforcement:**
   In cases where masonry walls exhibit significant cracks or instability, stitching techniques can be employed to provide additional strength and reinforcement. A commonly used technique elsewhere is to insert metal rods or dowels into the masonry joints, spanning across the cracks, and secure them with specialized grouts or epoxies. This stitching process helps to distribute the load and enhance the overall structural integrity of the wall. This is an important technical aspect that needs to be further researched and applied in Bhutan.

5. **Compatibility and Aesthetics:**
   When carrying out repairs on historical masonry, it is crucial to use materials and techniques that are compatible with the original construction. Matching the type of stone, mortar composition, joint profiles, and surface finishes ensures a seamless integration of the repaired sections with the existing masonry. This attention to

compatibility helps to preserve the visual harmony and aesthetic value of the historical structure.

6. **Conservation Ethics:**
   Repairing and stitching of stone masonry walls align with the principles of conservation ethics, promoting the concept of minimal intervention and reversibility. Skilled craftsmen, trained in traditional techniques, employ their expertise to execute repairs with minimal disturbance to the original fabric, respecting the historical value of the building. We must follow the value-based protection approach that is followed and practiced in Bhutan.

Detection and process for stitching wall:

In heritage buildings constructed using conventional stone masonry, various types of cracks can be observed, which often require localized repair and stitching to address specific failure mechanisms. Two common types of cracks found in such buildings are lintel cracks and cracks originating from *Chams* (joists). These cracks can be repaired without significantly affecting the overall behavior of the structure.

The process of stone stitching involves the use of similar stone and mortar to ensure compatibility and visual harmony with the existing masonry. The repair process typically includes the following steps:

- **Removal of Plaster:** The first step is to carefully remove any plaster or surface finishes applied to the affected area. This exposes the underlying masonry, allowing for a thorough assessment of the extent and nature of the cracks.
- **Clearing and Opening Cracks:** The cracks are then carefully cleared and opened to prepare them for repair. Loose debris, dirt, and deteriorated mortar are removed to ensure proper bonding with the new materials.
- **Removal and Replacement of Stones:** In areas where cracked or damaged stones are identified, they are cautiously removed from the masonry. The stones are replaced with new ones that match the characteristics, color, and texture of the original stones. Proper bonding is ensured by using appropriate mortar mix consistent with the historical construction techniques.
- **Insertion and Bonding of New Stones:** The new stones are inserted into the openings left by the removed stones, following the original pattern and alignment. Special care is taken to achieve a tight fit and secure bonding with the surrounding masonry. This ensures structural integrity and enhances the aesthetic continuity of the wall.
- **Plastering or Exposed Finish**: Depending on the location of the repaired wall (internal or external), plastering or an exposed finish is applied. For internal walls, plastering with suitable materials and techniques is carried out to provide a smooth or desired,

finished surface. In the case of external walls, the repaired area may be left exposed, with a white wash or other compatible treatments applied to match the surrounding masonry.

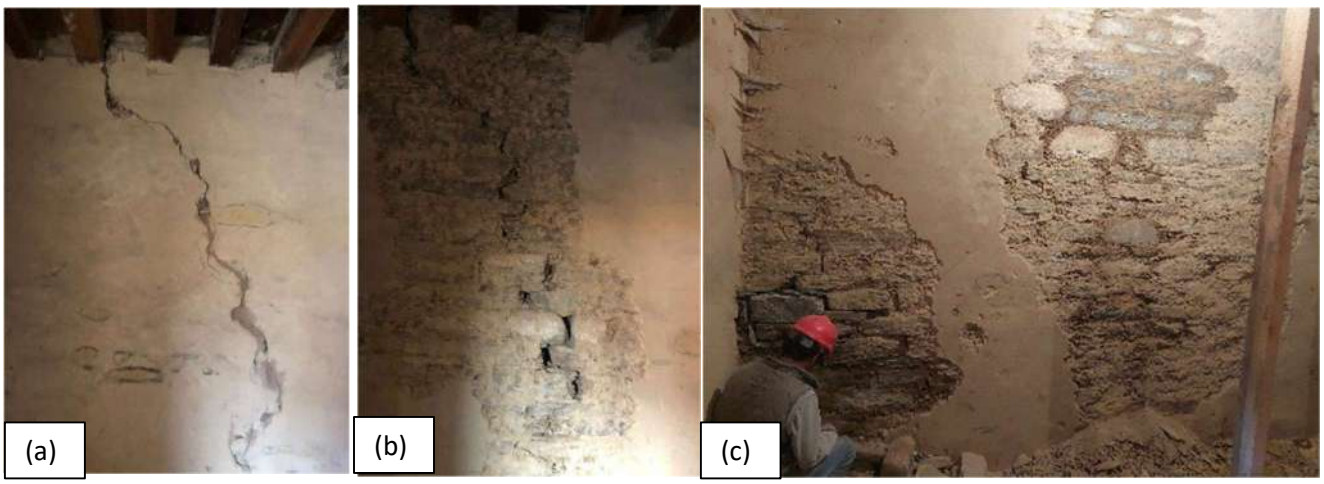


Figure 28: (a) Crack originating from *Cham* (b) removal of plasters and (c) Stone stitching of wall

For the purpose of measurement, documentation is the foundation. Before beginning any intervention work, it is critical to thoroughly document the impacted area. This documentation serves as a reference point for assessing the nature, type, and extent of the damage, enabling the identification of areas that need to be repaired.

Once the damaged areas have been identified, precise measurements of length, width, and height should be taken after the repair work has been completed. These measurements are used to determine the quantity of work done. Payments are then made based on the measured quantity in cubic meters (m3). If other modern interventions are provided, these interventions will be handled separately.

In addition, clear communication and understanding between the contracting parties are critical. Both parties should agree on the measurement methodology and units of payment to avoid any misunderstandings or disputes regarding the final payment.

SM2011 - Repair and stitching of existing stone masonry walls in mud mortar using local materials and traditional methods

Measurement: The measurement shall be in cubic meters and the length, breadth and height should be measured to the nearest 10mm.

Rate: The rate shall include the cost of all labor, materials and tools used in repair and stitching works of stone masonry walls in mud mortar.

Rammed earth wall

Earth as a natural building material:

Earth, as a natural building material, has been used for thousands of years and continues to be a prevalent choice in construction. It is estimated that 40% of the global population resides in earth dwellings, highlighting its enduring popularity. Additionally, earth plays a significant role in cultural heritage, with approximately 15% of the world's cultural sites constructed using earth materials. There are three common forms of earth construction: adobe block, cob, and rammed earth. Rammed earth, in particular, has been widely utilized as a traditional building technique across various regions, including Asia, North Africa, Australia, North and South America, and parts of Europe. It involves compacting moistened earth mixtures inside *Padom* (formwork) to create solid walls. The mixture typically consists of clay, silt, sand, and gravel. In un-stabilized rammed earth, clay serves as the sole binding material, providing cohesion and strength. However, an excessive amount of clay can lead to wall cracking.

The traditional rammed earth technique offers several advantages, contributing to its popularity. Firstly, it is a natural and locally available resource, eliminating the need for industrial processing. This aspect ensures immediate use of the material on-site and reduces energy consumption. Moreover, rammed earth is reusable without requiring treatment, further minimizing its environmental impact. However, it should be noted that traditional rammed earth construction has limitations in terms of seismic performance, which can be a drawback.

Rammed earth construction:

Rammed earth construction is a traditional building method that is still widely used in Bhutan. Rammed earth buildings are characterized by massive walls made of compacted earth, which are often combined with wooden components. The walls of rammed earth buildings are typically at least 2 feet thick, and can be even thicker in larger buildings. The core elements of a typical village landscape in the western region of Bhutan consist of clusters of two- or three-story rammed earth houses. There are also a few four-story *Lhakhangs* (temples) and *Nagtshangs* (historical mansions) that have been constructed using rammed earth techniques. Although the exact origins of rammed earth construction in Bhutan are unknown, there are several outstanding rammed earth buildings that date back to the 16th century.

In order to understand the rammed earth construction practices in Bhutan, it is important to survey and understand the good practices that have been adopted over the centuries to suit the local conditions. It is also important to study the vulnerable areas of rammed earth buildings so that measures can be taken to improve their construction using traditional and modern techniques and materials. The Department of Culture and Dzongkha Development has carried out extensive surveys and vulnerability assessment over the last one decade. The

key factors to produce strong and stable rammed earth buildings are to ensure the production of good quality walls and to prevent the development of vulnerable areas in the walls.

Process of constructing a rammed earth wall:

- Selection of soil. The ideal soil for rammed earth is a sandy loam that is free of rocks and other debris. The soil should have a high sand and gravel content with some silt and just enough clay to act as a binder and assist soil compaction. The soil should also have a moisture content of 10-15%.
- Preparation of soil. This involves removing any rocks or debris from the soil and adding a stabilizer, such as lime or cement if required. The consistency of the soil should be
- Preparation of *Padom* (formwork). The *Padom* is a temporary structure that will hold the rammed earth in place until it dries. It can be made of wood, steel, or concrete. The major components of *Padom* are *Ju-shing*, *Pa-shing*, *Gu-shing*, *Row*, *Shab* (wooden wedge) and side shutter plank.
- Compaction of soil. The soil is compacted into the *Padom*. The traditional tools used in Bhutanese rammed earth construction are the rammer with a *Hiw* (hammerhead) for standard compaction and the rammer with a *Sotee* (wedge head) for edges. The degree of compaction is measured by the dry density of the soil, which depends on the initial water content and the amount of energy applied during compaction. In geotechnical engineering, tests such as the Standard Proctor test, Heavy Proctor test, and Vibrating hammer test are used to determine the optimum water content. In Bhutan, however, the moisture content is commonly checked through traditional field tests, such as squeezing a handful of earth, throwing a ball against a wall, and forming a ball of earth and tossing it in the air. These traditional tests provide practical indicators of moisture content suitability. The soil is compacted in layers to achieve the required rammed earth block height of 50 mm.
- The layer thickness in rammed earth blocks significantly affects their mechanical characteristics. Generally, thinner layers are preferred over thicker ones. Thinner layers allow for greater compaction, resulting in increased average compressive stress and higher elastic modulus. On the other hand, thicker layers may lead to the formation of honeycombs due to inadequate compaction. Therefore, it is recommended to use thinner and more layers of rammed earth within each block to achieve optimal results. The preferred layer thickness is 50mm.
- Removal of the *Padom*. Once the soil has been compacted, the *Padom* can be removed. The wall will still be wet at this point, so it is important to protect it from the weather.
- Allow the wall to dry. The wall will need to dry for several months before it is fully cured. During this time, the wall will shrink slightly.

(a) (b)

(c) (d)

Figure 29: (a) Installation of Padom, (b) Pouring of moist soil, (c) Compaction and (d) Finished rammed earth block

Figure 30: Typical wooden shutter set used for rammed earth construction

Improving the mechanical properties of rammed earth through stabilization:

The use of stabilizers can improve the mechanical properties of rammed earth, making it a more durable and sustainable building material.

- Cement is the most common stabilizer used in rammed earth construction. It increases the compressive strength of the soil and can also improve its erosion resistance. The recommended amount of cement is between 5% and 10%.
- Lime is another stabilizer that is sometimes used in rammed earth construction. The recommended amount of lime is between 6% and 12%.

- Fibers can be added to rammed earth to improve its thermal performance, bending strength, and tensile strength. The ideal soil for fiber stabilization has a plasticity index between 15% and 35% and a liquid limit from 30% to 50%. However, the use of fibers can also decrease the compressive strength of the soil.
- Dung can also be used to stabilize rammed earth. It improves the cohesion and plasticity of the soil, but more research is needed to determine the optimal amount to use.

However, the rate here doesn't include the use of stabilizers.

- *Providing and constructing rammed earth wall in superstructure including cost of Padom (formwork) and Zungshing, etc.*

SM2012 - Up to first floor level

SM2013 - First floor level and above

Measurement: The length, height, and thickness of the wall shall be measured to an accuracy of 10 mm. The quantity shall be calculated in cubic meters, rounded to two decimal places.

Rate: The rate shall include all labor and materials involved in the work.

CHAPTER 5: *BJI* (MUD PLASTERING WORKS)

PL2001 - Providing and laying 3 layers (Bjidhen-Dacha-Zhungdah) of Bji (mud plaster) using traditional techniques with finished surface (thickness 25mm to 50 mm)

Description:

Bji is a traditional and time-tested method of applying a coating of mud to walls and other surfaces. It is a sustainable and environmentally friendly building material that has been used for centuries. *Bji* is made from a mixture of clay, sand, and water with additives like strew. The proportions of these ingredients will vary depending on the type of clay and the desired finish.

Bji has a number of advantages over other types of plaster:

- **Sustainable and environmentally friendly:** It is made from natural materials that are readily available. It is also a renewable resource, which means that it can be easily replaced.
- **Durable**: It is a very durable building material that can last for many years. It is also resistant to fire and pests.
- **Insulating:** It helps to insulate a home, which can save on energy costs.
- **Moisture control properties:** It is breathable, which means that it allows moisture to escape from the wall. This helps to prevent mold and mildew growth.
- **Fire resistant:** It is a very durable building material that is also fire resistant and insulating.
- **Aesthetically pleasing**: It can be finished in a variety of ways, from smooth to textured to patterned.

Process of preparation and application of *Bji*:

1. **Preparation of mix:** Traditional mud plaster, commonly referred to as *Bji* in Bhutan, has three distinct layers: *Bjidhen*, *Dacha*, and *Zhudah*. The materials used are soil, sand, straw, and water, which are mixed in a wooden container. The materials are then mixed and transported to the site for application to the wall.

2. **Preparation of Surface:** The first step is to prepare the surface. The joints of masonry should be raked out properly so that the plaster can key into the masonry. Dust and loose mortar should be brushed out. Efflorescence, if any, should be removed by brushing and scraping. The surface should then be cleaned, sprinkled with water, and kept wet before plastering is commenced.

3. **Preparation of scaffoldings:** The next step is to prepare the scaffolding. For all exposed masonry walls, double scaffolding with two sets of vertical supports should be provided. The supports should be sound and strong, tied together with horizontal pieces over which scaffolding planks should be fixed. In some cases, single scaffolding

may be permitted. In such cases, the inner end of the horizontal scaffolding pole should rest in a hole provided only in the header course for the purpose. Only one header for each pole should be left out.

4. **Application of *Bjidhen*:** The third step is to apply the *Bjidhen* layer. This is the first coat of *Bji*, and it is applied evenly with a rough texture. It is the base course and the first course applied to the wall. Allow several days for this course of plaster to dry.

Figure 31: Wetting of wall surface with scaffolding (left) and First layer of wall plaster-Bjidhen (right)

5. Application of *Zhungdah*: After the *Bji*dhen layer has dried, exhibited through crack formed, apply the second coat of plaster, referred to as *Zhungdah*. This coat of plaster is primarily meant for leveling purposes. Allow several days for this coat of plaster to dry.

6. Application of *Dacha*: The final coat of *Bji*, referred to as *Dacha*, is then applied. The soil used for the final coat must be thoroughly sieved to remove any large particles, debris, and impurities. This will ensure that the plaster has a uniform texture and will be less likely to crack or flake. Once the plaster is applied, remove any entrapped air using a wooden stick. Finally, using a river stone with a flat surface, give the plaster a smooth finish.

Figure 32: Removal of entrapped air (left) and rubbing the wall plaster using a river stone with flat surface (right)

7. **Finish:** The plaster shall be finished to a true and plumb surface and to the desired degree of smoothness as required for *Bji*. The work shall be tested frequently as the work proceeds with a true straight edge not less than 2 meters long and with plumb bobs. All horizontal lines and surfaces shall be tested with a level and all jambs and corners with a plumb bob as the work proceeds.

8. **Thickness:** The average thickness of the plaster shall not be less than the specified thickness.

9. **Curing:** Traditional *Bji* are air-dried, without the use of artificial curing methods. Natural ventilation is preferred for drying the wall plasters. However, if the location and weather conditions are not favorable, rooms may be smoked to help the plaster dry.

Measurement: Length and width should be measured to the nearest 10 mm and the area should be calculated in square meters to two decimal places.

Deductions for openings: No deduction will be made for openings or ends of *Cham*s, beams, posts, etc. up to 0.5 square meters in area. No additions will be made for jambs, soffits, and sills of such openings. This procedure will apply to both faces of the wall. For openings (doors, windows, etc.) that exceed 0.5 square meters but do not exceed 3 square meters each, deductions will be made for reveals, jambs, soffits, sills, etc. of these openings.

Rate: The rate shall include the cost of labor and materials involved in all the operations described above.

PL2002 - Providing, repairing and consolidation of damaged Bji (Mud plaster) on masonry wall including removal of damaged Bji and disposal of debris within 200m lead

Description:

The application of *Bji* follows the same procedure as specified above, with the additional task of dismantling the damaged plaster. The process of application and measurement of *Bji* also follows the same as MP01, but the rate should include the dismantling work and disposal of unserviceable materials within 200 meters.

Measurement: Length and width of the repaired part should be measured to the nearest 10 mm and the area should be calculated in square meters to two decimal places.

Deductions for openings: No deduction will be made for openings or ends of *Chams* (Joist), beams, posts, etc. up to 0.5 square meters in area. No additions will be made for jambs, soffits, and sills of such openings. This procedure will apply to both faces of the wall. For openings (doors, windows, etc.) that exceed 0.5 square meters but do not exceed 3 square meters each, deductions will be made for reveals, jambs, soffits, sills, etc. of these openings.

Rate: The rate shall include the cost of labor and materials involved in all the operations described above.

PL2003 - Providing and repairing of damaged Bji (Mud plaster) on both sides of the Shamig-Dakcha (ekra wall) including removal of existing Bji and disposal of debris within 200m lead

Description:

The *Bji* process for the *Shamig-Dakcha* closely resembles that of any stone masonry wall. Therefore, the procedure for *Bji* remains largely the same as that used for stone masonry walls, with a few key distinctions specific to the providing and repair of *Bji* for Shamig-dakcha:

- Removal of existing *Bji* from the *Shamig-Dakcha* in need of repair.
- The plastering mud must be appropriate for plastering tasks.
- The thickness of the *Bji* should be between 15 to 20 mm on one side.
- Unlike the surface preparation for *Bji* on stone masonry, the surface of the *Shamig-Dakcha* must be thoroughly cleaned and kept moist before plastering begins.

Measurement: The length and width of the repaired part should be measured to the nearest 10 mm, and the area should be calculated in square meters to two decimal places. Measurements are to be taken on only one side.

Rate: The rate includes both labor and materials involved in all the operations described above.

CHAPTER 6: CONSERVATION OF TIMBER COMPONENTS

- *Providing, hoisting & fixing dressed wood work on Chams (joists), including applying wood preservative to unexposed surfaces embedded to the existing masonry wall*

WW2001 - Class 'A', (conifer)

WW2002 - Class 'B', (conifer)

WW2003 - Class 'A', (broad leaf)

WW2004 - Class 'B', (broad leaf)

Description:

Timber *Joists*, commonly referred to as "*Chams*," are part of the flooring system for masonry structures. These structural elements transfer both live and dead loads to the adjoining walls. The size of the *Chams* varies depending on the span of the walls and the load transfer mechanism. The *Chams* can either be embedded into the masonry walls or supported by *Dhung*, which may be spanned across the wall and embedded into the wall or supported by *Kachen* with *Zhu* (capital). The spacing of the *Chams* also varies from 150 mm to 450 mm, depending on the floor level or architectural requirements. However, it is important to ensure that the spacing of the *Chams* is sufficient to meet the deflection and serviceability criteria.

Work specification:

1. Prepare the scaffoldings according to the chapter under Scaffolding and Propping Works.
2. Secure the location of *Cham* insertion. For rammed earth walls, the walls may need to be punctured to accommodate the size of the *Cham* for insertion. In stone masonry, the holes are left during construction, and the wall construction and *Cham* layout occur simultaneously.
3. Ensure that the specified timber is used. The timber is of blue pine, mixed conifer, or hardwood.
4. Fabricate *Chams* with accuracy according to the dimensions provided in the working drawing.
5. Apply a coat of wood preservative to the unexposed surfaces of the *Chams* to protect the *Chams* from rot and decay.
6. The ends of the *Chams* embedded to the wall should not be less than 200 mm.
7. Ensure the *Chams* are accurately aligned and level, and verified by the engineer before continuing with additional work.

Measurement: The length, breadth and height of the *Cham* including embedded part shall be measured nearest to 10 mm. The quantity shall be calculated in cubic meters, rounded to two decimal places.

Rate: The rate shall include the cost of materials and labours described in the item excluding the cost of scaffolding.

- *Repairing the damaged part of Chams (joists), including applying wood preservative to unexposed surfaces embedded to the existing masonry wall*

WW2005 - Class 'A', (conifer)

WW2006 - Class 'B', (conifer)

WW2007 - Class 'A', (broad leaf)

WW2008 - Class 'B', (broad leaf)

Description:

This activity involves a series of work starting from inspection to removal and re-fixing of *Chams* after necessary treatment works. In this task, after the removal of the *Chams* and inspection, the condition of the *Cham* is found to be in good condition, so it does not warrant any repairing works. Therefore, the *Cham* is just treated with wood preservative at the unexposed surfaces and reinstalled to the wall. This activity requires experience and knowledge of the behavior of vernacular load bearing structures.

Work specification:

1. Prepare the scaffoldings according to the chapter under Scaffolding and Propping Works.
2. Secure the location of *Cham* insertion.
3. To ensure *Chams* are removed properly, dismantle the wall sufficiently. Refer to dismantling works for dismantling of walls to remove the *Chams*.
4. Inspect the *Chams* and verify their structural integrity. If any *Chams* require repair, proceed with the specified woodwork.
5. Apply a coat of wood preservative to the unexposed surfaces of the *Chams* to protect the *Chams* from rot and decay.
6. Ensure the *Cham* are accurately aligned and level, and verified by engineer before continuing with additional work
7. Reconstruction of the walls after insertion of the *Chams*. Refer to stone masonry works for wall repairing works.

Figure 33: Conditional assessment of Chams and replacement process

Measurement: The length, breadth and height of the repaired *Cham* shall be measured to an accuracy of 10 mm. The quantity shall be calculated in cubic meters, rounded to two decimal places.

Rate: The rate shall include the cost of materials and labours described in the item excluding the cost of scaffolding.

WW2009 - *Reinstallation of repaired Chams (joists) including hoisting to the existing masonry wall*

Description:

This activity involves re-installation of *Chams* after necessary repair and treatment works are done on the damaged part of *Cham*.

Work specification:

1. Prepare the scaffoldings according to scaffolding and propping works.
2. Secure the location of *Cham* insertion.
3. Ensure the treated *Cham* are accurately aligned and level, verified by the engineer before continuing with additional work

4. Reconstruct the walls after insertion of the *Chams*. Refer to stone masonry works for wall repairing works.

Figure 34: The unpainted Chams were reinstalled

Measurement: The length, breadth and height of the reinstalled *Cham* including embedded part shall be measured to an accuracy of 10 mm. The quantity shall be calculated in cubic meters, rounded to two decimal places.

Rate: The rate shall include only the cost of labour involved.

- *Providing & fixing in position dressed wood works in frames of doors and windows in the existing masonry wall including applying wood preservatives*

WW2010 - Class 'A', (conifer)

WW2011 - Class 'B', (conifer)

WW2012 - Class 'A', (broad leaf)

WW2013 - Class 'B', (broad leaf)

Description:

Heritage structures are irreplaceable sources of inspiration and tangible aspects of cultural heritage that hold immense cultural heritage value. However, they are susceptible to deterioration, particularly in their timber components. To ensure the continuity of these structures and preserve their cultural heritage value, repair and replacement work becomes necessary.

The decision of whether to repair or replace timber components in heritage structures is a challenging one. On the one hand, it is important to maintain the structural integrity of the structure. On the other hand, it is also important to preserve the historical authenticity of the

structure. Experts in conservation architecture, structural engineering, and heritage preservation must carefully assess the extent of the damage to the timber components before making a decision. They will consider factors such as the overall condition of the timber components, the historical significance of the structure, and the impact of potential interventions on its integrity and authenticity.

In cases where the deterioration is severe or irreparable, complete replacement of the timber components may be necessary. However, such replacements must adhere to strict guidelines and be executed with great care. The new timber components should match the original design, materials, and techniques to maintain historical accuracy. Partial repair is often the preferred option, as it allows for the retention of the historic fabric and craftsmanship of the structure. Partial repairs can involve patching or reinforcing weakened sections of the timber components. This approach minimizes disruptions to the overall character of the structure and helps to preserve its cultural heritage value.

By addressing deterioration and making necessary repairs, heritage structures can be safeguarded for future generations. These interventions ensure the continuity and longevity of these irreplaceable treasures, allowing them to continue sharing their stories and enriching our understanding of the past.

Activities

The activities mentioned above involve the replacement of entire wooden components for doors or windows. They include the following tasks:

1. Fabricating the frames of doors and windows following the detailed architectural drawing.
2. Installation of doors and windows in existing masonry wall.

Other specifications:

- Timber: The specified timber shall be used and it shall be sawn in the direction of the grains. The timber shall be planed smooth and accurate to exact dimensions, rebate, rounding, and moulding accurate to drawings.
- Joints: Joints shall be mortise and tenon type, *Phokha-mokha*, *Trangthue*, *Dro*, *Tongthue* and other traditional joinery.it shall fit in accurately without filling. The joints shall be glued, framed, put together, and pinned with hardwood or bamboo wedge not less than 10 mm in diameter.
- Surface treatment: All portions of timber abutting against masonry or embedded in ground shall be painted with approved wood preservative.
- Fixing in position: The frames shall be placed in proper position and secured to walls.

Measurement: The length, breadth and height/thickness of each piece shall be measured nearest to 10 mm. The quantity shall be worked out in cubic meters nearest to two decimal points.

Rate: The rate includes the cost of materials and labour for the fabrication and installation works.

WW2014 - Refurbishment of doors and windows components including sanding, surfacing and patch-filling without disassembling

Description:

For existing timber components in heritage sites, sometimes the timber members deteriorate due to exposure. If the exposed timber members have not suffered significant deterioration and do not require extensive treatment, they are considered sound and durable. In such cases, minor maintenance works are sufficient, including:

1. Use a hard brush to thoroughly clean the surface of the timber member that needs repair.
2. Remove the damaged part.
3. Prepare the new timber patch to the exact size to that of the damaged part
4. Follow up with a soft brush to remove any accumulated dust.
5. Apply the sealant to all sides to ensure complete coverage.
6. Use sandpaper to carefully sand the surface, making it even and smooth.

Measurement: Only the repaired and touched portion of the woodwork will be measured. The area of the damaged portion to be repaired will be measured in square meters.

Rate: The rate includes the cost of materials and labor for all the works mentioned above.

- *Repair of doors and windows components including sanding, surfacing, applying of wood preservative, etc. with disassembling complete*

WW2015 - Class 'A', (conifer)

WW2016 - Class 'B', (conifer)

WW2017 - Class 'A', (broad leaf)

WW2018 - Class 'B', (broad leaf)

Description:

In this task, the timber components need to be completely removed from their original position for refurbishment. Consequently, the work becomes more extensive and requires meticulous planning. The refurbishment process involves the following steps:

1. Numbering of Timber Components: Assign unique numbers to each timber component for easy identification during reassembly.
2. Disassemble Timber Components: Carefully dismantle the timber components, ensuring proper documentation and organization of parts for efficient reassembly.
3. Hard Brush Cleaning: Utilize a hard brush to thoroughly clean the surfaces of the timber components that require repair.
4. Remove the damaged part.
5. Prepare the new timber patch to the exact size to that of the damaged part.
6. Soft Brush Dusting: Use a soft brush to remove any accumulated dust from the timber surfaces.
7. Sealant Preparation and Application: Prepare a sealant mixture using timber, sawdust, and adhesive. Apply the sealant mixture to the damaged areas, ensuring complete coverage for effective restoration.
8. Use of Wedge: use the wedge or pins made from the same timber species.
9. Surface Sanding: Employ sanding techniques to achieve a smooth and even surface, enhancing the visual appeal and functionality of the timber components.
10. Reassemble Timber Components: Carefully reassemble the timber components, following the documented numbering system and ensuring precise alignment.

Before fixing the refurbished timber components back into their original positions, the Engineer or heritage professionals should inspect the completed works and provide necessary clearance. Once the timber components are fixed, it becomes challenging to remove them again for further modifications.

Figure 35: The orange-colored timber elements shows the retained timber components of a Rabsey

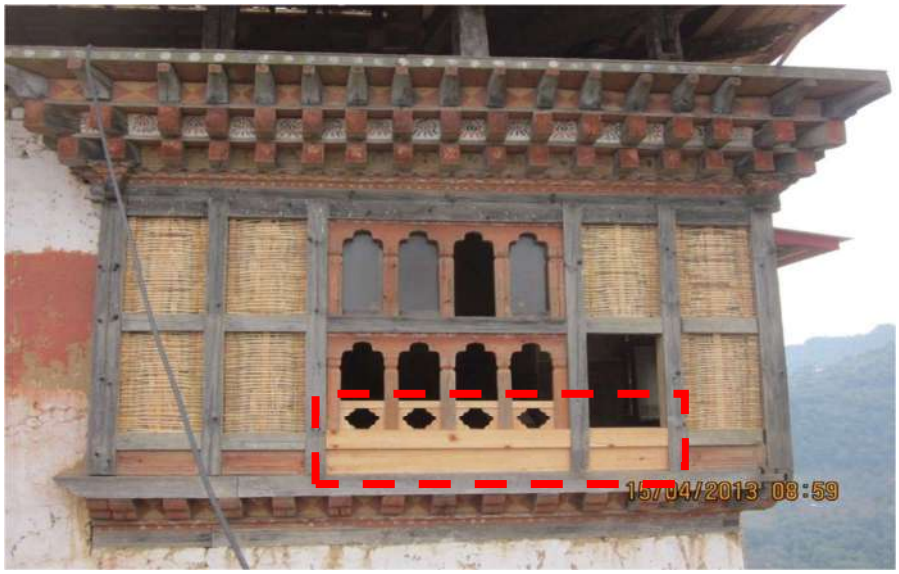


Figure 36: Repaired window components, Thrangcho and Tshegay

Measurement: Only the repaired doors and timber components will be measured. The length, breadth and height of the repaired doors and timber components will be measured to the nearest 10mm. The quantity shall be worked out in cubic meters nearest to two decimal points.

Rate: The rate includes the cost of materials and labor for all the works mentioned above.

- *Reinstallation of timber doors and windows to the existing wall*

WW2019 - Ground floor level (<3.0 sqm surface area)

WW2020 - Ground floor level (3.0 sq.m to 6.0 sq.m surface area)

WW2021 - Ground floor level (> 6.0 sqm surface area)

WW2022 - First floor level and above (<3.0 sqm surface area)

WW2023 - First floor level and above (3.0 sq.m to 6.0 sq.m surface area)

WW2024 - First floor level and above (> 6.0 sqm surface area)

Reinstalling timber components such as doors and windows to an existing stone masonry or rammed earth wall involves several steps to ensure a secure and functional fit:

1. **Assessment**: Before reinstalling the timber components, a thorough assessment of the existing wall and the condition of the components is necessary. This helps identify any damage or deterioration that needs to be addressed before installation.
2. **Preparation**: Prepare the existing wall surface by cleaning it thoroughly and ensuring it is free from any debris or obstacles that could interfere with the installation process. Repair any damaged areas or inconsistencies in the wall surface to create a smooth and stable base for the timber components.

3. **Alignment**: Ensure proper alignment of the door and window frames with the openings in the wall. Use a level and measuring tools to ensure that the frames are positioned correctly and evenly within the openings.
4. **Fixing**: Securely attach the door and window frames to the wall using appropriate fasteners such as screws or anchors. Depending on the design and weight of the components, additional support may be required to ensure stability and structural integrity.
5. **Sealing**: Apply sealant or caulking around the edges of the frames to prevent air or water infiltration and to provide a weather proof seal. This helps enhance the energy efficiency and durability of the installation.
6. **Testing**: Once the timber components are installed, conduct thorough testing to ensure proper operation, including opening and closing of doors and windows, as well as checking for any gaps or leaks. Make any necessary adjustments to ensure a tight seal and smooth operation.
7. **Finishing**: Complete the installation by adding any finishing touches such as trim or moulding around the frames to enhance the appearance and conceal any gaps or imperfections.

For reinstallation to an existing stone masonry or rammed earth wall, careful attention to detail and adherence to best practices for construction and installation are essential to ensure a secure, functional, and visually appealing result.

Figure 37: Reinstalled timber windows on existing wall

Measurement: The reinstallation of timber doors and windows to the existing wall shall be measured in numbers depending on size/area of the openings. The length and breadth of the opening must be measured correctly, allowing for a tolerance of 10mm. It is important to note

that the measurement should include the opening size, incorporating any windows or doors within the wall.

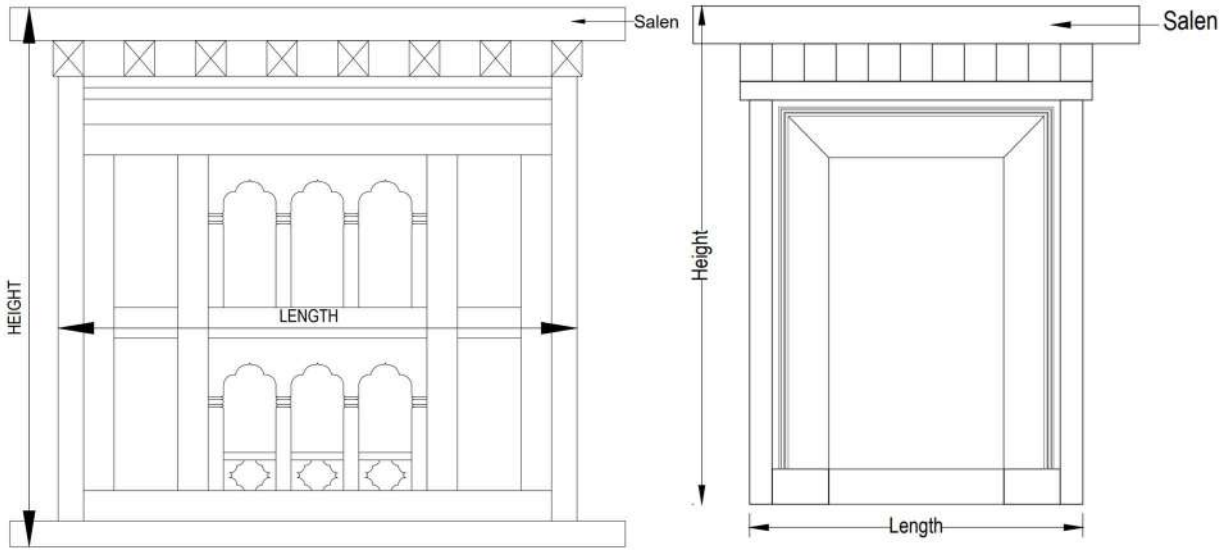


Figure 38: Measurement of timber window and door

Rate: The rate includes the cost of labor only for the operations mentioned above.

- *Providing & fixing in position dressed wood work for Kachen (column), Zhu (capital) and Phue including applying wood preservatives, decorative*

WW2025 - Class 'A', (conifer)

WW2026 - Class 'B', (conifer)

WW2027 - Class 'A', (broad leaf)

WW2028 - Class 'B', (broad leaf)

- *Providing & fixing in position dressed wood work for Kachen (column), Zhu (capital) and Phue including applying wood preservatives, non decorative*

WW2029 - Class 'A', (conifer)

WW2030 - Class 'B', (conifer)

WW2031 - Class 'A', (broad leaf)

WW2032 - Class 'B', (broad leaf)

Description:

Kachen and *Zhu* are integral components of traditional Bhutanese architecture. The more decorated *Kachen* and *Zhu* are typically found in *Dzongs* (fortresses), *Lhakhangs* (temples), and palaces, as well as in the main altar rooms of family homes. Simpler versions, known as Kawa or simple posts, are commonly found in farmhouses.

The term "*Kachen*" is derived from the Dzongkha words "Ka" meaning column or post, and "Chen" meaning large. Thus, *Kachen* refers to a large column. While *Kachen* designs can vary in shape and form, the four main types commonly found in Bhutan are:

- Square shaped *Kachen*
- 12 corner *Kachen*
- Circular shaped *Kachen*
- Octagonal shaped *Kachen*

On top of the *Kachen*, the *Zhu* is placed as a bow-shaped timber bracket. The *Zhu* serves a structural purpose by supporting the load from the beam above, known as *Dhung*. The selection of the *Zhu* type is not strictly regulated and depends on the intricacy of the surrounding architectural elements. However, care is taken to ensure that the shape and proportions of the *Zhu* are in harmony with the *Kachen*. Bhutanese traditional architecture categorizes *Zhu* into three main types based on the level of intricacy in *Patra* (carvings) and paintings. The three main different categories are the following:

- *GyalpDhen Zhu*
- *Zhu Jaam sam*
- *Langna Drey Zhu*

Figure 39: Kachen (decorative) (left) and Kachen (Non-Decorative) (right)

In this case, the *Kachen* are determined to be beyond repair and require complete replacement. To provide and fix the entire *Kachen* section, the necessary propping to the existing *Dhungs* (beams) should be carefully positioned before removing the entire *Kachen* and *Zhu*. The following steps are then followed:

1. Proper Seasoning and stacking of timber: The timber is appropriately seasoned and stacked to ensure its stability and quality.
2. Fabrication of the timber components: The new timber components are fabricated according to the provided drawings. The joints between the components are

carefully crafted as mortise and tenon joints, ensuring accurate fitting without the need for filling. These joints are then glued and framed together.

3. Application of Wood Preservative: To protect the base of the *Kachen* from moisture, a wood preservative is applied if it comes into contact with a wet surface. Additionally, all portions of timber abutting against masonry or embedded in the ground are painted with an approved wood preservative, including the base of the *Kachen*.
4. Installation: The fabricated timber components are positioned correctly and secured to the base *kadhen* (plinth) and top, ensuring alignment with the established line and level.
5. Removal of propping and disposal of debris: After the work is completed, the scaffolding/ propping is removed, and any debris generated during the process is properly disposed of.

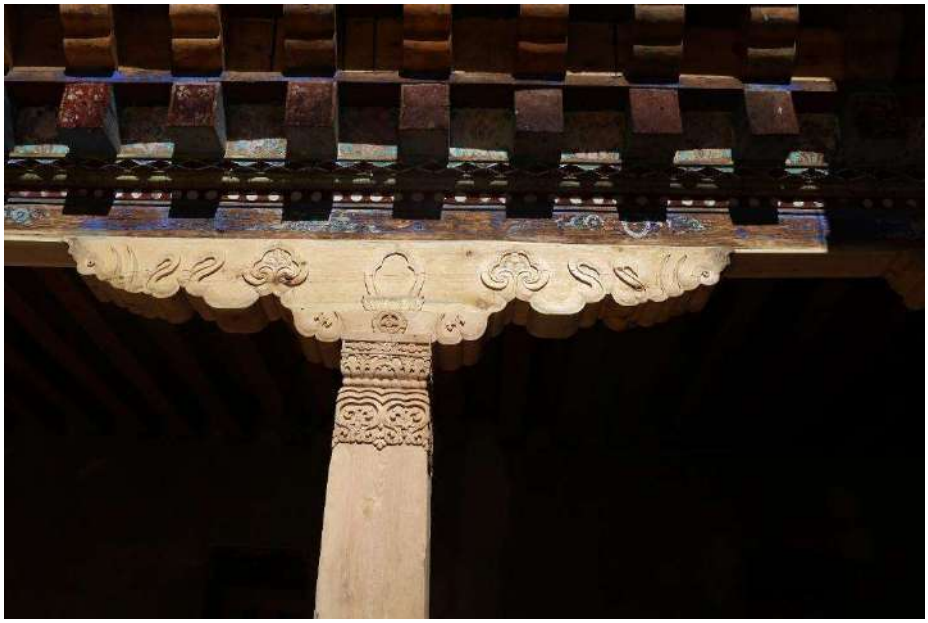


Figure 40: Replaced Kachen, Zhu and Phue with other intact timber components

Measurement: The fabricated timber components shall be measured based on their finished dimensions. The width and depth of *Kachen*, *Zhu* and *Phue* shall be determined by averaging the measurements taken at the lowest, middle, and highest points. The volume of each piece will be measured in cubic meter nearest to two decimal places.

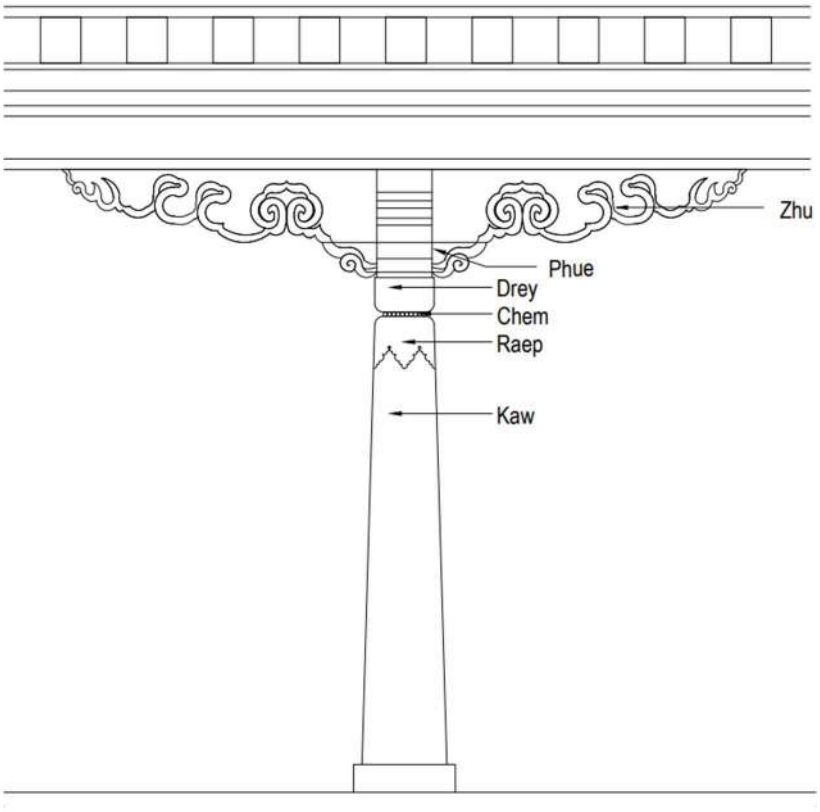


Figure 41: Components of Kachen and Zhu

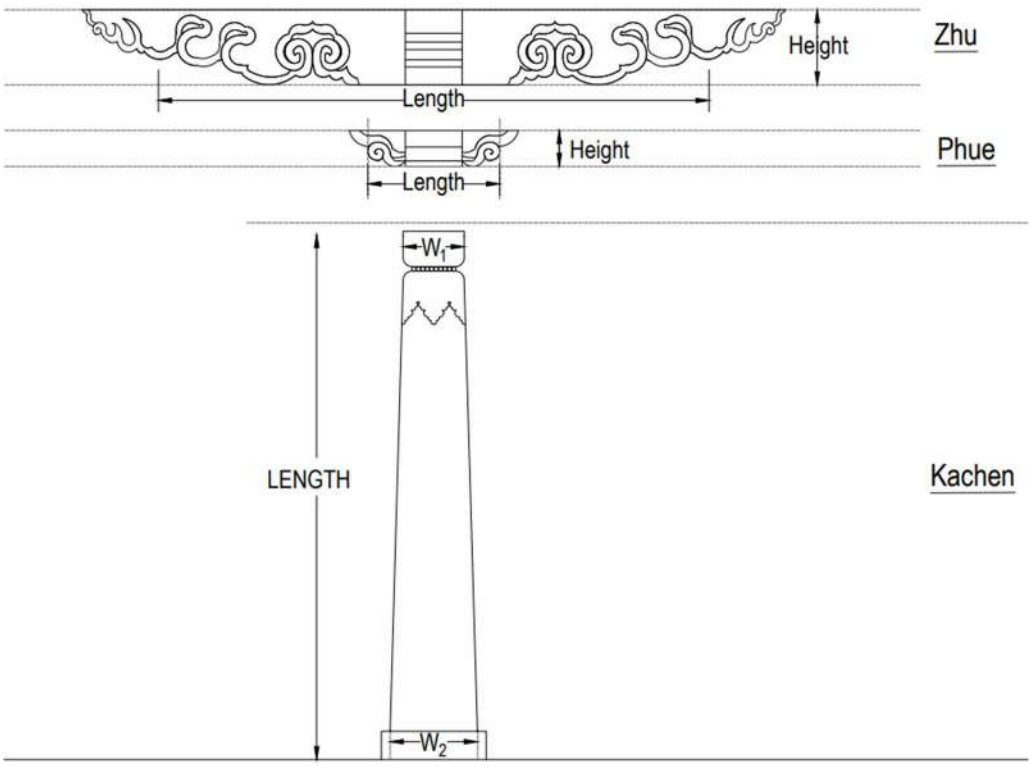


Figure 42: Measurement of Kachen and Zhu

Rate: The rate specified includes the cost of both materials and labor required for all the operations outlined above.

- *Restoring the damaged part of the existing Kachen (column), Zhu (capital) and Phue, including sanding, surfacing and patch-filling in its original position*

WW2033 - Non decorative

WW2034 - Decorative

Description:

Opportunities exist to restore these unique architectural elements without completely changing or replacing them, particularly if the deterioration is not severe. Different types and degrees of damage can affect timber components. In cases where only certain parts of these elements are deteriorated superficially, only those specific portions of timber need to be treated. While it may seem easier to replace damaged timberwork rather than repairing it, opting for repairs holds immense value in preserving the historic fabric, traditional craftsmanship, and techniques involved. By choosing repair over replacement, we can save a significant amount of cultural heritage value, ensuring the retention of essential features and decorative elements.

There are various repair methods and techniques available, depending on the extent of damage. In instances where the damage is minimal, a process involving minimal intervention is employed. This process includes thorough cleaning of the damaged surface and the application of resin filling techniques and patch fillings. The work procedure typically involves the following steps:

1. Cleaning: Thoroughly clean the surface that requires repair with a hard brush to remove any loose debris or dirt that may hinder proper adhesion during the repair process. Follow up with a soft brush to meticulously remove any remaining dust or fine particles. This ensures a clean and smooth surface for the subsequent repair work.
2. Preparation of sealant: Prepare a suitable sealant mixture using timber, sawdust, and adhesive. The combination of these materials helps replicate the composition and texture of the original timber. The precise ratio of the ingredients may vary depending on the specific requirements of the repair work.
3. Patch Filling: Prepare a patching compound using timber shavings or sawdust mixed with adhesive or wood glue. This mixture should closely match the composition and color of the surrounding timber to ensure a seamless repair. Apply the patching compound to fill any larger cracks, holes, or voids in the damaged timber, ensuring a level surface that blends seamlessly with the surrounding wood. Press the mixture firmly into place and allow it to dry completely. Once dry, sand the patched area to smooth out any rough edges and achieve a uniform finish. This step ensures structural integrity and aesthetic consistency throughout the repair process.

4. Curing: Allow the sealant and patching compound to cure and dry for the specified amount of time. This allows the materials to harden and bond effectively with the timber.
5. Finishing: Once the sealant and patching compound have cured, sand the repaired area with sandpaper or a sanding block to gently smooth the surface, removing any excess material and creating a seamless blend with the surrounding timber. Sanding helps achieve a uniform and even finish, ensuring that the repaired section seamlessly integrates with the rest of the architectural element.

This method is particularly important when the damage is minimal, and the restoration process focuses on thorough cleaning, resin filling (sealant), and patching to control the damage. Structural integrity and condition are closely monitored throughout the process.

Measurement: The woodwork is measured based on the repaired damaged portion. The length and breadth shall be measured correct to 10mm. The area of the damaged portion to be repaired is measured in square meters correct to two decimal places.

Rate: The rate for the repairing work includes all costs related to materials and labour.

- *Repair and replacement of the damaged part of Kachen (column) and its components including sanding, and surfacing, non-decorative*

WW2035 - Class 'A', (conifer)

WW2036 - Class 'B', (conifer)

WW2037 - Class 'A', (broad leaf)

WW2038 - Class 'B', (broad leaf)

- *Repair and replacement of the damaged part of Kachen (column) and its components including sanding, and surfacing, decorative*

WW2039 - Class 'A', (conifer)

WW2040 - Class 'B', (conifer)

WW2041 - Class 'A', (broad leaf)

WW2042 - Class 'B', (broad leaf)

Description:

The nature and extent of damages to *Kachen*, *Zhu* (capital), and *Phue* can vary. In such cases, the damaged or deteriorated portion of the component is removed and replaced with a new element that seamlessly blends with the existing structure. When undertaking repairs and replacements, the following considerations are important:

1. **Timber Choice**: Selecting the correct type of timber is crucial for any repair. The new and old timber junction will expand and contract based on temperature, moisture

content, and grain direction. Therefore, it is essential to choose a similar type of timber with matching grain direction to ensure compatibility and minimize future issues.

2. **Technique:** Employing similar repair techniques as the original construction is essential. It is crucial to have experienced craftsmen carry out the repair work under the supervision of heritage professionals, ensuring that traditional techniques and methods are faithfully followed.
3. **Joining:** Utilize traditional Bhutanese carpentry jointing techniques, such as mortise and tenons, splices, bridle joints, and other suitable joineries. Discreetly positioned dowels can also be used, nearly invisible along the edges of the repaired pieces. Modern interventions like using stainless steel screws or other corrosion-resistant materials are rarely employed in Bhutanese carpentry.

During the repair process, adherence to safety protocols and skilled workmanship is of utmost importance. The following steps are typically followed:

1. Provide stable propping to safely remove the components and provide support to existing elements.
2. Carefully assess the damage and accurately cut off the damaged portion.
3. Fabricate the replacement portion to match the original design.
4. Fix the fabricated portion securely to the existing component, employing appropriate joinery techniques.
5. Ensure the repaired component is positioned correctly, aligning it with the original structure.
6. Perform necessary alignment and finishing work to achieve a seamless integration of the repaired and existing elements.

Figure 43: Repair and replacing the deteriorated part of Kachen

Measurement: For measurement purposes, the woodwork is quantified based on the repaired damaged portion, with no allowances for wastage or dimensions beyond the specified requirements. The length and breadth shall be measured correct to 10mm. The area of the damaged portion to be repaired is measured in cubic meters.

Rate: The rate for the repair work includes the cost of materials and labour involved.

WW2043 - Restoration of damaged inner core portion of Kachen (column) including disassembling, refilling, surfacing & reinstallation

Description:

As previously mentioned, the damages to the *Kachen* vary in nature and extent. In cases where the inner core of the *Kachen* has deteriorated while the external fabric remains intact, a reinforcing method is employed to restore its structural integrity. This involves inserting a new timber block into the core of the *Kachen*. The repair process consists of the following steps:

1. Propping: It is crucial to ensure stable propping works are installed to adequately support the existing components and maintain the continuity of the load transfer mechanism. This helps prevent any further damage during the repair process.
2. Removal of *Kachen*: Once the propping is in place, the *Kachen* is carefully removed from its position. This should be done with caution to avoid any additional damage to the surrounding structure.
3. Coring: Skilled craftsmen use traditional tools to meticulously remove the deteriorated inner core of the *Kachen*. It is important to pack the *Kachen* properly using nylon rope or a similar material to maintain its integrity during the repair process.
4. Fabrication of Inner Core: A new inner core is fabricated using hardwood. The craftsmen ensure that the new piece fits precisely into the *Kachen*, matching the required size and shape.
5. Fitting: The fabricated inner core is inserted into the existing *Kachen*. Careful attention is given to ensure a proper fit and seamless integration between the new and old components. Application of Sealant: A sealant mixture is applied to the repaired area, ensuring the new and old timber pieces are securely bonded. This sealant provides additional strength and helps preserve the integrity of the repaired section.
6. Fixing to Original Position: Once the repair is completed, the *Kachen* is fixed back into its original position, aligning it accurately with the rest of the structure. This ensures the restored component maintains its intended functionality.
7. Alignment: Finishing touches are applied to align the repaired *Kachen* with the existing elements. This involves performing necessary alignment and finishing work to achieve a seamless integration, both structurally and aesthetically.

Figure 44: Propping to remove the Kachen (Left) and coring of the inner core of Kachen (right)

Measurement: The length, breadth and height of the inserted timber are measured correct to 10mm. The quantity of the infilled timber shall be measured in cubic meters correct to two decimal places.

Rate: The rate for the repair work encompasses all costs associated with the restoration process. It includes the expenses for materials and labors. The rate also covers the necessary efforts to ensure that the component is fixed back into its original position, maintaining its integrity and functionality.

WW2044 - *Realignment of Kachens (columns) components excluding the cost for propping*

Description:

During the structural assessment of heritage sites, it is crucial to thoroughly examine the load transfer mechanism and observe the load factor. This assessment helps determine the stability and condition of the structure. In structures with substantial walls, stability is generally maintained, and damages are typically concentrated in the walls. However, in larger structures *Kachens* are utilized to create more spacious rooms. The number of *Kachens* varies depending on the size of the room.

When assessing structures with *Kachens*, it is important to evaluate their alignment and how the loads are distributed. Proper functioning of the load transfer mechanism ensures the structural fitness of the building. However, this is just one aspect of the assessment process. Sometimes, *Kachens* may be found leaning or out of plumb. This misalignment could be a result of excessive loading on the floor above or settlement issues. It is essential to identify the underlying cause of this misalignment. Based on the examination, the solutions may involve adding more *Kachens* or realigning the existing ones.

The task at hand involves the realignment of the *Kachens* to ensure they are vertically aligned with plumb. The work process comprises the following steps:

1. Propping: Prior to the realignment, stable propping is provided to the flooring system and other adjoining structures connected to the *Kachens*. This propping ensures the safety and stability of the surrounding elements during the realignment process.
2. Realignment Process: Once the necessary propping is in place, the *Kachen* components are carefully adjusted to achieve vertical alignment. The loads are transferred to the propping system during this process to maintain structural integrity.
3. *Kachen* Adjustment: The realignment of the *Kachens* is achieved by moving and adjusting the *Kachen* components to their proper positions. Careful attention is given to ensure the alignment is precise and accurate.
4. Propping Removal: After the realignment is completed, the propping is removed. It is essential to ensure the integrity of the timber elements and verify that they have been restored to their intended condition.

Measurement: For measurement purposes, the realignment of *Kachens* is quantified based on the number of *Kachens* that have been successfully realigned.

Rate: The rate for this task includes the cost of all labor costs.

- *Providing & fixing in position dressed wood work for Dhung and applying wood preservative to unexposed surfaces*

WW2045 - Class 'A', (conifer)

WW2046 - Class 'B', (conifer)

WW2047 - Class 'A', (broad leaf)

WW2048 - Class 'B', (broad leaf)

Description:

The *Dhung* is a crucial transverse beam that spans the length of a wall, providing structural support. It is essential to ensure the *Dhung* is in good condition. The following outlines the process for fabricating and installing a new *Dhung*, focusing on proper installation techniques for optimal results.

Work Process:

- **Fabrication**: Based on the architectural drawings and specifications, the new *Dhung* will be meticulously fabricated using the specified timber. Skilled craftsmen will ensure precise measurements and adhere to the required design details, replicating the original *Dhung* accurately.

- **Installation**: During the installation process, utmost care will be taken to ensure a perfect fit and alignment. The following steps will be followed for a successful installation:
  a. Plumbing and Leveling: The new *Dhung* will be installed using a plumb line and level to ensure it is perfectly aligned vertically and horizontally. This meticulous process guarantees that the *Dhung* is straight and level within the wall structure, promoting stability and aesthetics.
  b. Insertion into Walls: The new *Dhung* will be inserted into the walls with proper bedding. This involves securely placing the *Dhung* in its designated location, ensuring it fits snugly and integrates seamlessly with the surrounding structures. Skilled craftsmen will take care to achieve a precise fit, facilitating a strong and reliable connection.
  c. Adequate Support: Proper propping and support will be provided during the installation process to maintain the stability of the *Thinzhi enta* and surrounding components. This precautionary measure safeguards the structure and prevents any additional damage during the repair work.
  d. Moisture Protection: The ends of the *Dhung* will be treated with suitable adhesives to protect against moisture and potential timber deterioration. This sealing process ensures the longevity and durability of the *Dhung*, reducing the risk of damage over time.

Measurement: The length, breadth and depth of the *Dhung* will be measured to the nearest 10 mm. The cubic contents will be calculated accurately to two decimal places.

Rate: The rate will encompass all the work described in the item, including materials and labor.

WW2049 – Providing and repairing of Dhung, Norbu Horzhu, Bagam and Pem Choetse without removal from the original position (Patch work), including hoisting, applying wood preservative on unexposed surfaces

Work process:

- **Timber Selection**: The species of the same kind of timber should be chosen and fabricated to accurate dimensions as indicated in the working drawing, following the damage assessment report.
- **Removal of damaged:** timber components: The work requires highly skilled technique to cut and remove the damaged portion with minimized disruption to the adjoining components.
- **Fabrication**: Based on precise measurements, the damaged sections of the *Dhung* will be meticulously replicated through the process of fabrication. Great care will be taken

to reproduce the original components, ensuring they match the exact design, form and species of timber.

- **Fixing**: Utilizing traditional skills, the newly fabricated parts will be expertly integrated to replace the damaged sections of the timber components. This meticulous process ensures a seamless integration of the new parts with the existing structure. Traditional joinery techniques will be employed to ensure a perfect connection between the components.
- **Sealant Application**: A sealant mixture will be prepared by combining timber, sawdust, and an adhesive. This blend of materials is commonly used to create a durable and effective sealant for wooden components. The sealant mixture will be carefully applied to the repaired areas, effectively filling any cracks, gaps, or damaged sections. This step is crucial for restoring the structural integrity of *Dhung*, *Norbu Horzhu*, *Bagam* and *Pem Choetse*.

Measurement: The length and breadth of woodwork is measured correct to 10mm. The area of the damaged portion to be repaired is measured in square meters correct to two decimal places.

Rate: The rate for the repairing work includes all costs related to materials and labour.

- *Providing, repairing & installation of Dhung with disassembly from the wall, including hoisting, applying wood preservative on unexposed surfaces*

WW2050 - Class 'A', (conifer)

WW2051 - Class 'B', (conifer)

WW2052 - Class 'A', (broad leaf)

WW2053 - Class 'B', (broad leaf)

Work process:

- **Timber Selection**: The species of the same kind of timber should be chosen for *Dhung* and is fabricated to accurate dimensions as indicated in the working drawing, following the damage assessment report.
- **Removal of *Dhung***: special consideration should be given during the removal of existing *Dhung* to minimize disruption to the adjoining wall and flooring components.
- **Fabrication**: Based on precise measurements, the damaged sections of the *Dhung* will be meticulously replicated through the process of fabrication. Great care will be taken to reproduce the original components, ensuring they match the exact design and form.
- **Fixing**: Utilizing traditional skills, the newly fabricated parts will be expertly integrated to replace the damaged sections of the *Dhung* components. The Traditional joinery

techniques will be applied to ensure a seamless integration of the new parts with the existing structure.

- **Sealant Application**: A sealant mixture will be prepared by combining timber, sawdust, and adhesive. This blend of materials is commonly used to create a durable and effective sealant for wooden components. The sealant mixture will be carefully applied to the repaired areas, effectively filling any cracks, gaps, or damaged sections. This step is crucial for restoring the structural integrity of the *Zhu* (capital) and *Phue* components, thus preventing further damage.
- **Installation**: Once the sealant has been applied and allowed sufficient time to dry or cure, the installation process will proceed, ensuring the newly repaired sections are aligned accurately and leveled. The Engineer's approval will be obtained before proceeding with further work. Additionally, the unexposed surfaces of the *Dhung* will be coated with wood preservative to enhance their longevity.

Measurement: The length, breadth and depth of the *Dhung* will be measured to the nearest 10 mm. The cubic contents will be calculated accurately to two decimal places. These measurements will be carried out specifically for the replaced or repaired part, rather than the entire length of the *Dhung*.

Rate: The rate will encompass all the work described in the item, including materials and labor.

- *Providing & fixing in position dressed wood work for Pem Choetse including applying wood preservatives*

WW2054 - Class 'A', (conifer)

WW2055 - Class 'B', (conifer)

WW2056 - Class 'A', (broad leaf)

WW2057 - Class 'B', (broad leaf)

Description:

The *Pem* and *Choetse* are two decorative elements that are often found together in Bhutanese architecture. The *Pem* is a painting of a lotus flower, while the *Choetse* is a carving of a stack of prayer books. They are usually placed over the *Dhung* (beam) and below the *Bogh* and *Phana* components. In some cases, the *Pem* is used without the *Choetse*. And when the *Pem* and *Choetse* are used to decoratively frame a door or window, they can be installed around the door or window without the *Dhung*. In this activity, the *Pem* and *Choetse* are fabricated using the specified timber and architectural design, and then placed at the designated location.

Minimum width of *Pem* and *Choetse* is 250mm

Measurement: The measurement shall be taken along the length of the *Pem Choetse* at the specified level along the line of junction of the *Pem Choetse* in running meter correct to 10mm. Measurements are to be taken on only one face.

Rate: The rate shall include all work described in the item including materials and labour. The rate shall cover for both faces.

- *Providing & fixing in position dressed wood work for Norbu Horzhu and Bagam including applying wood preservatives*

WW2058 - Class 'A', (conifer)

WW2059 - Class 'B', (conifer)

WW2060 - Class 'B', (conifer)

WW2061 - Class 'B', (conifer)

Description:

The *Norbu Horzhu* is an element typically found in traditional architecture, specifically carved or painted on a timber block. It consists of three Norbu, which are symbolic of precious jewels, framed together by three curved motifs. These Norbu are framed together by three curved motifs. In architectural design, the *Norbu Horzhu* is often installed as a component alongside the *Pem Choetse*. Its placement is typically at the top of the *Rabsey*, which is an architectural feature in traditional buildings. However, in religious structures, the *Norbu Horzhu* can also be positioned below the *Rabsey*, depending on whether *Bogh* layers are used instead of *a Tsechu-khanyim*. The *Norbu Bagum* is a set of interlocking square timber bracket components like an intricate inverse mountain block of jutting cubes, placed above the *Norbu Horzhu*.

Measurement: The measurement shall be taken along the length of the *Norbu Horzhu* and *Bagam* in running meter correct to 10mm. Measurements are to be taken on only one face.

Rate: The rate includes the item including materials and labour. The rate shall cover for both faces.

- *Providing & fixing in position dressed wood work*

WW2062 - Bogh single layer

WW2063 - Bogh double layer

WW2064 - Phana/Phuto boow including Phakhep complete

Description:

Bogh and *Phana* are traditional Bhutanese cornices (*Gucha*). The *Bogh* is a projection of the *Cham (joist)*, an interior timber *Chams* for ceiling or upper floor levels that are set to project

outside the wall as *Gucha* (Cornice). The *Phana*, on the other hand, is a timber *Gucha* shaped like a pig's nose or neck of a duck, it is laid over the *Bogh*. The *Bogh* and *Phana* are typically laid over the *Rabsey*, which is a decorative element that consists of the elements *Pem*, *Choetse*, *Bogh*, *Boghkhep*, *Cham*, *Chamkhep*, *Phana*, and *Phanakhep*. On most traditional old buildings, only one layer of *Bogh* and *Phana* are used in a *Rabsey*. However, the double layer of *Bogh* and *Phana* was found mainly in *Dzongs* (fortresses). The *Bogh* and *Phana* elements are also laid over traditional windows, doors, and sometimes *Kachen (column)* and *Zhu* (capital).

The *Gucha*, whether it consists of a single layer or double layer at each floor level, must adhere to the approved design in all respects. This requirement extends to the *Phana* as well. It is crucial to ensure that the dimensions, rounding, and moulding of the *Gucha* are uniform throughout its entire length. This uniformity contributes to the aesthetic harmony of the structure. Furthermore, the *Gucha* must be installed with precision, maintaining true line and level to ensure a visually pleasing and structurally sound result.

Figure 45: (a) Single Bogh layer, (b) double Bogh layer, (c) Phuto boow with Phakhep

Measurement: The measurement of the length shall be taken along the junction of the *Gucha* and wall corrected to 10mm. Measurements of the *Gucha* shall be taken at each floor level along the line of the *Gucha* in running meter correct to 10mm.

Rate: The rate shall include all work described in the item including materials and labours.

- *Providing & fixing in position dressed wood work for Langna Drey Zhu complete including applying wood preservatives*

WW2065 - In class 'A', (conifer)

WW2066 - In class 'B', (conifer)

WW2067 - In class 'A', (broad leaf)

WW2068 - In class 'B', (broad leaf)

Description:

The *Langna Drey Zhu* is a timber element that extends as a cantilever from the walls and provides support for the *Rabsey* and other components located above. It plays a vital role as an important structural element by effectively transferring loads to the walls. Therefore, it is essential that the *Langna* is securely embedded into the main structural walls, and all three elements (*Langna*, *Drey* and *Zhu*) are interconnected with proper joinery and connection systems. In more intricate designs, the *Langna* can be replaced by *Gyetsa*, which takes the form of mythical animal heads.

When repairs or replacements are required for the *Langna Drey Zhu*, it becomes necessary to remove them from their positions. To remove the *Langna Drey Zhu*, the walls into which the *Langna* is inserted will be carefully dismantled to a suitable extent. This strategic dismantling allows for the safe extraction of the *Langna* and associated elements, minimizing the risk of damage to the surrounding structures. Based on the provided design specifications and drawings, skilled craftsmen shall fabricate a new Drey *Zhu* using the specified timber and employing precise joinery techniques. After the fabrication process is complete, the newly crafted *Langna Drey Zhu* shall be installed back into their exact locations. Any necessary repairs to the walls will be undertaken, restoring them to their original condition. This ensures that the newly installed elements blend harmoniously with the rest of the structure. Once the *Langna Drey Zhu* and associated elements are securely in place, the propping and support systems can be safely removed.

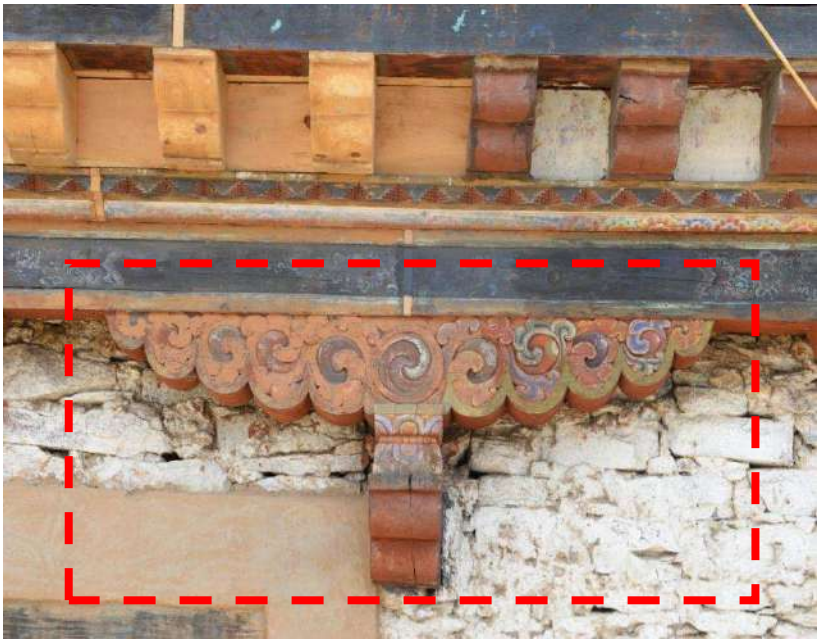


Figure 46: Langna Drey Zhu

Measurement: The length, breadth and height of the woodwork, specifically the wrought frames will be measured nearest to 10mm. The cubic content shall be calculated nearest to two decimal places.

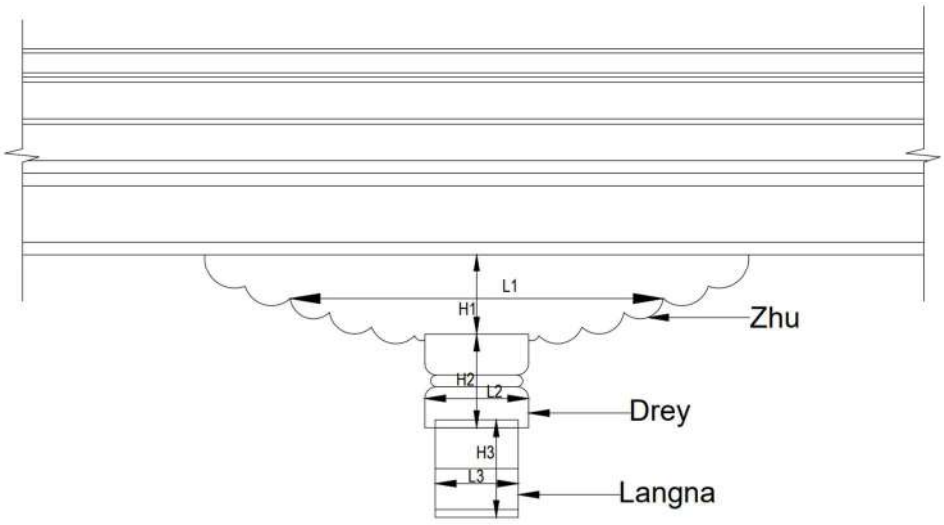


Figure 47: Measurement of Langna Drey Zhu

Rate: The rate shall include all work described in the item including materials and labour.

- *Providing, making and fixing dressed woodwork in traditional Tshegay 25mm to 75mm thick as per architectural drawing complete*

WW2069 - In class 'A', (conifer)

WW2070 - In class 'B', (conifer)

WW2071 - In class 'A', (broad leaf)

WW2072 - In class 'B', (broad leaf)

Description:

The fabrication process for the *Tshegay* will adhere to the provided architectural drawing and design, utilizing the specified timber components. During fabrication, great care will be taken to ensure that the dimensions, rounding, and mouldings of the *Tshegay* are consistent and uniform throughout its entire length.

Measurement: The length and breadth shall be measured nearest to 10mm. The area IN square meter shall be calculated correct to two decimal places. The embedded part will not be considered for the measurement.

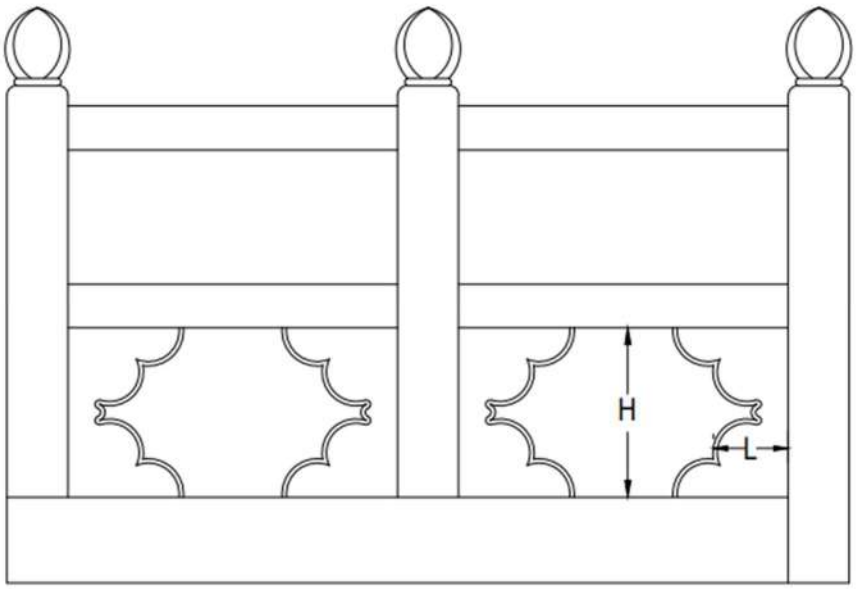


Figure 48: Measurement of Tshegay

Rate: The rate shall include all work described in the item including materials and labour.

- *Providing & fixing 50mm thick, half-lapped Thinzhi enta (Timber flooring) / Nampa enta (Ceiling plank) including fixing with iron screws etc. complete, excluding the cost of frame*

WW2073 - Class 'A', (conifer)

WW2074 - Class 'B', (conifer)

- *Providing & fixing 75mm thick, half-lapped(wider) Thinzhi enta (Timber flooring) / Nampa enta (Ceiling plank) including fixing with iron screws etc. complete, excluding the cost of frame*

WW2075 - Class 'A', (conifer)

WW2076 - Class 'B', (conifer)

Description:

The timber flooring with specified thickness, 50 mm and 75 mm, are placed on top of the *Cham* (supporting joists) overlain by *Nampa enta* and *Satha* (mud fillings). The work process involves the following:

- The timber boards shall be planed true on the top face only, unless otherwise specified in the description of the item.
- Jointing works: The longitudinal joints of planks shall be half lapped for a width of 12 mm or more, while the heading joints shall be of the square butt type and shall occur over the centerline of the supporting *Chams*. Heading joints in adjacent boards shall not be placed over the same *Chams*. Otherwise, the joints shall be properly executed on the leveled mud fillings.

- Fixing: The joints on which the planks shall be fixed shall be checked and corrected to levels. The end boards shall be accurately fixed with the sides parallel and close to the walls. Each adjoining board shall be carefully jointed and shall be tightened in position and fixed with screws. The floors should be fixed using iron screws of the slotted countersunk head type or nails, of length greater than the plank thickness plus 25 mm, with a minimum length requirement of 40 mm.
- Finishing: The surface of the floor shall be waxed or finished otherwise as specified in the work specification.

Figure 49: Laying of Thinzhi enta (left) and finished Thinzhi enta (right)

Measurement: The length and breadth of the finished work shall be measured to the nearest 10 mm. The area shall be calculated in square meters to two decimal places.

Rate: The rate shall include the cost of the labour and materials involved in all the operations described above.

WW2077 - Repairing and fixing of existing Thinzhi enta (Timber flooring) /Nampa enta (Ceiling plank) including cleaning, sanding, etc. complete

Descriptions:

In many heritage sites, the existing timber floor boards are often in good condition, but there are unevenness and defects caused by extensive use. When these issues are not related to structural deformations in the underlying timber *Chams* (joists), it is possible to repair the wooden flooring. Here is a clear and corrected step-by-step process:

- Carefully dismantle the timber floor boards and store them properly.
- Inspect each timber board for warping, damage from insect attacks, or dampness.
- Based on the assessment, if the timber shows warping, planning is necessary. If the damage is concentrated in certain areas, those affected sections should be cut off and replaced with similar timber species. If the damage is beyond repair, the timber boards should be discarded.
- Level the existing sand/mud bedding.

- Finally, place the timber boards back in position and secure them using the same technique specified in WW0033. Finish the boards as per the prescribed specifications.

In this activity, the objective is to reuse the existing floor boards to the fullest extent possible and only replace them when the damage is beyond repair.

Figure 50: Timber flooring using repaired floor boards

Measurement: The length and breadth of the finished work shall be measured to the nearest 10 mm. The area shall be calculated in square meters to two decimal places.

Rate: The rate shall include the cost of the labour and materials involved in all the operations described above.

CHAPTER 7: *PATRA* (CARVING WORKS)

- *Traditional Carving on the fabricated timber components, excluding the cost of timber*

CR2001 - Rab (hard wood)

CR2002 - Ding (hard wood)

CR2003 - Thama (hard wood)

CR2004 - Rab (soft wood)

CR2005 - Ding (soft wood)

CR2006 – Thama (soft wood)

Description:

Traditional Bhutanese timber carving (*Patra*) is a meticulous craft practiced on mainly two types of wood: hardwood and softwood.

Classification:

Patra in Heritage conservation works are classified into three categories namely *rab*, *ding* and *thama* depending on the intricacies of the elements.

Rab: *Patra* of animal and bird figures/ statues

Ding: *Patra* of flower/ *Norbu Chadhuen*/ *Tashi Zegay*

Thama: *Patra* of *Bjana chari*/ letters/ *Lenza*/ *Urung*

Figure 51: Rab - Dragon Patra on Kachen Choesham

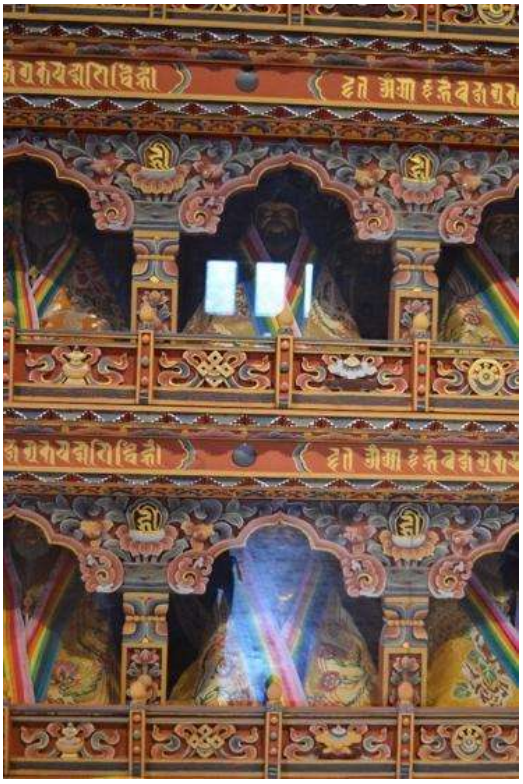


Figure 12: Ding - Flower and Tashi Zegay Patra on

Figure 2: Thama - Lenza Patra on Rabsey

Preparation of surface:

Wooden Surface: The woodwork to be carved shall be dry and moisture content should be less than 10%. The surface shall be thoroughly cleaned. All unevenness shall be rubbed down smooth and shall be well dusted.

***Remoo/Tsakpar*:**

The desired designs to be carved are transferred onto the surface using a technique called *Tsakpar*. Adjust the paper to the surface to be carved, draw the design on the paper, and prick the lines of design by a pin. Place the paper back to the surface to be carved and rub the powder soaked cloth on the design paper. When the paper is withdrawn, powder marks are left on the surface which is to be carved for specified *Patra*. This process is continued for carving the required surface.

***Patra* (Carving)**

Artisans use traditional tools to sculpt the wood, bringing the intricate designs to life across various elements which includes the following members:

1. ***Gucha* (Cornices)**: *Bogh*, Pem, *Norbu Horzhu* and *Dhung* are the elements of *Gucha* for *Patra*.
2. ***Rabsey*:** *Zurchen*/ Zurkaw, *Thrangcho*, *Zing*, *Kachung*, *Tshegay*, *Jugshing* and all elements of *Rabsey*.
3. ***Kachen* (*Kazhi-Dhungzhi*)**:
    - Kachen (column): *Pem*, *Chem* and *Reb*, *Gong*, etc.
    - *Phue*: *Churi* and *Norbu Chadhuen*, *Dhenzhu juk*, etc.
    - *Zhu* (capital): *GyalpDhen zhu*, *Tse Patra*, *Reda choekhor*, *Druk khathap*, etc.
    - *Dhung*: *Norbu Chadhuen*, *Tashi Zegay*, *Namta*, *Choepai Lhamo* (protective deities), etc. are the elements in *Kachen* for *Patra*.
4. ***Zhukthri*:** *Norbu-tok*, *Baychen*, *Baychung*, *Pem*, *Khorlo* and *Druk khatab*, etc. are the elements in *Zhukthri* for *Patra*.

Physical Checking:

Physical checking shall be carried out on the quality of *Patra*. The following steps shall be used as thumb rule to check the quality of the completed works:

I. Inspect the depth of the *Patra* and compare with the specified *Patra* depth.

II. Check for any loosely attached or broken piece of timber.

III. Check the *Thobthang* (traditional requirement) of the *Patra* and proportioning with the timber member.

This art form requires patience, precision, and a deep cultural understanding. The resulting *Patra* not only serves decorative purposes but also holds symbolic significance, reflecting Bhutanese heritage and tradition.

Measurements: The length and breadth shall be measured correct to 10mm. The area shall be calculated in square meters correct to two places of decimal.

Rate: Rate shall include the cost of all labour and tools used in *Patra*.

- *Traditional 3D Carving (Drukim) complete, excluding the cost of timber*

CR2007 - Rab

CR2008 - Ding

CR2009 – Thama

Description:

Traditional 3D carving is done on the *Choesham* components (*Kachung* and *Zing*). While *Patra* (carving) techniques remain same, in terms of surface preparation and drawing tsakpa, the main difference lies in their classification as follows:

Rab

This technique involves carving statues such as *Choepai Lhamo* (protective deities), intricate flowers, and leaves separately. These carved elements are then fixed onto the main component, known as *Drukim*. The quality of the carved surface is more detailed and well projected (*lobor* and *khid*). Refer to the following figures.

Figure 3: Drukim - rab

Ding

Ding involves carving designs like *Norbu Chadhuen*, *Doyoen Nga*, and *Tashi Zegay* directly onto the surface of the *Drukim*. The quality of the carved surface is subtle and less projected (*lobor* and *khid*). Refer to the following figures.

Figure 4: Drukim - ding

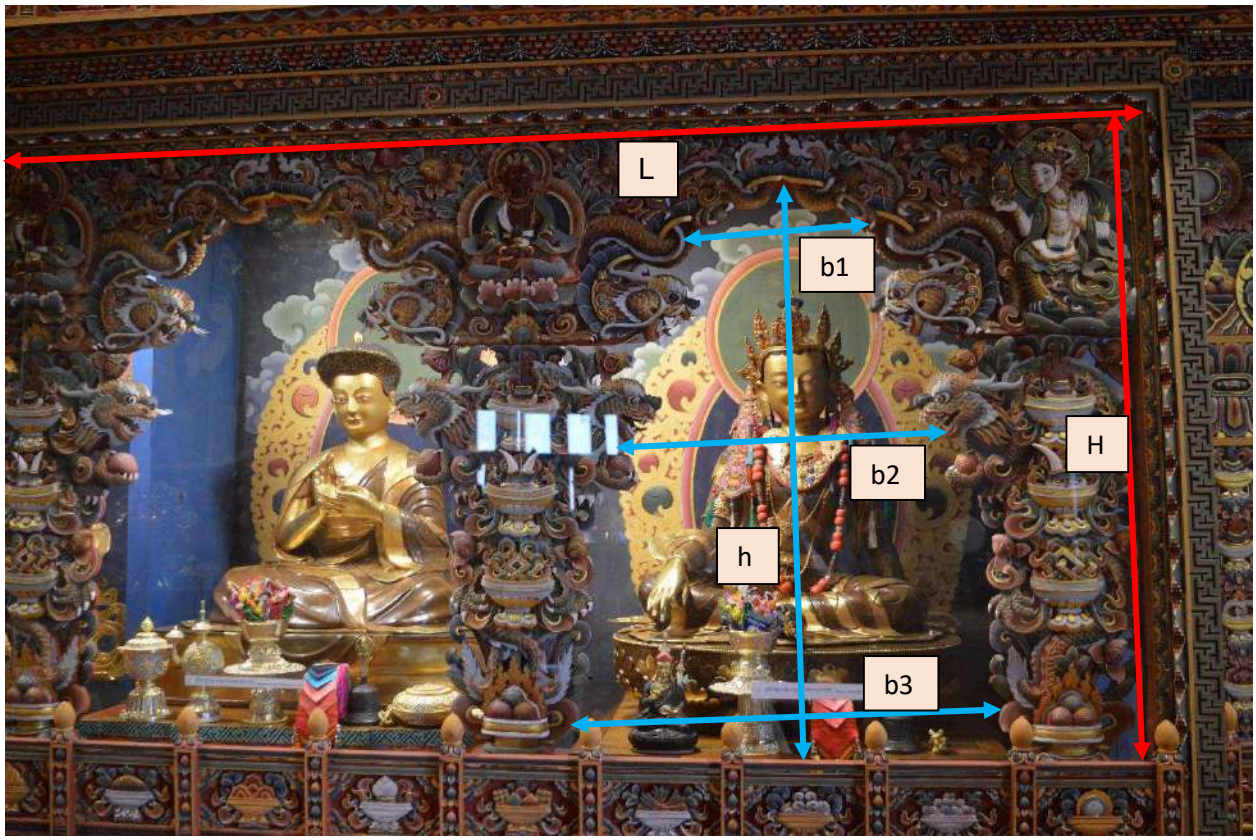
Thama

Thama involves simpler *Patra* where basic floral motifs, leaves, and other decorative elements are carved directly onto the *Drukim*. This technique is characterized by its minimal projection and is often used for more straightforward designs or as a base for more intricate *Patra*. Refer to the following figures.

Figure 5: Drukim - thama

These various *Patra* techniques showcase the rich artistic tradition of Bhutanese woodworking, each method requiring precision, skill, and a deep understanding of the craft's cultural significance.

Measurement: The length and breadth of the whole surface area is to be measured correct to 10mm. The area shall be calculated in square meters correct to two places of decimal. The measurement shall be as per the actual carved deducting the opening surface as illustrated in figure below.



Carved area in above figure = (LxH) – 2*(b1+b2+b3)/3)*h

Rate: The rate shall include the cost of all labour and tools used in *Patra*.

- *Traditional 3D Carving (Masks; Meshang, Chuseng, Singye, etc.) complete, excluding the cost of timber*

CR2010 - size < 0.036sq.m c/s area

CR2011 - size 0.036sq.m to 0.058sq.m c/s area

CR2012 - size > 0.058sq.m c/s area

Description:

Traditional 3D Carving is used in the *Dzongs* (fortresses) and *Lhakhangs* (temples), mostly above the main door and below *Rabsey*. While *Patra* (carving) techniques remain the same,

this kind of *Patra* differs in size and details of *Patra*. These kinds of *Patra* resemble more like a *Patra* of traditional masks used for mask dances, and are always carved fully using one single timber piece.

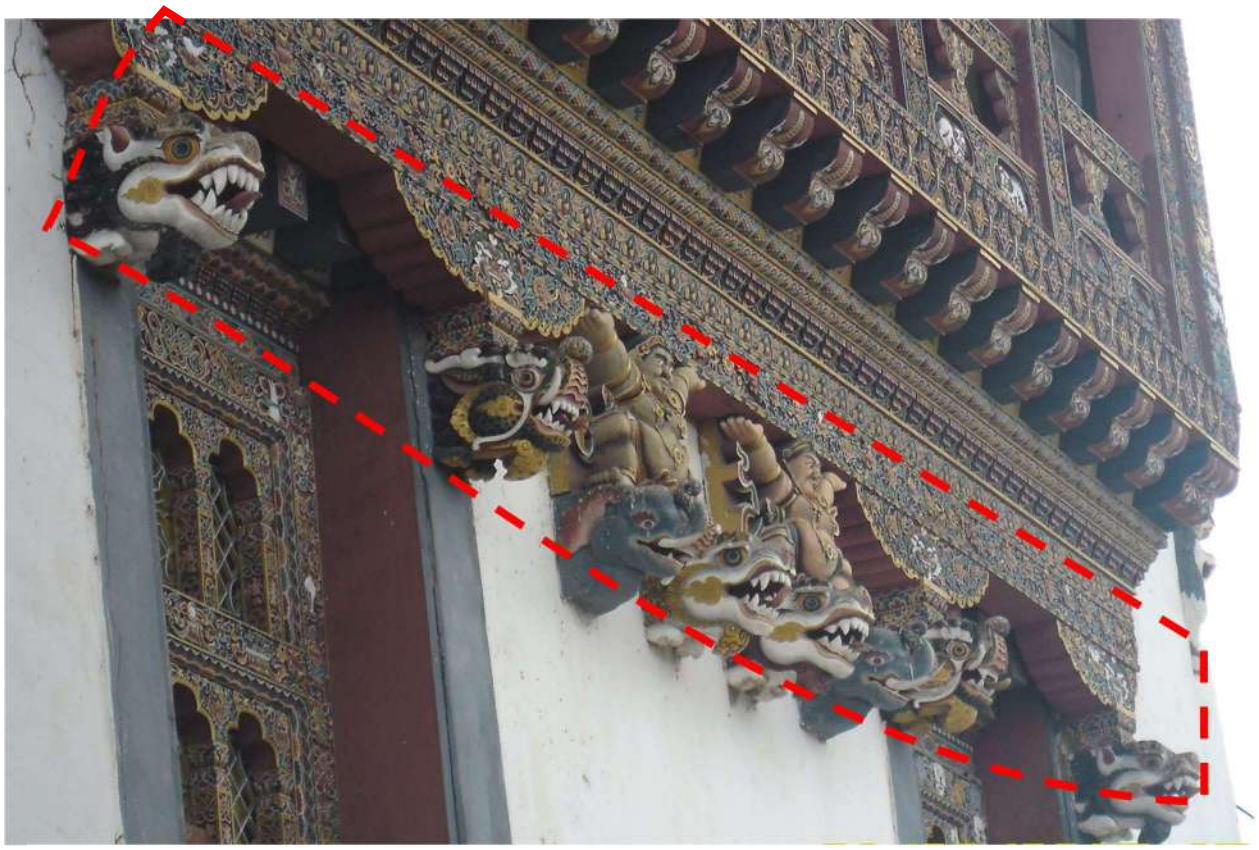


Figure 57: Traditional 3D Carved Masks

Measurement: The traditional 3D Carving shall be measured in numbers depending on size/area of the fabricated members.

Rate: The rate shall include the cost of all labour involved and tools used in traditional 3D *Patra* excluding the timber.

GLOSSARY OF TERMS

Bagam	བ་གམ
Bjana chari	རྫ་ནག་ལྷགས་རི
Bji (Mud plaster)	བྱི་ལ
Bjidhen	བྱི་ལ་གདན
Bogh	བོག
Boghkhep	བོག་ལེབས
Cham (Joist)	ལྕམ
Chem	ལྕེམ
Choepai Lhamo (protective deities)	མཆོད་པའི་ལྷ་མོ
Choesham	མཆོད་བཤམ
Choeten (Stupa)	མཆོད་རྟེན
Churi	ཆུ་རི
Chuseng	ཆུ་སྲིན
Depri (mural paintings)	ལྡེབ་རིས/གྱང་ཐིས
Dhenzhu juk	གདན་གཞུ་མཇུག
Dhung	གདུང་
Door	སྒོ
Doyoen Nga	འདོད་ཡོན་ལྔ
Dro	ཁྲོ
Drukim	འབྲུག་ཀིམ
Dzong (Fortress)	རྫོང་
Foundation	འགྱམ
Gong	གོང་
Gucha (Cornices)	མགུ་ཆ
Gu-shing	མགུ་ཤིང་/མགུ་སྟེལ
GyalpDhen zhu	རྒྱལ་པོ་གདན་བཞུགས
Gyetsa	གྱད་རྩ
Heritage	ཡར་ལྷུན
Hiw (hammerhead)	ཧཱིཝ
Jugshing	རྒྱུག་ཤིང་
Ju-shing	མཇུག་ཤིང་
Kachen (column)	ཀ་ཆེན
Kachung	ཀ་ཆུང་

Kadhen	ཀ་གདན།
Khorlo	འཁོར་ལོ
Langna Drey Zhu	སྣང་སྣ་བྱེ་གཞུ
Lap-do (Regular sized stones)	ལེབ་རྡོ
Lenza	ལེན་ཛ།
Lhakhang (Temple)	ལྷ་ཁང་
Meshang	མེ་ཤང་
Nagtshang (Historical mansion)	ནག་ཚང་
Nampa enta (Ceiling plank)	གནམ་པང་ཨེན་ཏ
Namta	གནམ་ཏ
Nang-do (Inner stones)	ནང་རྡོ
Norbu Chadhuen	ནོར་བུ་ཆ་བདུན
Norbu Horzhu	ནོར་བུ་ཧོར་གཞུ
Norbu-tok	ནོར་བུའི་ཏོག
Padom (Formwork)	པར་སྒོམ
Pa-shing	པར་ཤིང་
Patra (carving)	པ་ཏྲ
Pem Choetse	པདྨ་ཆོས་བརྩེགས
Phakhep	ཕག་ཁེབས
Phana	ཕག་སྣ
Phokha-mokha	ཕོ་ཁ་མོ་ཁ
Phue	ཕུད
Phuto boow	ཕུ་ཏུ་ཝཱུ
Rab Ding Thama	རབ་འབྱིང་ཐ་མ
Rabsey	རབ་གསལ
Rammed Earth wall	ས་ཁྱང་
Reb	རསད
Reda choekhor	རེ་དགས་ཆོས་འཁོར
Remoo	རེ་མོ
Row	རུ་བོ
Salen (Lintel)	ས་ལེན/བཟང་ཤིང་
Satha (Mud insulation)	ས་ཟླག
Shab (wooden wedge)	ཤབ
Shamig-Dakcha (Ekra wall)	ཤག་མིག་འདག་ཐྲེབ
Singye (Lion)	སེང་གེ

Sotee (wedge head)	སོ་བཟྱིར
Stone masonry wall	རྡོག་གྱང་
Tashi Zegay	བཀྲིས་རྩས་བརྒྱད
Thinzhi enta (Timber flooring)	འཐིང་གཞི་ཨེན་ཏ
Thobthang (requirement)	ཐོབ་ཐང་
Thrangcho	ཁྲང་རྩོར
Tongthue	ལྷོང་མཐུད
Trangthue	ཀྲང་མཐུད
Tsakpar	ཚ་གཱ་པར
Tse patra	རྩེ་པ་ཏྲ
Tsechu-khanyim	བཙས་ཆུང་ཁ་གཉིས
Tshegay	ཚེགས་རྒྱན
Urung	གཡུ་རུང་
Window	སྒོ་ཆུང་/པར་གཡབ
Zhu (capital)	གཞུ
Zhu Jaam sam	གཞུ་འཇམ་སམ
Zhukthri	བཞུགས་ཁྲི
Zhungdah	གཞུང་དཀ
Zing	ཟིང་
Zungshing	གཟུངས་ཤིང་
Zurchen	ཟུར་ཆེན
Zur-do (Cornerstone)	ཟུར་རྡོ

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