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# DAMAGE ASSESSMENT OF HISTORICAL BUILDINGS:
## A CASE STUDY OF HISTORIC SHRINE OF MULTAN

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***Abstract-*** Assessment of safety is very important before taking any prevention decision through qualitative and quantitative data. Qualitative information involves visual examination of structural failure, erosion, and damage, and quantitative data includes a measurable quantity such as laboratory testing, numerical methods, etc. The quantitative data is a comprehensive approach to collecting data that requires expertise as well as takes more time and resources. Hence, there is a need to find out effective approaches for examining the damage level of such structures because there are so many historical landmarks and only a few experts in this area. There are guidelines and checklists are available for designing seismic resistance structures especially for current structures including assessing damage level. However, damage assessment before the hazard is still not common for historical buildings and shrines. This research presents the visual inspection practice for the identification of the damage level of the historical masonry buildings. Based on the assessment results, this study will help specialists to design the high-damage buildings towards the visual inspection.

***Keywords***- Historical structures, Masonry, Damage assessment, visual inspection.

## 1 INTRODUCTION

The most significant aspect of cultural identity is historical structures and monuments. The art and cultural importance of such structures is the source of attraction and used by millions of people for a hundred years. Due to this reason, human duty is to protect historical and cultural buildings for new generations. Many of the existing architectural structures are complex because of constructed from masonry works including bricks, blocks, adobe, and mortar. The taxonomy, design, and layout of the structure, the size of the elements/blocks, the choice of building materials depends on the construction time and cost [1]. Historical structures have faced numerous acts during their lifespan over long periods as they suffered from long-term weakening effects and seismic loads. The description of the historical design depends entirely on both construction time and the cultural history to which it originally belongs, as well as the location. Therefore, there is no benchmark set for the assessment of historical structures[2]. The damage assessment of historical structures is required a versatile team of experts, and different approaches. It is very significant to assess and estimate possible damages for historical masonry buildings caused by natural catastrophic events. However, there are structural codes, standards, and guidelines are exist for new constructions such approaches not used in the safety inspection of historical buildings[3]. It is a challenging task to carry out precise damage evaluation of ancient masonry construction. The data based on qualitative and quantitative is important before taking any treatment decision for safety evaluation. Various surveyors have obtained and documented the qualitative data in the literature from a visual examination of structural failure, disintegration, and erosion. The acquisition of quantitative data involves very complex and difficult procedures that require specialists and consume time and resources. Thus, such approaches only worked on a small number of buildings but primarily used in the final phase of the diagnosis and safety evaluation[4]. However, Historic monumental buildings are original. For assessing the safety condition of such structures, it is very important to define and use different methods and strategies. It is necessary to examine each structure component in its state and consider it as a whole in the assessment process while evaluating structural deterioration and damage[5].

This paper presents an approach of visual inspections for evaluating the damage level of monumental heritage buildings in prone situations. This research focuses on the inspection approach based on an acquisition of visual data and the description of the potential consequence of the inspected structure. Since the work in this area mainly focuses on vernacular architecture, this research focuses on domed and vaulted historical monumental masonry structures in Pakistan.

## 2 MATERIALS AND METHODS

A comprehensive methodology has been formulated in the Fig.1 which is formulated based on existing research literature[5, 6] related to historical building damage assessments.

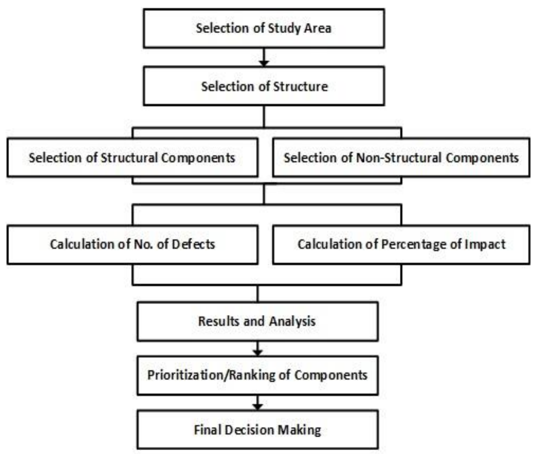



Figure 1. Framework for Research

### *2.1 Study Area*

Shah Ali Akbar was a descendant of Hazrat Shah Shams-ud-Din Sabzwari and 18th in line as one of his great-grandsons whose disciples and descendants inhabited the Suraj Miani village. Suraj Miani is situated to the northwest of Multan and it became quite well known during the Durrani period due to its trade with Kabul. So strong was the relationship between Suraj Miani and Kabul that, the houses of the village imitated the style of Afghani residences. Consequently, the village was often referred to as a "Kabuli Mohallah", (Mohallah of Kabul, Multan Gazetteer, 1926). However, there seems to be some Arab influence on the village as well. A local historian has recorded that the original name of Suraj Miani, "Sura Miani", was derived from Al-Mansura—the name of an Arab cantonment during the Abbasi period. There were once several palaces and gardens in the vicinity which today, have been overrun by the urban sprawl of Multan [7].

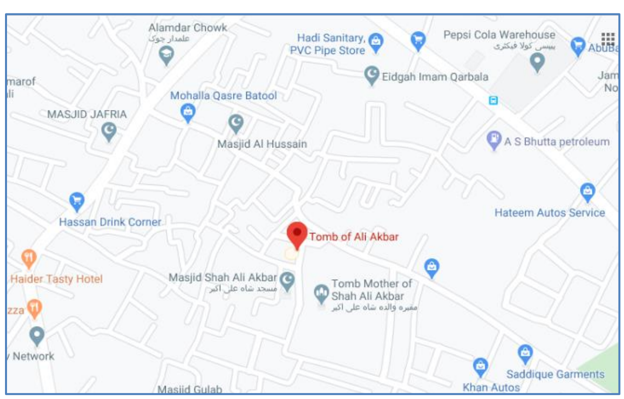


Figure 2: Location Map of Tomb of Ali Shah Akbar

The Shrine is situated adjacent to the graveyard of Suraj Miani, north of the tomb of the Saint's mother as shown in Fig.2. It is surrounded by residences in the north and west and by the unplanned graveyard on the other sides. The site is accessible through a metaled road from the city. It is believed that Shah Ali Akbar's Shrine was built by master builders hired from Lahore, Ahmed Nabi Khan mentions their names as Ibrahim and Rajab, sons of Musa of Lahore. The builders were trained in the traditions of the early Mughal style of architecture and a unique feast of fresco ornamentations is seen on the Shrine which was unknown to the local artists.

Although this shrine is a smaller version of Shah Rukn-e-Alam's shrine, it is richer in faience embellishment and tile inscriptions as shown in Fig.3. It has an octagonal plan, three stories tall and tapering angle buttresses crowned by turrets similar to the Shrine of Shah Rukn-e--Alam. The entire structure is almost 85 feet in height with an external finish of glazed geometric patterned tiles. These are still intact and reflect the development of the Multani style of the blue tile set in brick masonry. The walls have horizontal wooden beams laid within the masonry courses and are decorated with brick designs and tile work. The openings have wooden grills, some of which have been damaged in the second storey and are now blocked by brick masonry. There are arches one above the other with openings set with wooden fretwork screens in the upper two levels. There is a staircase created within the thickness of the wall just adjacent to the entrance that provides access to the roof of the second storey through one of the windows. The floor of the entrance is finished in large square tiles with a glazed design whereas the rest of the floor inside the shrine is finished with bricks on the edge. The external six feet high platform, upon which the structure rests, has recently been plastered with cement. The front solid wood door is painted green. The interior is richly embellished with original specimens of *naqashi* in *floral* and *geometric* patterns in horizontal and vertical panels, following the structural elements and recesses in the walls. Some of the rarest examples are arabesque designs in relief which can be seen on the interior walls. However, all these specimens currently are in a precarious state. The interior of the monument has been considerably damaged by the smoke of the candles and mustard oil lamps that are lit by the pilgrims visiting the shrine particularly the *naqashi work* and lime plaster. Little of the original decoration survives in presentable condition. Externally, decay has set in at several places including walls, corner buttresses, grills, and panels of inscriptions due to rising dampness and weathering.

Figure 3: Mausoleum of Shah Ali Akbar-Historical shrine of Multan, Pakistan.

### *2.2 Research Methodology*

The first stage of the safety evaluation process is to collect qualitative data by examining the existing status of the building. The qualitative data involves the damage and physical condition of the structure, each structural component, and location of the structure, seismic region, etc. Such information can be collected through visual inspection and literature [8]. The current study area lies in the low seismic zone of Pakistan the zone name 2A (0.8-1.6 m/ sq. sec) has very low hazard probability of earthquakes according to building code of Pakistan [9]

The inspector relates each new case with cases during the assessment of the structure that he/she has seen before and individually makes his / her decision. Due to this fact, inspection depends not only on the current state of the structure but also on the experiences and expertise of the inspector. Thus, to prevent or mitigate this problem, the suggested approach is carried out via the computer database system based on the "the inspection form," which involves a questionnaire with choices. The checklist of damages is also prepared for inspections in which types of damage are described. Such practice makes the method rational and quite common for all surveyed structures. There are a few works in safety assessment and damage prediction on vernacular masonry structures with basic geometry in earthquake zones. After any natural disaster, there are checklists are available for assessing the damage level of existing concrete structures and vernacular masonry buildings such as FEMA (Federal Emergency Management Agency, part of the U.S. Department of Homeland Security). However, the pre-hazard evaluation of historical buildings is rare. It is very necessary to recognize the potential damages of seismic in damage-prone areas for mitigation strategies and minimizing the effect of the disaster to maintain cultural heritage [6]. Thus, previous research studies show, there is no standard and general approach is available for safety and damage assessment of historical structures. There are different methods are in practice for protection and conservation of heritage based on culture, structural typology, and economy of the country. Visual inspection is the first phase of the damage assessment using checklists, questionnaire forms, hazard atlases, etc. It is clear that identifying the structural components with complex shapes and examine the structure as a whole during the assessment process is very crucial but is still a challenge [10]. Due to this reason, only a few specialists are available in this area, as there are many historical buildings present in the world. Therefore, it is recommending that to fill the inspections forms or checklists with the help of non-experts who are willing to survey historical buildings i.e. architectural students. Hence, the specialists will save time for comprehensive inspections that can be worked out for a small number of buildings. So, the Steps to be followed will be as:

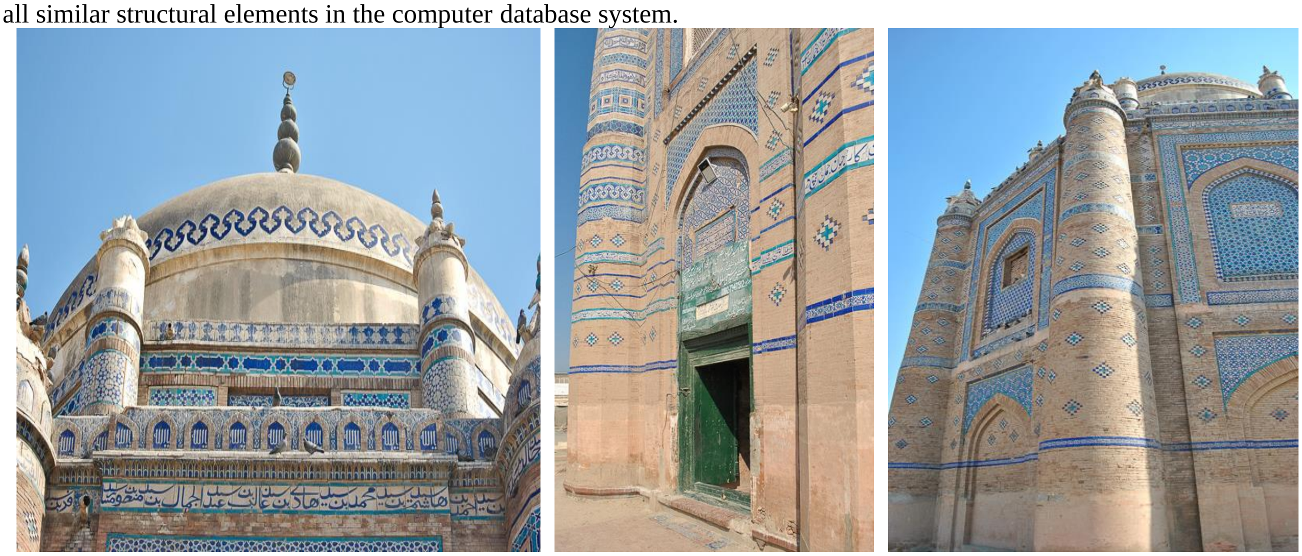
**Step. 1:** Selection of Structural Component i.e. Walls, Boundary Walls, Roof (Dome/Flat), Arches, Beams, Turrets, Domelets /Kiosks, Floor, Lintel, Pillars, Stairs etc. and Selection of Non-Structural Component i.e. Doors, Windows, Ventilators, Drains, Pigeon Holes etc.

**Step. 2:** Calculation of number of cracks on each structural and non-structural component. Further, calculation of percentage impact of each components with reference to damage contribution.

**Step. 3:** Evaluation of Damage Value of each components to set the ranking and prioritization for repair, rehabilitation and conservation.

### *2.3 Representation of Structural Element.*

The computer database program analyzes the inspection data in the proposed system. Therefore, it is important to identify each structural element of the inspected building as well as a general method in computerized data properly using Excel analyzing the existing structure component-wise [11]. Also, checklist and questionnaire forms should be used and organize properly for inspection in a computer database. It is a hard job to examine the structure as well as to make interrelation of all similar structural elements in the computer database system.



a. Dome b. Front c. Columns

Figure 4: Example of Analyzing Existing Structure Component Wise

During the inspection, each structural element is therefore inspected to characterize its real geometry in the form of the datasheet. The structure is divided into components before inspection of the existing structure by which each structural feature can be defined by its actual geometry shapes such as circular, semi-circular, curvilinear, or irregular and its location i.e., orthogonal, or non-orthogonal or octagonal. It is not necessary to be precise in drawing applications while giving the axes and drawing every axis through the center of the component. The focus is to straightforwardly identify all structural components and using the minimum axis lines as much as possible. The way of giving an axial method to historic buildings as an example is displayed in Fig.3.

### *2.4 The development of the inspection form.*

The inspection form has been created by site visits and visual inspection of the Historical shrines in Multan. The inspection form is changed systematically based on experiences and feedback. The data is collected by reviewing the inspection form involving structural typology, topography, visual damage of material degradation, defects, human-made damage, etc. and structural element dimensions.MS Office-Excel software is used to create the inspection form and contains seven key sections as given below.
A-General details,

B-Physical data,

C-Structural elements of dimensions,

D-Images of the building,

E- Damage and the current condition of the facades,

F- Surveyed information of floor,

G- The layout of the interior spaces and damage and the existing condition of the structural elements within.
The inspection tasks are divided into two key sections as a measurement of the dimensions and damage state of inspected structural elements based on the test user's feedback. The first task is to measure all structural elements and to fill in the relevant part of the inspection form by using the code of the element for each inspected structural element. In inspection form, part C is the measuring part divided into external and internal structural elements such as interior and exteriors walls, pillars/columns, and arches/lintels. The first step of inspection will be completed after measuring of all structural elements. Also, the layout of the structure and damage survey are classified as exterior and interior inspection.

## 3. ANALYSIS OF DATA

In this method, data is collected after selecting shrine, data is analyzed after counting the structural, and non-structural deflects of the shrine. Then, deflects of these components were computed in percentages. There are different criteria for the evaluation of damage by using this method.

### *3.1 Analysis of Structural Components*

In this research, the structural elements such as walls, boundary walls, roof, arches, columns, dome lets/ Kiosks, walls, lintels, staircases, and pillars are observed for damage assessment. On the other hand, non- structural components include doors, windows, ventilators, drains, and pigeonholes. The structural and non-structural components of the shrine were examined, and data was collected by visual inspection. Then, obtained data of each storey structure are presented in table 1. However, example calculation mechanism can be observed as follows:
Component.1: Walls

Total Number of Cracks Observed in Walls=13

Total Number of Cracks Observed on All Structural Components=52

Percentage Share of Cracks of Walls=13/52*100=25%

Detail calculation has been presented in table.1 following the same pattern.

Table 1-Structural deflects of Hazrat Ali Akbar shrine

| Defects in Structural Components of the Shrine | | | | | |
|---|---|---|---|---|---|
| **Sr.#** | **Shrine** | **Components** | **No. of Defects** | **%age of defects** | **Rank** |
| 1. | Hazrat Ali Akbar (Shrine Age:431 Years) | Walls | 13 | 25% | 1 |
| | | Boundary wall | 1 | 1.90% | 8 |
| | | Roof | 10 | 19.20% | 2 |
| | | Arches | 7 | 13.40% | 3 |
| | | Beams | 0 | 0% | 9 |
| | | Turrets | 2 | 3.80% | 7 |
| | | Domelets/Kiosks | 3 | 5.70% | 6 |
| | | Floor | 7 | 13.40% | 3 |
| | | Lintel | 5 | 9.60% | 4 |
| | | Pillars | 0 | 0% | 9 |
| | | Stairs | 4 | 7.70% | 5 |
| | | Total | 52 | 100 | |

Among, all listed structural components of the shrine in the table, walls have most defected around 25% which is the highest proportion of defection in contrast to other structural components of the shrine. Correspondingly, the roof has the second-highest proportion equal to 19%.

### *3.2 Analysis of Non-Structural Components*

Non-structural components i.e. Doors, Windows, Ventilators, Drains, and Pigeonholes etc. of the shrine further demonstrate the imperfections of the shrine in table 2. Among, all non-structural components, doors and windows of shrine demonstrate major proportion disorder as associated with other components. Following the similar pattern of calculation as explained in section 3.1, percentage weight of defects has been calculated. Further ranking will also help to prioritize the damage level of the components.

Table 2-Non-Structural deflects of Hazrat Ali Akbar shrine

| Defects in Non-Structural Components of the Shrine | | | | | |
|---|---|---|---|---|---|
| **Sr.#** | **Shrine** | **Components** | **No. of Defects** | **%age of defects** | **Rank** |
| 1. | Hazrat Ali Akbar (Shrine Age:431 Years) | Doors | 4 | 36.4 % | 1 |
| | | Windows | 3 | 27.3 % | 2 |
| | | Ventilators | 2 | 18.2 % | 3 |
| | | Drains | 2 | 18.2 % | 4 |
| | | Pigeon Holes | 0 | 0% | 5 |
| | | Total | 11 | 100 | |

## 4 CONCLUSIONS

The damage assessment before the hazard is very important in determining the potential threat of the historic masonry structures, especially in seismic areas. The Classification of damage levels helps to mitigate, preserve, and conserve the cultural and heritage building before the hazard. It also gives the ability to guide specialists in the most critical buildings and save time for intensive research. Damage evaluation is a systemic process and requires teamwork. Since there are few experts in this area, who can conduct extensive research whereas the massive historical buildings exist around the globe. Therefore, the participation of non-experts plays a significant role in developing and improve the first phase of damage assessments. Also, comprehensive procedures for damage assessment could be extended and restricted to the most important buildings. In this study, the proposed method adopted to assess the existing condition of the historical masonry monuments through visual inspections, so that necessary steps taken for conservation and protection of historical buildings before any natural hazards. The outcomes results of this study elaborate on the present condition of structural & non-structural components of the shrine that involve numerous components of each structure. Doors & windows type of non-structural components indicate a high proportion of defects equal to 36% and 27 % respectively. Instead, a total of 11 structural components of a shrine out of which 7 components having less than 10% defects proportion of the whole shrine.

The remaining 4 components have greater than 10% defects proportion that designates the evidence of improper maintenance and negligence of higher authorities of the shrine. Ranking procedure will also help to take decision about financial and technical prioritization for decision making. Due to which both type defects proportion of shrine further increase in future that damage this cultural and heritage monument. Therefore, the inspected buildings are monitor regularly by conducting the visual inspection that gives direction towards depth assessment of high-damage buildings by specialists.

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