Field Survey on Historical Monuments for Assessment of Earthquake Resistant Structures: Case Study of Srinagar Capital City of Jammu & Kashmir, India

Sidrat Ul Muntaha Anees[1,*], M. Sultan Bhat[1], and O. P. Mishra[2,]**

[1] Department of Geography & Regional Development, University of Kashmir
* (Corresponding Author; E-mail: s.anees13@gmail.com)
[2] Formerly SAARC Disaster Management Centre, New Delhi
**(Now Ministry of Earth Sciences, New Delhi)

Abstract **-** The purpose of the present research is to identify the earthquake resistant features of some selected Historical monuments of Srinagar city. The historical monuments selected for the study include, Jamia Masjid, Shrine of Shah-e-Hamdan, Mosque and Tomb of Madin Sahib, Patthar Masjid, Tomb of Zain-ul-Abidin's mother and Mosque of Akhun Mulla Shah. A qualitative vulnerability assessment of the monuments is performed. The methodology includes the Literature survey and Rapid inventory of the monuments under study. The main indicators which were selected in the study for the visual inspection of the historical monuments include; Age of the monument, Building material, Earthquake resistant features, Renovation, Inspection of structural elements, Damages to structural features, Surrounding site conditions and Emergency measures available. The results of this study bring forth the traditional construction practices used in the construction of the surveyed historical monuments. We inferred that traditional methods of constructing structures may found more effective measures for safety of those structures, which can also be adopted into the present scenario to help construct disaster risk resilient buildings under the climate change scenario that influencing several types of natural disasters under the name of climate change induced disasters. In order to generate a comprehensive earthquake risk resilient building design codes it is imperative to augment the traditional building design codes with seismic microzonation observations of the Srinagar city that may provide information about the basement materials and properties of soils lying beneath the historical buildings in Srinagar that help assess the vulnerability map of the city for better urban planning.

Index Terms **-** Historical monuments; Earthquake resistant features; Qualitative vulnerability assessment; Rapid inventory; Visual inspection.

I. INTRODUCTION

Historic monuments are an important part of the cultural heritage and their protection is the concern of every person in the society. Historical city buildings are an integral part of the built heritage that need to be preserved (Ramos and Lourenco 2004), and their safety is a primary requirement in seismically active areas that are frequently vulnerable to earthquake hazards (Mishra 2011; Mishra et al. 2011). It is observed that historical structures suffered impacts of different natural disasters differently, including the effects of gravity forces in the long term, earthquake, environmental effects, and anthropogenic actions such as architectural alterations, intentional destruction, inadequate restorations (Roca et al. 2010). Under the change of the climate scenario, it has been also argued that the rate of seismicity is going to be enhanced since there are close relationship among the uneven earth rotation, tilting of earth axis during the great earthquakes, and the melting of glaciers due to global warming (Mishra 2014). Under such alarming situation it is an urgent need for adopting viable safety and prevention measures to save not only the lives of faunas, but also the safety of our historical monuments which are regarded as treasures of our cultural heritage. Seismic microzonation can provide us additional information about the future degree of the damage to the historical monuments during the earthquake shaking (Mandal et al. 2013). Several set of studies argued that preservation of the past architectures as heritage is essential and such endeavor needs to be considered a fundamental issue in the life of the modern societies (D'Ayala et al. 2008; Cantell 2005). It is so because historic buildings help define the character of our communities by providing a tangible link with the past (Cantell 2005).

Survival of historical buildings after earthquakes is the concern of people from many disciplines. The cultural importance of these monuments brings people from many disciplines into the decision making process on safeguarding these buildings against earthquakes (Ziyaeifar et al., 2004). Historical structures are often characterized by a very complex geometry (Roca et al. 2010). It is much more difficult to measure the geometry of ancient buildings. Normally these buildings are characterized by an irregular geometry and a very complex surface; very often a deformation of parts of the building or the complete building can be observed (Weferling 2000). Scientifically it has been established that complexity in the design of buildings invites difficulty in detecting the

actual cause of vulnerability of the structures. It is, therefore, detailed study on structural evolution of the buildings (Binda et al., 2006) can shed important light on the pattern and extent of damage of structures during the earthquake shaking. The analysis of historical masonry constructions is a complex task (Lourenco 2001). Historical or traditional materials such as earth, brick or stone masonry and wood are characterized by very complex mechanical and strength phenomena, which are still remained a challenge for assimilating a plausible models to understand the principal cause of damage to structures or buildings. Historical materials, including brick or stone masonry, are found normally very heterogeneous even in a single building or in the composite constructions. Rigorous field inspections and surveying of damaged building structures suggest that historical structures often associated with many additions and repairs done with different materials (Roca et al. 2010).

Our study is directed to analyze the historic monuments which have survived some of the deadly earthquakes in the past. This study is focused on pre-hazard condition survey based on visual inspection of historical monuments. This study highlights the techniques involved in the construction of these historical monuments by identifying the strong as well as weak features of these monuments and come out with appropriate conservation strategies which can be adopted into the present scenario to construct disaster risk resilient and safer buildings. In the present study we discussed ancient traditional structural design by addressing several issues pertinent to the historical evolution of the historical monuments; the building material, construction and typology; structural features of the historical monuments; and earthquake resistant features in the historic monuments, with aim to suggest some of doable and economical structural measures for the present scenario derived from the ancient traditional building construction codes for better urban planning of the capital city of Srinagar.

A. History of Earthquakes in Kashmir Region

The Kashmir Himalayan region of India is seismically active as it falls in the Seismic zone V of the Seismic Zonation map of India (Bhatia et al., 1999), which is associated with several exposed and hidden seismogenic faults (Ghosh and Mishra 2008). The study area is influenced by the northwestern termination of Pakistan-Kashmir Himalayan mountain front, a zone of thrusting produced due to inter-continental collision between Indian and Euro-Asian sub-plate, marked by a continuous belt of earthquakes. The history of North Pakistan-Kashmir shows that the region, as with the entire Himalayas, is visited regularly by moderate to strong earthquakes. The underthrusted Indian plate, overthrusted Euro-Asian sub-plate and a decoupled pre-collision deformed Neoproterozoic-Paleozoic metasedimentary wedge, contained between the two converging continental plates are the main elements of active tectonics of the area (Ghosh and Mishra 2008). Kashmir Valley is, therefore experiencing a series of earthquake shakings since ages and is very much vulnerable to earthquake hazards that always pose a great threat to the sustainability of the historical monuments and vital structures located in the Valley. Since earthquakes are unique among natural hazards in sense that these occur without warning and thus it can pose a sudden threat to the lives of flora and fauna in comparison to that of other natural disasters. Earthquake provides a negligible response time to the responders that left with no time for taking any safety measures, even to the victims that can reach to the safest locations. It has rightly been said that “earthquake does not kill the people it is the structure that kills the people” (Bolt 2006). This is why each structure used by people in an earthquake-prone region must be able to avoid collapse in an earthquake that may strike at any moment (Langenbach 2009). Past earthquake catalogue shows some of severe damaging earthquakes that had rocked Kashmir during different periods, such as in 2082-2041 B.C, 1500 A.D, 1552 A.D, 1662 A.D, 1668 A.D, 1735 A.D, 1778 A.D, 1784 A.D, 1803 A.D, 26th June 1827 A.D, 1863 A.D, 1878 A.D and 30th May 1885 A.D (Koul 1925). However, the available information about most of these earthquakes is very scanty. In addition to these some of well documented damaging earthquakes that rocked Kashmir Valley are the 1974 Pattan earthquake (M 5.9) and the 2005 Muzaffrabad, Kashmir earthquake (M 7.6), which demonstrated that structural designs and quality of structures might have controlled the pattern and style of damage to the buildings. It is, further reported that degree of damage to structures during these earthquakes varies from place to place and impacts of earthquake shaking were different at different parts of the structures (e.g., wall; corners; foundational base; pillars, etc) as the strength of earthquake shaking is dictated by the size and focal depth of the earthquake (Ghosh and Mishra 2008, Mishra et al. 2011).

B. Archaeological and Historical Backgrounds of Monuments

Srinagar, the capital city of Jammu & Kashmir State of India has witnessed the presence of several historical monuments that found detailed descriptions in the several literatures of ancient and medieval periods of the history of the State that shed lights on the rich cultural heritage of the valley, which sustained, even after occurrences of mega natural disasters in the region. Sikandar (1389-1413 A.D.), son of Qutub-ud-din was the founder of wooden architecture in the valley. Among his monumental buildings are Jama Masjid and the mosque at the Khanqah of Sayyid Ali Hamadani. The reign of Sultan Zain-ul-Abidin (1420-70 A.D.) constituted a notable epoch in the field of architecture. He built palaces of fantastic proportions the most prominent being the tombs of his own mother commonly known as Budshah monument, or the mosque and tomb of Sayyid Muhammad Madani near Zadibal in Srinagar. The style of architecture associated with the domination of the valley by Muslims in the 14th and 15th centuries is almost of wood and bricks which received a distinction of its own (Shali, 1993).The architecture of the period of Sultans of Kashmir can be divided under two heads; the masonry style; and the wooden style. One of the buildings belonging to the first category, which still exists, is the tomb of Zain-ul-Abidin’s mother in Srinagar. Although it is constructed on the plinth of an ancient temple, the brick structure above the plinth is built in the style of a Muslim tomb. It was however, not the masonry style but the wooden style of architecture that was more common in the Valley. This is perhaps due to the fact that buildings constructed of wooden framework are less liable to fall in

earthquakes than an edifice of brick or stone. The mosques and tombs are all built in a similar style. They are all square in plan (Hasan 1974). The mosques are either self-contained, square buildings like the tombs or else they consist of a group of square-planned buildings connected together by a colonnade like the Jama Masjid in Srinagar (Kak 2002). The walls are constructed sometimes of bricks and mortar, sometimes of logs laid across each other, the space between logs being in some cases filled with brick-work. In large chambers where the timbers of the roof or ceiling require intermediate support, modern columns are used with very good effect. The typical roof covering consists of turf laid in brick bark, which retains waterproof properties for a great number of years.

The Muslims in Kashmir were in the beginning far too few to initiate an architecture of their own. All that they did was to utilize the materials of disused Hindu temples for construction of their mosques. The result was peculiar. The most characteristic examples of this style are the mosque of Madin Sahib, outside the Sangin Darwaza of the Hari Parbat fort and its adjacent ruins, and the mosques on the roadside at Vitsarnag and Zain-ul-Abidin's mosque on the island in the Wular Lake are some of structural designs of the buildings, reflecting the types of structures. Another structure belonging to this period and fundamentally different from all other buildings in Kashmir is the tomb of Zain-ul-Abidin's mother. The plinth originally belonged to a Hindu shrine and does not seem to have been tampered with by the Muslim architect, who simply followed the lines laid down by his Hindu predecessor. A peculiar feature of the brick buildings of this period is the glazed tile-work with which they were decorated (Kak 2002). Several of the historic mosques in Srinagar are of "cribbage" construction, a variation of timber-laced masonry construction that can be found in the Himalayan Mountains of northern India, northern Pakistan near the Chinese border, and parts of Afghanistan. This has proven to be particularly robust in earthquake prone regions, but as wood supplies became depleted it must have been found to be extravagant (Langenbach 2009).

In this study, we selected a total of 6-historical monuments for this study, which include Jamia Masjid, Shrine of Shah-e-Hamdan, Mosque and Tomb of Madin Sahib, Patthar Masjid, Tomb of Zain-ul-Abidin's mother and Mosque of Akhun Mulla Shah. Except Jamia Masjid and Mosque and Tomb of Madin Sahib, all the others are Centrally Protected Monuments of Kashmir Valley according to the Archaeological Survey of India. The details of historical monuments regarding their locations are shown in Table1.

Table 1: Details of Historical monuments selected for the study

Name of the monument	Year of construction	Location
Jamia Masjid	1394 A.D	Nowhatta
Shrine of Shah-e-Hamdan	1395 A.D	Zainakadal
Mosque and Tomb of Madin Sahib	1483 A.D	Mandibal
Patthar Masjid	1623 A.D	Zainakadal
Tomb of Zain-ul-Abidin's mother	1427 A.D	Maharajgunj
Mosque of Akhun Mulla Shah	1649 A.D	Hari parbat

II. METHODOLOGY AND DISCUSSIONS

Seismic assessment of historical buildings is a complex problem due to the wide variety of involved aspects, such as the quality of masonry, the structural systems, the large effort in inspection and diagnosis, the economical and cultural implications (Fusco et al., 2008). A preliminary in-situ survey is useful in order to provide details on the geometry of the structure. Also the historical evolution of the structure has to be known in order to explain the signs of damage detected on the building (Binda et al. 2006). The most significant historical monuments were selected for the study. Information for each monument was collected which included their history, geometrical and material properties, earthquake resistant features, description of damages from various angles.

A qualitative vulnerability assessment of the monuments was performed. This procedure is based both on in-situ inspection and on a preliminary knowledge of the building history and its architectural and technical features (D'Ayala et al. 2008). History is an essential dimension of the building (Roca et al. 2010). The survey inspection has been designed to understand the actual morphology of the building, the relationship with its surroundings, the state of damage and the collapse or decay processes. Based on the earlier approach (D'Ayala et al. 2008), we adopted the technique of analyzing the alterations that occurred in the structure during the time, including repair and restoration works. As mentioned above, the main indicators which were selected in the study for the visual inspection of the historical monuments include; age of the monument, building materials, earthquake resistant features, renovation, inspection of structural elements, damages to structural features, surrounding site conditions, and emergency measures available.

The study involved a rigorous literature survey and the rapid inventory. In literature survey, material is collected from secondary sources for concept development, understanding of the building typology, materials, construction and evolution process. The rapid inventory has been made a very brief survey of historical buildings to help develop a concept on buildings and understand extent of work. This survey covers building materials, technology, skills, construction process, age and impact of past earthquake on the building. A questionnaire for rapid inventory is prepared. Analytical descriptions of all six historical monuments are discussed below.

A. JAMIA MASJID

Jamia Masjid (Figure 1), the biggest Mosque in Kashmir, located in Nowhatta, is known as one of the sacred shrines of Islamic followers. The type of its architecture, its massiveness, complexity, size and perfection of design makes it one of the most extraordinary achievements of early Islamic art in the valley (Shali, 1993). The Jamia Masjid contains all the typical features of the Kashmiri wooden style. It was many times destroyed by fire, but was each time restored. The final reconstruction was effected by Aurangzeb who seems to have retained the original plan (Hasan 1974).

Jamia Masjid, Srinagar was built by Sultan Sikandar Shah Kashmiri Shahmiri in 1394 A.D, father of Sultan Zain-ul-Abidin. He is said to have laid its foundation in 1398 A.D and completed it in 1402 A.D. His illustrious son is reported to have greatly exerted himself in adding to its aesthetic attractions (Kak 2002). Jama Masjid is the developed form of wooden architecture in Kashmir valley. It was due to its prestige and ancient lineage that in spite of repeated reconstructions and changes, the original style continued to be adopted as far as possible.

The mosque is a quadrangle and roughly square in plan, its northern and southern sides being 384 feet in length. Its principal features are the four minars, one in the middle of each side. They are covered by a series of pyramidal roofs, which terminate in an open turret crowned by a high pinnacle. The roof of each minar is supported on eight wooden columns, 50 feet in height and over 6 feet in girth, whose modern substitutes still stand on the original square limestone bases. The columns are plain and unornamented (Kak 2002). The main entrance is on the south side and consists of a recessed portico leading across the colonnade into the interior courtyard. A series of arched arcades with a clerestory goes round the courtyard, but in the centre of each side there is a square frontage containing an archway, while above it is the usual pyramidal roof and steeple (Hasan 1974).

The area of Jamia Masjid extends up to an area of 384 feet by 381 feet. The built in area of the Masjid is 1, 46, 000 square feet. The width of the outer and inner brick walls is 5 feet and 4 feet. Jamia Masjid with its unique architecture has majestic 378 wooden deodar pillars, each one an entire tree-trunk of deodar (a distinctive, local, evergreen tree) supporting wooden ceiling with 346 pillars of 21 feet high and 5 feet girth and 32 pillars of 48 feet high and 6 feet girth. The Masjid is provided with a fountain measuring 33 feet by 34 feet which also serves purpose of ablution. This spacious mosque holds a capacity to accommodate more than 33,333 people offering prayer at a time. The inside view of the Jamia Masjid, Srinagar, Kashmir is shown in Figure 2.

In 1479, it was reduced to ashes by a devastating fire and was re-erected and completed in 1503. Again in 1619, a severe conflagration broke out which destroyed the mosque and the surrounding residential houses. In 1674, the mosque caught fire for the third time; however it was rebuilt in three years time (Kaul 1971). During the Pathan rule (1753-1819), the structure was twice repaired. In Dogra regime also, attempts were made to repair the mosque. The grand mosque of Jama Masjid even in its present condition reflects a remarkable current of religious fervor witnessed in the valley soon after its occupation by the Muslims.

Observations & Findings of the study

- Building material of the monument includes stone, bricks, wood, cement and tin sheets.
- Fire extinguishers provided at many places within the mosque for safety measures.
- Fencing is put around the mosque in order to keep the mosque away from the hustle of the surrounding markets.
- The wide spread area and the thick outer and inner walls provide strong resistance to the building against the impact of earthquakes.
- Walls are provided with small openings which increases the strength of the structure.
- Wooden pillars used to support the roof are placed at regular distances from each other which provide a good balance and strength to the roof above.
- The compound in the centre of the mosque can be accessed through many openings and can be useful in case of emergencies.
- As such no damages were found in the structure except some minor damages on the wooden roof which have been caused due to age factor.
- The building is in good condition and it is under regular renovations and maintenance under retrofitting plan of the building.

B. SHRINE OF SHAH-E-HAMDAN OR KHANQAH-E-MOULA

The shrine of Shah-e-Hamdan or Khanqah e Moula (Figure 3) is one of the oldest Muslim shrines in Kashmir situated on the banks of river Jehlum. It was the first mosque to be built in Srinagar and is a typical example of the wooden architecture of the Valley (Hasan 1974). The shrine was originally constructed by Sultan Sikander (1389-1413 AD) in 1395 A.D in the memory of Muslim preacher Mir Syed Ali Hamdani who is believed to be the main person behind the spread of Islam in Kashmir.

The shrine incorporates features of Buddhist, Hindu and Islamic architecture. The interiors of the building have beautiful paintings and carved woodwork. Antique chandeliers add to the beauty of the wooden structure. The mosque has its foundations composed of ancient temple materials. Barring its verandah extensions, it is in plan a square. Over it, the walls of the lower portion of the structure are formed of logs, trimmed square and then laid in alternate courses. The projections under the eaves are also of logs

laid crosswise. The superstructure also in wood is comparatively lighter and is represented by arcades, verandahs and porticos. The pyramidal roof crowning the whole structure is in three tiers and carries a distinctive style of its own. The entire roofing material now stands replaced covering the structure by corrugated tin sheets. The mosque of Shah Hamadan which is in three storeys, carries architectural embellishment in the interior of one of the only large hall on the ground floor as against the upper storey which is plain (Shali 1993).

The large hall inside, measures 63 by 43 feet and is flanked on the south and north side by 14 other chambers. The one on the north-west corner has the tomb of the Saint. Walls inside the hall are decorated with paneled wood work gone brown with age (Kaul 1971). The interior hall has no great significance from the point of construction, but its tapering eight-sided ornamented posts, the arched and recessed mihrab, its paneled walls and ceilings painted in multicolored designs and the valuable prayer carpets of different colors on the floor give it an air of elegance and dignity (Hasan 1974). The ceiling of the hall is supported by four wooden pillars 20 feet in height with an ornamental dado and other decorations (Shali 1993). The tomb chamber is decorated with glass and glazed work. Four wooden columns, supporting the ceiling are decorated with painted wooden chips arranged in fish bone pattern in the shafts, carved with lotus motifs at the base and leaf patterns at the capitals which are sixteen sided.

The Khanqah-e-Moula in Srinagar has undergone lots of additions and alterations. It was twice destroyed by fire, once in 1479 and the second time in 1731. Sultan Hassan Shah (1472-84) repaired it on the first occasion and the second time Abul Barkat Khan, Deputy Governor of Mughals repaired the mosque in 1733 when he took up his post for the fourth time (1733-37) (Shali, 1993). Apart from the cloisters, which have been added later, and the additions and alterations that are being carried on by its present-day caretakers, the original building is a square structure. Its chief structural peculiarity is that it is for the most part built of wooden balks. The spaces between the balks are filled by very small and carefully dressed bricks. Some of the doors and windows are beautiful examples of wood carving, and the wooden cornice of the plinth is an exquisite piece of workmanship. The inside view of the Khanqah e Moula (Figure 4) has been studied by the team to understand the parameters that provide stability of the structure.

Observation & Findings of the study

- This monument is made up of wood mostly with less brick work.
- Use of wood in high quantity imparts strength to the building.
- It has the capacity to occupy 60,000 people approximately at a time.
- The window openings are too large which decreases the strength of the walls.
- The wooden pillars are not strong enough to provide strong support.
- The building didn't encounter any damage due to the earthquakes which occurred in the area.
- Renovation work done few years back included construction of windows for the third storey.
- For the safety of the building, CCTV cameras, fire extinguishers and fire alarms are fitted at many places in the building.

C. MOSQUE AND TOMB OF MADIN SAHIB

The tomb and mosque of Syed Mohamad Madin was built by Sultan Zain-ul-Abidin in early 15th century A.D. The mosque of Madin Sahib is another edifice constructed of wood and adjoins the tomb of Madin. This is in a very bad state of preservation. The mosque looked like the tomb on the site of an old Hindu temple. It is also found that just as two carved stone columns have been used in the inner chambers of the tomb, so some similar columns have been used in the porch of the mosque (Hasan 1974).

Mosque of Madin Sahib

Among the pre-Mughal Muslim buildings of Kashmir, one of the most prominent is the mosque of Madin Sahib at Zadibal (Figure 5). The base is square and is built entirely of materials belonging to a plinth of a mediaeval temple. The superstructure consists of four walls, adorned externally with trefoiled brick niches. The corner pilasters of the walls as well as pilasters of the niches stand upon bases, and are surmounted by capitals which are purely Hindu in style. The spandrels of the arches of the niches are decorated with beautiful tracery work. The cornice over the walls is composed of half a dozen courses of wood (Kak 2002). Below the eaves the cornice are made of wooden courses, which at places have delicate carving. The chamber is covered by a pyramidal earth and birch-bark roof. The roof is pyramidal with a spiral apex; the only remnants of which that exist are a single long upright pole and a few pieces of timber. The entrance to the prayer chambers is through an elaborately carved wooden doorway flanked by two fluted stone columns originally belonging to the adjoining Hindu ruins. The prayer chamber inside has Khatamband ceiling (i.e. thin pieces of soft wood woven into geometrical pattern), supported on four multi-sided wooden columns.

Tomb of Madin Sahib

Constructed in the 15th century, the tomb of Madin Sahib is one of the most attractive tombs in Srinagar. It was constructed in memory of saint Madin Sahib and is situated north of the Madin Sahib mosque at Zadibal. A number of inscriptions and architectural styles highlight the history of that period. Its walls were originally decorated with glazed tiles, an attractive style of 15th century

Kashmir architecture, most of which are missing. A few remaining ones have been preserved in the Srinagar museum. The mosque and the tomb were built in 1483 A.D. in the reign of Zain-ul-Abidin (Kaul 1971).

There are many inscriptions on the walls and lintels of the mosque, highlighting its period of construction and religiously important sermons. A carving showing a beast with the body of a leopard is adorned at the entrance. The tile work seen usually on masonry buildings in Kashmir is visible in the archway jambs. Both the tomb and the mosque were built in memory of the same person, and the inscription on the lintel of the entrance of the mosque records the date of its erection as 1483 A.D in the reign of Zain-ul-Abidin. The tomb may have been built a few years later, though it is not impossible that it was built at the same time as the mosque, for among Muslims the practice of building tombs during the lifetime of their future occupants is not uncommon. The inside view of the protecting structure of the tomb is shown in Figure 6.

Observations & Findings of the study

- The building material used in both the tomb and mosque include stone and wood.
- Both the structures are having stone foundations and the structures are also made up of stone except the windows and the roof.
- The windows and the roofs are made up of wood in both the structures.
- These monuments are under conflict and are thus not kept open for general public.
- Foundations of the monuments are also of stone but the roofs are completely wooden.
- Both the monuments are in a poor condition and the wooden roofs have started decaying with time.
- Presence of an electricity transformer in the compound of the monuments can cause treat of fire.

D. PATTHAR MASJID

Patthar Masjid (literally Stone Mosque) located in Zaina-kadal (Figure 7), is the largest surviving example of Mughal architecture in Kashmir. It is very different to other monumental Srinagar mosques in both design and materials. This stone mosque of polished grey lime-stone built by Noor Jahan, the legendary beauty and wife of the fourth Mughal Emperor Jahangir, in 1623 A.D, consists of nine arches horizontally constructed. Soon after its completion, the mullas of Kashmir declared the mosque unfit for religious use and since then it remained isolated and now a preserved monument (Kaul 1971). It is believed that the construction was supervised by the renowned architect and a well-known Mughal historian Malik Hyder Chaudhary. The masjid is in ruins today and is of great interest to get a closer look at the Mughal architectural styles. There are nine horizontally constructed arches in the facade, the middle one being the largest arched portico (Kaul 1971).

The inside view of the Patthar Masjid is shown in Figure 8. The arched openings are enclosed in shallow decorative cusped arches, which in turn are enclosed in rectangular frames. The horizontal construction of these arches is remarkable. All of them have recently been closed up with rubble stone masonry (Kak 2002). The visible coping stones of the now almost underground plinth have a series of large lotus leaves carved in relief and so have the portion of the walls between the projecting cornice and the eaves, some of which are also pierced. The roof consists of twenty-seven domes, the central one of which is the largest. The domes are mostly ribbed inside, though there are some which are flat. The roof is supported internally on eighteen extraordinarily massive square columns having projections on two sides. The lower portion of the columns is built of stone and the upper of brick covered by a thick coat of buff-colored lime plaster. The enclosure wall is built of brick masonry, with a coat of lime plaster, adorned by a range of shallow arched niches.

Observations & Findings of the study

- The building is used for the purpose of offering prayers.
- Monument has the capacity to occupy approximately 4,000 people at a time.
- Building material used in the monument is only stone with beautiful stone carved work.
- The mosque has a ground floor and an upper floor but only the ground floor is in use.
- In the renovation of the building, only the roof was repaired.
- Strong stone columns inside the building provide strength to the entire structure.
- In the building, no renovations can be made as the structure can lose its originality but only the polishing of the stone work is done whenever required.
- Being made of stone, it has no threat of outbreak of fire.

E. TOMB OF ZAIN-UL-ABIDIN'S MOTHER OR BUDSHAH TOMB

Near Sri Ranbirganj bazaar, Zainakadal, is the high and massive domed mausoleum built by Zain-ul-Abidin (1421-1472 A.D.) in 1427 A.D, entombing the mortal remains of his mother. He was also called Bud-Shah – the great king (Kaul 1971).

The tomb of Budshah (Figure 9) is one of the many tombs in a stone enclosure with a gateway. This stone enclosure really belonged to the old desecrated Hindu temple as was guessed by Cunningham and Cole by personal inspection that ascribed the temple to the 4th or

5th A.D. though other evidences available at the spot assign it to the 9th century. Here only the super-structure on a square plan, consisting of the single chamber in the middle with projected recesses at the angles was built by the king (Kaul, 1971). In plan it is square, with the angles cut off and replaced by rectangular projections. The superstructure follows the same plan, and consists of a single chamber in the middle with projections recessed internally at the angles, roofed over by five domes, the largest naturally being in the centre. The domes have been raised on moulded string courses. The drum of the central dome is decorated with semi-circular cupolas with sunk or ground panels. The exterior walls are studded with glazed and moulded blue bricks by way of decoration. The wooden lintels of the ventilation apertures are remarkably well preserved. Inside the structure, hanging from an iron plate attached to the apex of the central dome, is an iron chain which has given rise to the misconception, common among the Hindus of Kashmir, that the structure in its present shape was originally a Panchamukha (five-faced or five headed) temple, such chains being usually found in Hindu shrines, attached to the principal bell.

Immediately to the north of this building is a Hindu enclosure wall with gateway, which contains a number of tombs, one of which is said to preserve the remains of the king himself. The wall is a real Hindu one, as its materials and massiveness amply prove, though it is undoubtedly later than the fifth century A.D. A further proof of its Hindu origin is the number of carved stones still found round the site, which bear sculptured reliefs of Hindu deities. The whole group is enclosed in a massive stone wall with a ridged coping. The outer wall as well as its two entrances, one on the riverside and the other opening on the road, likewise is dated back to Hindu times. Since the time of Zain-ul-abidin this enclosure has been used as a cemetery, and many of the notabilities of Muslim Kashmir are interred here.

Observations & Findings of the study

- The complete structure is made up of bricks (small kiln bricks) and clay with stone foundation.
- The compound of the tomb is used as a cemetery.
- The whole structure is in an enclosed form with a small opening for entrance and a few small window openings.
- The thick walls also add to the strength to the structure.
- The grave of Sultan Zain-ul-Abidin's mother is the only grave inside the tomb while as the graves of Sultan Zain-ul-Abidin and his dynasty are outside the tomb in a small compound.
- Renovation of the tomb was done in 2000 and 2004.
- In the renovations the cracks on the exterior of the tomb were filled up but no changes were made on the interior of the tomb.

F. MOSQUE OF AKHUN MULLA SHAH

The mosque of Akhun Mull Shah (Figure 10) is located on the slope of Hari Parbat Hill and is a little way up above the Kathi Darwaza. It was built by Dara Shikoh, son of Shah Jahan, in 1649 A.D, for the use of his tutor, Akhun Mulla Shah (Kak 2002).

It is a unique structure built in stone rather than in wood. This small mosque is made of highly polished beautiful grey limestone. The mosque is the only surviving example in Kashmir which has intact the stone lotus finial over the pulpit. The facade has no decorations except the rectangular panels around the cusped arches. Its plan is rather singular. The small prayer hall, where pulpit stands, is flanked by two such chambers which are rather arcades on the two sides, while a similar arcaded chamber projected on the front serves as the gateway. Ruins of the arched halls on a lower level show them as lodgings for pilgrims. A Hammam, bath, is a little further off and has an inscription on the lintel of its doorway, giving in the chronogram of the last line the year Hijra, 1059 (1649 A.D.) as the date of the construction of the mosque and the hammam (Kaul 1971). The inner structure of the mosque has been rigorously inspected during the field to understand the structural design and set up of the mosque.

Observations & Findings of the study

- The building material used includes stone, bricks (small kiln bricks) and red clay.
- The building is not in used and the structure is in a deteriorated condition.
- The stone foundation and walls make the structure resistant to earthquakes.
- In the past times when the mosque was in good condition the diamonds engraved on the interior walls of the mosque got stolen.
- Due to rains few years ago, one side of the mosque got damaged and fell down but it was restored, suggesting lesser cohesiveness among the materials of the structure
- Renovation was done on the structure about five years ago and at that time the lower storey of the mosque was excavated which was buried under earth. This portion of the mosque served as a hostel for the students of Akhun Mulla Shah, who taught them in the mosque.
- Renovation work is in process at present also in which the enclosing walls of the structure are being repaired and strengthened by providing them support with iron rods under the periodical retrofitting program of the structure with much lesser cost of expenditures than that of required for constructing new structures.

III. CONCLUSIONS

This study reviews the traditional methodologies that went into the construction of the historic monuments. The results of this study bring forth the traditional construction practices used in the construction of the surveyed historical monuments. The studied historical monuments have several earthquake resistant features inherent in the structure. These features have helped these buildings survive the various earthquakes that the valley has encountered in past years. Wide area coverage, use of wood for construction, small openings, thick walls and stone foundation are the common earthquake resistant features found in most of the monuments. These old traditional structures are being periodically maintained and repaired under retrofitting plan of these structures, which ensure the lesser degree of damage of structures during the past events of natural disasters. It is, therefore such traditional construction techniques can be studied and understood thoroughly in order to utilize them for the construction of buildings under the urban planning of the city and its adjoining areas. We emphasized that such endeavor of adopting traditional style of building constructions into the modern design of buildings / structures can lead to a safer built environment by addressing the key issues of preparedness and prevention of structures under disaster management cycle for the society. We infer that under climate change scenario, where occurrence of more seismic events are expected the adoption of the traditional building design codes may prove as one of the effective measures for constructing earthquake risk resilient structures in the Srinagar city of Jammu & Kashmir, India. In order to generate a comprehensive earthquake risk resilient building design codes it is imperative to augment the traditional building design codes with results derived from seismic microzonation studies of the Srinagar city that may provide information about the basement materials and properties of soils lying beneath the historical buildings in Srinagar to assess the vulnerability map of the city.

Thus the study suggests inculcating the construction practices of historical monuments in present times so as to obtain an earthquake resistant built-up environment. These traditional methods can be adopted into the present scenario to help construct disaster safe buildings (PAHSIB 2007) as these monuments have survived the test of time and understanding and reviving the lost art will provide us with a window to the safe future.

APPENDIX

Figure 1

Figure 2

Figure 3

Figure 4

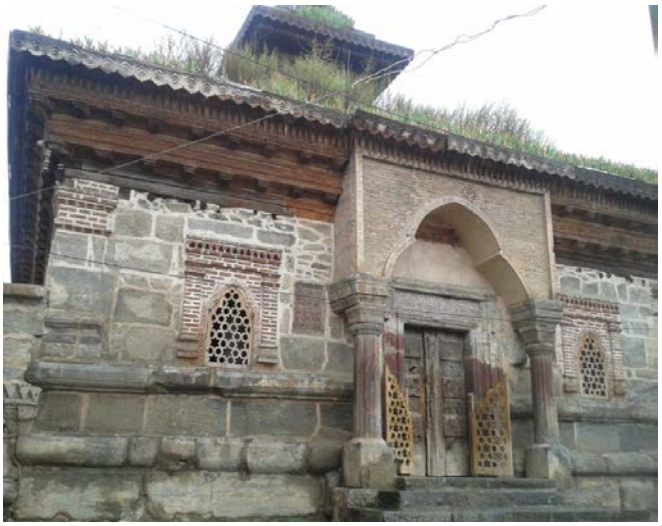

Figure 5

Figure 6

Figure 7

Figure 8

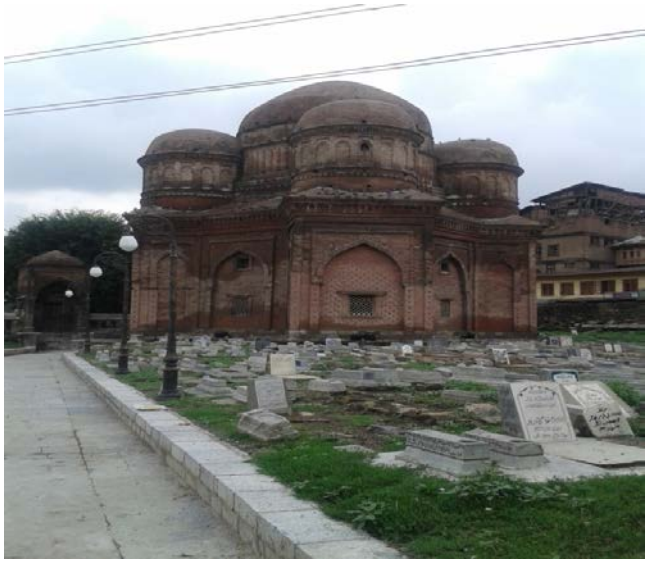

Figure 9

Figure 10

ACKNOWLEDGMENTS

The author gratefully acknowledges the special contribution of Mrs. Anees Hamdani and Qurrat Anees Hamdani in the survey conducted for the study.

REFERENCES

- Binda, L., Cardani, G., Saisi, A. and Valluzzi, M. R. (2006) Vulnerability Analysis of the Historical buildings in Seismic area by a multilevel approach, *Asian Journal Of Civil Engineering (Building and Housing)* 7 (4): 343-357.
- Bhatia, S.C., Ravi, K.M., and Gupta, H.K. (1999) A probabilistic seismic hazard map of India and adjoining regions, *Annali di Geofisica, 42: 1153–1166.*
- Cantell, S. F. (2005) *The Adaptive Reuse of Historic Industrial Buildings: Regulation Barriers, Best Practices and Case Studies*. Submitted in partial fulfillment of the requirement for the degree of Master of Urban and Regional Planning, Virginia Polytechnic Institute and State University.
- Central Europe Programme, *Survey on EE in Historic Building*, GovernEE – Good Governance in Energy Efficiency. Napoli, Italy.
- D'Ayala, D. F., Carriero, A., Sabbadini, F., Fanciullacci, D., Ozelik, P., Akdogan, M. and Kaya, Y. (2008) Seismic Vulnerability and Risk Assessment of Cultural Heritage Buildings Istanbul, Turkey, *14th World Conference on Earthquake Engineering*, Beijing, China.
- Fusco, E., Penna, A., Prota, A., Galasco, A. and Manfredi, G. (2008) Seismic Assessment of Historical Natural Stone Masonry Buildings Through Non-Linear Analysis,*14th World Conference on Earthquake Engineering*, Beijing, China.
- Ghosh, D., and Mishra, O. P. (2008) Earthquake generating process in Pakistan – Kashmir Himalayan front: A tectonic overview, J. Indian Minerals Special Issue, 61 (3 - 4) & 62 (1- 4), 27 – 40.
- Hasan, M. (1974) *Kashmir under the sultans*. Srinagar, Kashmir: Ali Mohammad & Sons.
- Kak, R.C. (2002) *Ancient Monuments of Kashmir*. Srinagar, Kashmir: Gulshan Publishers. p.50-93.
- Kaul, M. (1971) *Kashmir; Hindu, Buddhist and Muslim Architecture*. New Delhi-I: Sagar Publications. p.123-139.
- Koul, P. A. (1925) *Geography of the Jammu and Kashmir State*. New Delhi: Light and Life Publishers.
- Langenbach, R. (2009) *Don't Tear it Down! Preserving the Earthquake Resistant Vernacular Architecture of Kashmir*, United Nations Educational, Scientific and Cultural Organization (UNESCO). Oakland, California: Oinfroin Media.
- Lourenco, P. B. (2001) Analysis of historical constructions: From thrust-lines to advanced simulations, *Historical Constructions, P.B. Lourenco, P. Roca (Eds.), Guimaraes*: 91-116.
- Mandal, H.S., Shukla, A. K., Khan, P. K., and Mishra, O. P. (2013) A new insight into Probablistic seismic hazard analysis for Central India, Pure and Applied Geophysics (PAGEOPH), doi: 10.1007/s00024-013-0666-x.
- Mishra, O. P. (2014) Intricacies of Himalayan Seismotectonics and seismogenesis: Need of an integrated research, Current Science, 106 (2), 176 – 187.
- Mishra, O. P., Zhao, D., Ghosh, C., Wang, Z., Singh, O.P., Ghosh, B., Mukherjee, K. K., Saha, D. K., Chakrabortty, G.K., and Gaonkar, S. G. (2011) Role of crustal heterogeneity beneath Andaman - Nicobar Islands and its implications for coastal hazard, Natural Hazards, doi 10.1007/s11069-010-9678-3.
- Mishra, O.P. (2011) Three-dimensional tomography of Northeast India and Indo – Burma Region and its implications for Earthquake Risks, National Workshop Volume on Earthquake Risk Mitigation: Strategy in Northeast, February 24 – 25, 2011 by NIDM –AASC, 40 – 54.
- PAHSIB (2007) *Kangra District Historic Building Research, Preliminary Study*, Pan-Himalayan Study on Indigenous Technology of Earthquake Resistant Construction of Historic Buildings (PAHSIB) is a combined initiative by SEEDS and NSET to revive the indigenous building techniques in the pan Himalayan region.
- Ramos, L. F. and Lourenco, P. B. (2004) Modeling and vulnerability of historical city centers in seismic areas: a case study in Lisbon, *Engineering Structures Elsevier*, 26: 1295-1310.
- Roca, P., Cervera, M., Gariup, G. and Pela, L. (2010) Structural Analysis of Masonry Historical Constructions, Classical and Advanced Approaches, *Arch Comput Methods Eng*, 17: 29-325.
- Shali, S. L. (1993) *Kashmir, History and Archaeology through the Ages*. New Delhi: Indus Publishing Company.
- Weferling, U. (2000) The Integration of Conventional and Automatic Photogrammetric Methods to the Building Survey in Historic Building Research, *International Archives of Photogrammetry and Remote Sensing*, 33(B5): 880-886.
- Ziyaeifar, M., Meshki, H. and Rajaei, M. (2004) Rehabilitation of Historical Buildings subjected to Seismic Hazards, A Methodology, *13th World Conference on Earthquake Engineering, Vancouver, B.C. Canada*, Paper No. 1598.

Author Biography

First Author - Sidrat Ul Muntaha Anees, Research Scholar, Department of Geography and Regional Development, University of Kashmir, email: sidrathamdani@gmail.com

Second Author - M. Sultan Bhat, Professor, Department of Geography and Regional Development, University of Kashmir, email: msbhatgeog@yahoo.com

Third Author - O.P. Mishra, D.Sc. Scientist - "F", Ministry of Earth Sciences, Govt. of India**,** New Delhi, email: opmishra2010.saarc@gmail.com

Corresponding Author - Sidrat Ul Muntaha Anees, email: sidrathamdani@gmail.com, s.anees13@gmail.com, +91 9796395496