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ASSESSMENT OF POST EARTHQUAKE DAMAGE AT BAGH DISTRICT, AJK THROUGH GEOSPATIAL TECHNOLOGIES

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ABSTRACT

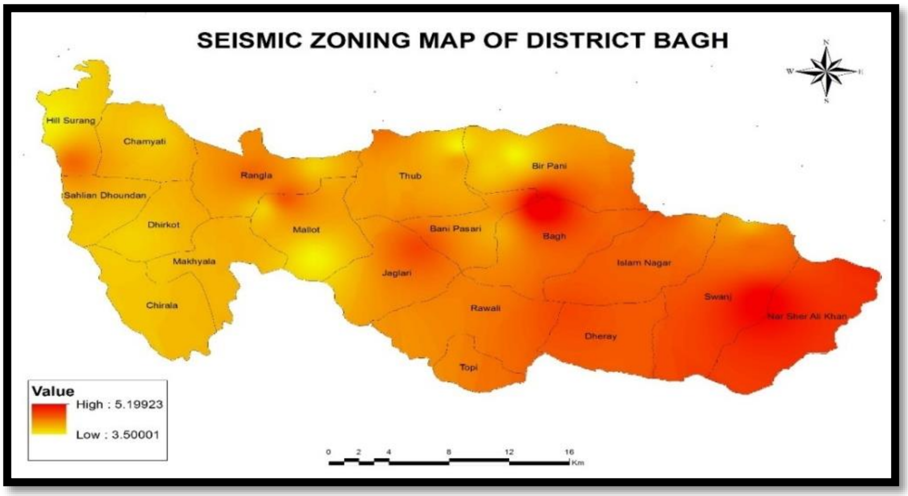
Earthquake is most unpredictable natural hazard, which creates sudden change in the normality of social processes. More than a million earthquakes arise around the world every year at the rate of two earthquakes per minute. Catastrophes have caused more than 780,000 deaths during the period of 2001–2011 of these calamities, the death toll caused by the earthquakes was estimated nearly 60% due to non-engineered building design and poor construction materials. Kashmir is highly vulnerable to seismicity because of consistent collision of Indian and Eurasian plates, while former continue to move into latter, thus building up great pressure at faults. This region was struck by severe earthquakes and hit a huge magnitude, consequently excessive loss was observed in the past 1555 and 1885. Recently in 8th October 2005 most disastrous earthquakes jolt the Azad Kashmir with the magnitude 7.6. Therefore, the objective of current study is to evaluate the post-earthquake damage through Satellite Remote Sensing (SRS) mainly through visual interpretation techniques. In addition, to analyze the main effect of earthquake on human settlements and to evaluate the infrastructure and buildings damaged by the earthquake. GPS coordinated field survey has been conducted and marked the affected houses on Landsat-7 image by using geospatial techniques with the help of ArcGIS and ERDAS imagine software. The results show the identification of four different types of building (walls was made-up of mud, blocks, stones and bricks, while the roof comprised of iron sheet, wooden roof, reinforced concrete (RC) respectively) on the basis of the construction material used in the District Bagh. Preparedness of earthquake can effectively reduce the economic losses and fatalities that caused by earthquakes. This study focused on the preparedness of the peoples of mountainous areas (District Bagh is earthquake prone area) that which building material is suitable for the construction and the ultimate resilience. The proportion of engineered building was relatively low and approximately 90 % buildings were found non-engineered design in District Bagh.

KEYWORDS: Post Earthquake; Building Material; Building Damage; Geospatial Technologies.

1. INTRODUCTION

Earthquake is the most unpredictable natural calamities and gives sudden misfortune to human population (Sesay and Bradley 2021). However, over a million earthquakes arise around the globe every year at the rate of two earthquakes per minute. Natural disasters including earthquake have caused more than 780,000 deaths through the period of 2001–2011 of all the disasters, the death caused by the earthquakes is assumed by 60% (Jackson 2021). Kashmir is highly vulnerable to seismicity for consistent collision of Indian and Eurasian plates while former continue to move into latter, thus building up great pressure at faults (Rafi *et al.* 2016; Khan *et al*. 2021). This region was struck by severe earthquakes in the past year of 1555, the Kashmir was hit by earthquake of huge magnitude resulting excessive loss which could not be ascertained, because of non-availability of data. Another inordinate earthquake affecting 100,000 sq. of Baramulla and Pattan region of Kashmir with epicentre (34.1°N, 74.8°E) shook this region in 1885. The most damaging earthquake with focal depth of 26 km and 7.6 magnitude shaken northern area of Pakistan on 8th October 2005 at local time 8:50 a.m. (03:50 UTC). The epicentre of earthquake was located at Muzaffarabad in Azad Kashmir 34.493° N. and 73.629° E., 20 km NE of (Khan *et al*. 2013), the impact of which is felt in many parts of Bagh District.

Figure 1. Seismic zoning map of District Bagh



On October, 8 major causes of earthquake compressive and bending stresses formed by subduction of Indo-Eurasian plate and the movement of tectonics is greatly accountable for eruption of mountainous ranges of Himalayan. Due to this subduction process several intermediate and few great tremors with an arc length of about 2500 km in a band of about 50-80 km width were formed (Molnar and Tapponnier 1975; Mokhtari *et al*. 2019). Though, we cannot stop the natural disasters, we can decrease the amount of loss afflicted by them either implementing extra safety measures beforehand or by quick response after the calamity strikes by strictly following Building Code is an appropriate strategy to avoid damage and loss of lives arising from earthquake. Global urbanization has made the human most vulnerable to suffer by earthquakes. Consequently, techniques of remote sensing play a vital role, both spaces borne and airborne (Wang 2011). Currently, GIS has recognised itself as a influential computer-based skill that is exploited for geographical visualization, database management and spatial analysis. GIS-based information systems are used for the prediction and planning for natural calamities like earthquakes or landslides (Carrara *et al*. 1999; Lee and Evangelista 2006; Dai *et al.* 2001). Usage of GIS technology growing extensively for the prediction of seismic zonation that triggered the risk of earthquake (Capolongo *et al*. 2002; Xu 2015). According to Saganeiti *et al*. (2020) remote sensing is the assessment tool for accessing the damage of post-earthquake. Team of researchers from US, Europe and Japan proved that through the analysis of optical and Synthetic Aperture Radar (SAR) imagery, it's possible to access the damaged buildings in the urban environment (Wang et al. 2007; Kalantar *et al*. 2020; Rehman *et al.* 2020; Adams *et al*. 2003; Abir *et al*. 2015).

In the northeast Himalayas of Pakistan, there is an active antiformal synclinal structure, the Hazara-Kashmir Syntaxis (HKS), which is the formation of folding of Himalayan thrust sheets and is arched to the hinterland and curved in to the headland. The northern part of HKS is a fitted antiformal erection, while the southerly fragment is an exposed structure. The thin crust faults the Panjal Thrust (PT), Barian Thrust (BT) and Main Boundary Thrust (MBT) bending round the HKS (Wadia, 1931; Calkins *et al.* 1975; Khan and Ali 1994). According to Baig *et al* (2010) that along the crest or western limb of the Jhelum River anticline the Jhelum fault that running equivalent or sub-parallel to river Jhelum (Figure 2).

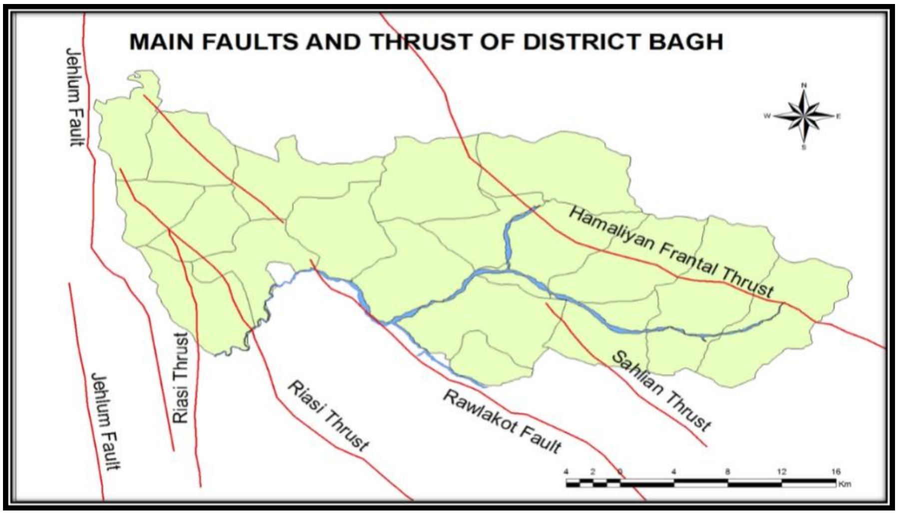


Figure 2. Main faults and thrust of district Bagh

Jhelum Fault is an active tectonic feature which is proven through the old linear landslides, seismicity, deflected drainage, nick points, sloped and elevated river terraces, nala fans and divided spurs. Naeem *et al.* (2007) explained that before the earthquake, rural Azad Jammu and Kashmir consisted of *katcha* houses, about 75% of the building are unreinforced stone masonry construction. Ozerdem (2006) emphasised that the area which has not been hit by tremors for decades, settlers are not ready to any disaster, susceptibility of rural housing was low graded materials, accredited to un-seismic resilient principles in construction. Hence, the main goals of the present study are, 1) to evaluate the visual interpretation of post-earthquake damage through Satellite Remote Sensing (SRS), 2) to analyses the main effect of earthquake on human settlements in terms of their structural and destruction type and 3) to assess the damaged buildings and infrastructure caused by the earthquake. According to Ao *et, al.* 2021 that preparedness of earthquake can reduces the risk of economic losses and causalities. Knowledge of the people and their perception about the earthquake effects greatly on their preparedness of earthquake.

1.1. Study Area

The present study work was carried out at Bagh District, AJK aiming to assess the impact of post-earthquake damage through geospatial technologies. The map location of District Bagh AJK is indicated in (Figure 3).

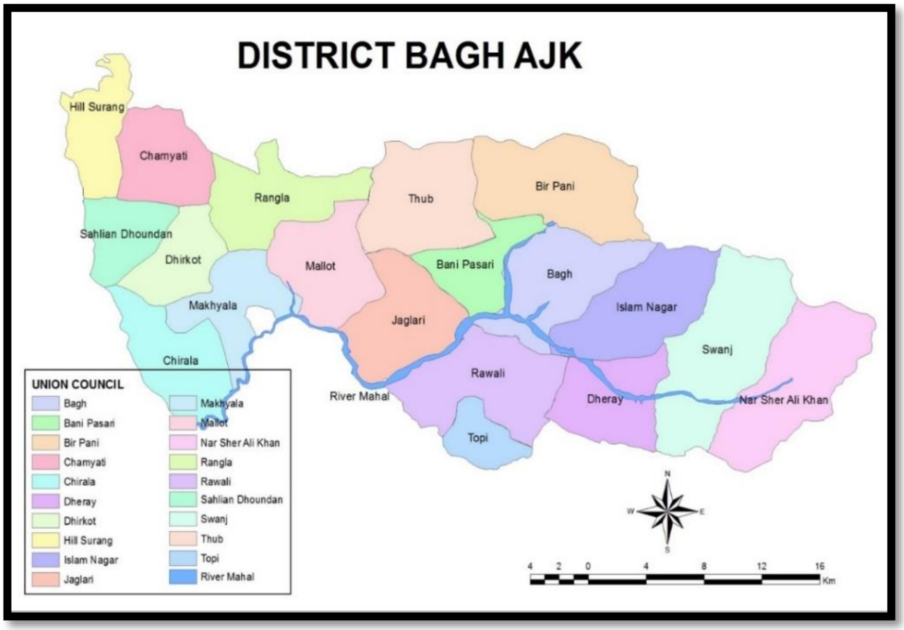


Figure 3. District Bagh, Azad Jammu and Kashmir

District Bagh, currently consists of three tehsils (Bagh, Harighel and Dhirkot) had been on continuous road of administrative division in past (Table 1). Before 1987 it was the Tehsil of District Poonch and before independence the part of "Poonch" state (occupied Kashmir). There lies District Muzaffarabad to its north, District Havali and occupied state of Jammu and Kashmir to its east, Poonch District, to its south and Rawalpindi and Abbottabad, Districts of Pakistan to its west.

Table 1. Divisions, Districts & Sub Divisions of District Bagh AJ &K 2013

District	Sub-Division	Number of Villages
Bagh	Bagh	52
	Dhirkot	61
	Harighel	27

Topographically, the whole Bagh zone comprise of mountainous ranges sloping from north- east to south-west and falls in lesser Himalaya's zone. The chief range is in Pir Punjal district and average elevation of area is amongst 1500 and 2500 meters above sea level. Coniferous trees densely covered up the mountain. Along with many seasonal streams, Mahl Nala is main stream of District.

2. MATERIAL AND METHODS

In this present study, we systematically described the results of housing typology in surveyed area. These surveys have been conducted in the selected areas of Bagh, Azad Kashmir. Furthermore, field survey of District Bagh AJK had been conducted through GPS (Global Positing System) per European Macro Seismic Scale (EMS). For the earthquake risk assessment methodology, comprehensive and accurate database of building inventory is a crucial fragment and appropriate explanation of building classification leads to a more precise attribution of building vulnerability. In order to gather the data of the types of building and their numbers around 30 cities and villages in 19 union councils were visited. Categorization of buildings depends on the amalgamation of materials used for roof and walls and structural system. 2005 Earthquake damages

Table 2. Deaths/Injured/Houses

District	Deaths	Injured	Houses (Uninhabitable)Damaged/ Destroyed
Bagh	9167	7,466	95,516

Source: SERRA Office, Muzaffarabad

2.1. Field Survey

GPS field survey has been conducted during research however oral interviews from residents, masons and engineers are directed to gather more in-depth information. The major types of settlements were documented through field pictures that are found in the study area. The demarcated settlements of surveyed area on satellite image of Landsat -7 and mentioned their masonry type and usage of construction material.

2.2. Geospatial Techniques

The data have been taken from high-resolution images of QuickBird. Landsat 7 image taken from USGS. The study maps were made up through geospatial techniques using Arc GIS and ERDAS imagine.

3. RESULTS AND DISCUSSION

3.1. Buildings of Surveyed Area of Bagh

According the type of the structure and the material used for the construction of roof and wall buildings were recognised. For the construction of wall, stone block, burnt bricks and cement concrete blocks are used. The wall material of the building is indicated in (Table 3). On the 8th of October 2005 earthquake with the 7.6 magnitude with the epicentre at the capital of Muzafarabad jolts the northern part of Pakistan and Kashmir. As reported by Naeem et al. (2011) around 4000 villages were damaged, overall causalities 73,000, 79,000 people injured and about 3.3 million rendered displaced. Whereas, around 65% of the hospitals severely damaged, 10,000 of the school’s buildings affected and about 470,000 houses were demolished. Major towns of Balakot, Muzzafarabad, Bagh and Rawalakot are hit devastatedly and wide-spread of destruction occurred in the region.

Table 3. Different housing and building wall materials

Material used in outer walls	Housing units by material used in roofs				Housing units	
	RCC/ RBC	Cement/ Iron sheets	Wood / Bamb oo	Other s	Total	%
Reinforced concrete	-	-	-	-	-	-
Stone masonry	2	95	-	5	10 2	14.01
Brick masonry	17	10	-	-	27	3.70
Block masonry	70	538	-	-	60 8	83.51
Adobe	-	-	-	-	-	-
Wood/Timber	-	2	-	-	2	0.27
Others (*Dhajji*)	-	64	-	-	64	8.79
Total	89	709	-	5	-	803
%	11.08	88.29	-	0.62	-	100

3.2. Stone Masonry Buildings

In some areas dressed stone was used in the construction of walls, where stone is available., Stone masonry buildings (like block masonry buildings) are also constructed with different roof such as sloping wavy GI sheet, RC and roof wooden roof. Mud mortal and cement-sand mortar are usually used to bond Stone (Figure 5). Basically, the main reason behind earthquakes of all sizes is plate tectonics, but great earthquakes are usually the most significant actions in terms of both hazards and tectonic motions, typically defined as those with seismic magnitudes ≥8.0. For the seismic energy-based moment magnitude Mw (Lay, 2015). Around the world from 1900 till now there are about 89 great earthquakes, this measurement recorded through seismological time interval taken from U.S. Geological Survey National Earthquake Information Centre bulletin, which draws upon the PAGER-CAT compilation for events prior to 1973 (Allen et al., 2009).

Figure 4. Stone masonry buildings.

3.3. Brick Masonry Construction

In the surveyed areas brick masonry buildings are observed. Material used for the construction of the wall is burnt clay bricks that are glued with the cement-sand mortar (Figure 6). As a result of 8th October earthquake in the Northern areas of Pakistan, causes great number of causalities and losses was largely the consequence of building destruction (Bird and Bommer 2004). In addition, Meyer *et al*. (2006) studied that it's clear that the main fault is thrust-type, NW Himalaya, stretches a complex network of secondary cracks that established in mixture with a external splitting thrust Kashmir earthquake of October 8,2005.

Figure 5. Brick masonry construction

3.4. Block Masonry

Construction of walls of buildings are cement concrete hollow blocks, while roof contained sloping wavy GI sheet roof, RC flat roof or wooden roof. The blocks are bonded together with cement-sand mortar. In sloping GI roofs, wooden beams are used to support the GI sheets. A wooden roof is constructed with wooden beams and covered with mud (Figure 7). Devastated earthquake that jolts northern Pakistan and India on October 8, 2005 with 7.6 magnitude that lasts in the region till 19 days and approximately 978 aftershocks of magnitudes ≥4.0. Farooq and Akram (2021) reported that this tremor is the worst in the recent history of the Indian subcontinent. Loss of life causes due to deprived building material and architectural design to collapsing structures. The destruction was annoyed by the many thousands of mass movements that were generated by the earthquake, which resulted in ~1000 direct mortalities and many more indirectly due to the interruption of communication links (Kamp *et al*. 2008).

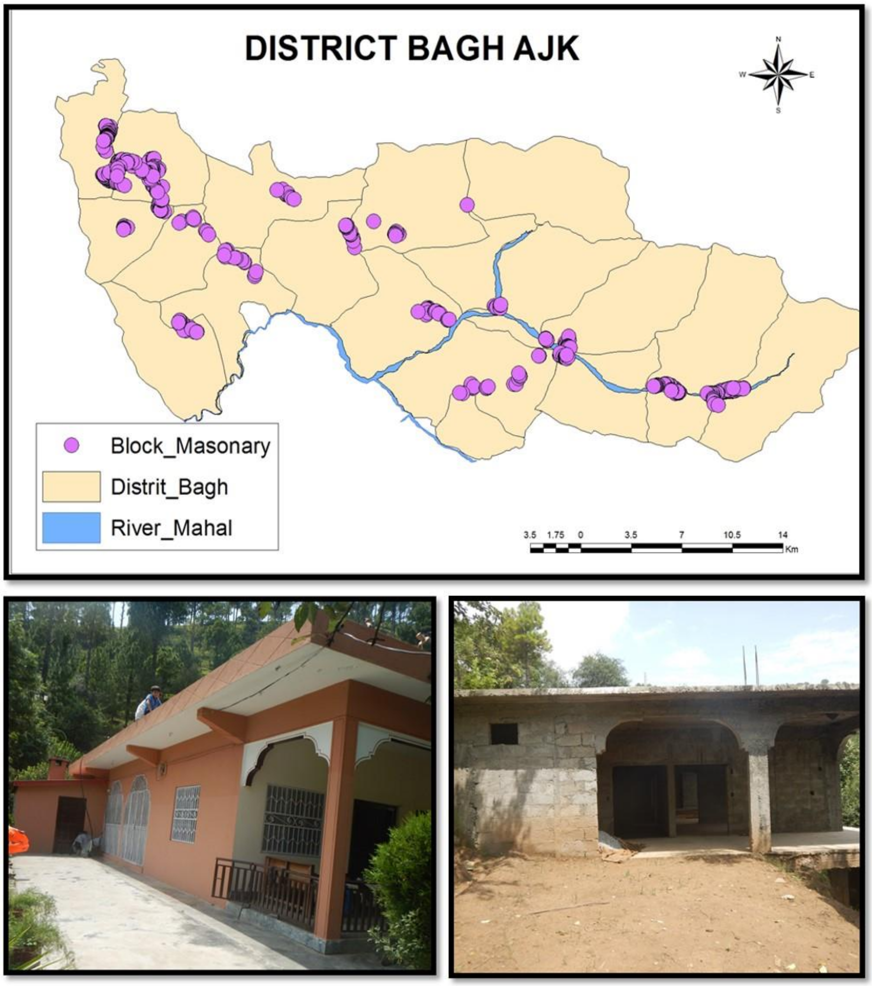


Figure 6. Block Masonry

3.5. Dhajji Masonry

For many years northern part of Kashmir region practises Dhajji, which is a traditional construction type. It is a wooden construction with erected wooden frame and roof truss and G.I sheets. Rubble stone masonry in mud mortar are used to fill the wall frames and then plastered with mud coating (Figure 8). This area is surrounded by the Main Boundary Thrust (MBT) and geologically the region encloses the Hazara–Kashmir Syntaxis, represents a region of considerable crustal shortening and uplift (Calkins *et al.* 1975; Owen *et al.* 2008). The generation of the powerful quakes through geologic forces shaped the rugged, mountainous region. Geology the motion of the Indian subcontinent controlled in northern Pakistan and India. It is pushed under the Asian continent at a rate of about 40 millimetres (1.6 inches) per year. As the continents collide, they push up the highest mountain ranges on the planet: The Himalaya, the Hindu Kush, the Karakoram, and the Pamir (Kazmi, 2006). The resistance also breakdowns the Earth's solid surface into complex series of faults. These fault lines are visible in the North and West of Pakistan. The epicentre was within the Indus– Kohistan seismic zone on the north-western side of the Hazara– Kashmir Syntaxis along the NW-SE trending Kashmir Boundary Thrust (KBT) in 2005's earthquake, it was reactivated during the earthquake (Growley 2008). Dionisio *et al.* (2015) predicted that this will promote communication within societies and increase expansion consequences via superior consensus among residents, designers, policymaker, and other investors.

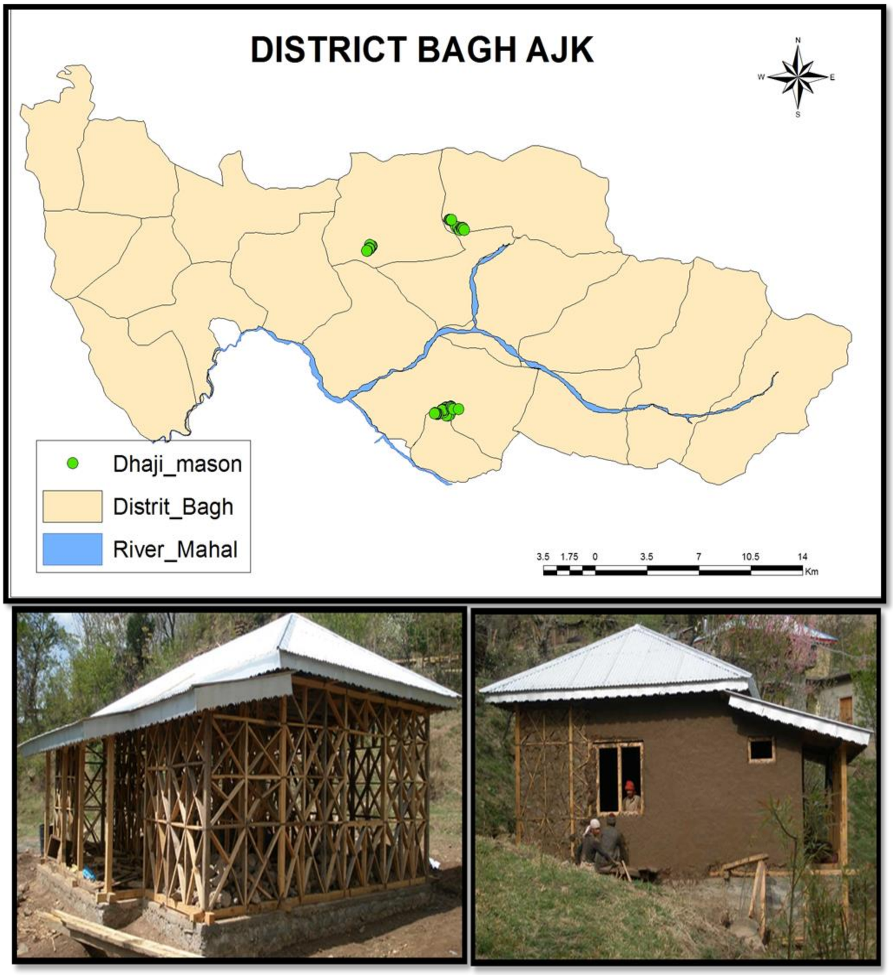


Figure 7. ***Dhajji*** **Masonry**

4. CONCLUSION

This study revealed the results of housing typology in the surveyed area. Selected parts of Bagh Azad Kashmir have been selected to gather the data of types of building and their numbers from 19 union councils and 30 villages. Categorization of building depends upon the combination of materials used and structural system of roof and walls. The key findings of the study revealed that there are 4 major types of the buildings in the surveyed area. It has been observed that building under Government used were engineered, while all other all non-engineered buildings. The types of buildings were different and reliant on the locally convenience of resources and local skills. Furthermore, block masonry buildings with contained sloping wavy GI sheet roof and stone masonry buildings with wooden earthen roofs are the widely-used buildings in most of the areas with similar proportions in the existing building stock. Moreover, the construction material used for buildings of walls, were made up of mud, blocks, stones and bricks, while the roof comprised of iron sheet, wooden roof, Reinforced Concrete (RC) respectively. Overall, it was concluded that the maximum proportion of engineered building was relatively low and/or an approximately 90% of buildings were constructed non-engineered design in district Bagh. It is the ultimate duty of the residents and the Government that they should prepare for the earthquake beforehand, and they should be aware of usage of construction material for building their houses which ultimately reduces the risk of casualties and damages of the houses. Manifestly, awareness and knowledge of earthquakes have an optimistic influence on the disaster preparedness of inhabitants living in earthquake-prone regions. Subsequently, government agencies should enhance the earthquake education of the residents as part of the national effort to mitigate the adverse effects of future earthquakes. As a way forward authors are working to correlate the impact of the earthquake on different masonry in the area which will further established the role of construction material as a preventive measure of the earthquakes.

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