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(Research Article)

Adapting Rapid Visual Screening (RVS) for Seismic risk assessment in developing countries: a case study of Dir City, Pakistan

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Abstract

Frequent seismic activity in Pakistan, exemplified by the devastating 2005 Kashmir earthquake, underscores the need for robust methods to assess building vulnerability. This study focuses on adapting FEMA's Rapid Visual Screening (RVS) methodology for application in developing countries like Pakistan, with Dir City which is situated in Zone III according to seismic hazard maps of Building Code of Pakistan in Khyber Pakhtunkhwa serving as a case study. The majority of the city's structures are old, non-engineered and were built by local masons, therefore they could be in danger during a seismic event. Recognizing local challenges, the FEMA Data Collection Form was modified to incorporate region-specific attributes such as slope, foundation type, liquefaction potential, and structural configurations, including unreinforced masonry, confined masonry, stone masonry, and RC frames with URM infill. The methodology emphasizes the use of score modifiers to account for material and construction practices unique to the region. This paper discusses the adaptation process, challenges in implementing RVS in resource-limited settings, and the importance of localized frameworks for seismic risk assessment. The study aims to provide a methodological foundation for future efforts to enhance seismic resilience in high-risk zones.

Keywords: Seismic Risk Assessment; Rapid Visual Screening (RVS); FEMA Data Collection Form; Earthquake Vulnerability; Seismic Resilience; Building Vulnerability

1. Introduction

Earthquake fault motion is driven by frictional sliding along a fault plane, where tectonic forces gradually overcome frictional stress, initiating an earthquake. This cycle involves tectonic stress building up until it surpasses frictional stress, causing fault motion, after which stress falls below friction, halting movement until the cycle repeats. This process of stress accumulation and sudden release at critical stress points leads to earthquakes [1].

Earthquakes have significant impacts, especially in urban areas, leading to structural damage and fatalities. The primary effects include ground shaking, surface faulting, and other ground deformations caused by tectonic activity, while secondary effects, such as tsunamis, liquefaction, and landslides, further exacerbate the damage [2]. Notable examples include the 2004 Sumatra-Andaman earthquake, the 2005 Kashmir earthquake, and the 2015 Hindu Kush earthquake, which caused widespread destruction [3].

Pakistan, located in a seismically active zone, is particularly vulnerable to earthquakes, with historical events such as the 1905 Kangra earthquake, the 2005 Kashmir earthquake, and the 2015 Hindu Kush earthquake. These events caused substantial damage and loss of life, highlighting the need for measures to reduce seismic vulnerability [4]. The region experiences frequent earthquakes, and the risk of high-magnitude events, especially in the Himalayan region, remains significant [5].

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Seismic vulnerability refers to the likelihood of a building sustaining damage during an earthquake. It depends on factors like seismic resistance, exposure to hazards, and building design. Vulnerability can be assessed using various methods, including analytical and visual screening techniques. While analytical methods like SPECTRA, HAZUS, and ATC-20 offer detailed analysis, they require significant time and expertise [6]. In contrast, visual screening methods, such as the Rapid Visual Screening (RVS) approach proposed by FEMA, offer a quicker way to assess a large number of buildings and determine their seismic risk [7].

Effective seismic risk mitigation can be achieved through proper building design and adherence to modern seismic codes, which help reduce structural vulnerabilities and minimize the potential for damage during earthquakes [8].

2. Rapid Visual Screening

Rapid Visual Screening (RVS) is a technique used to identify, inventory, and assess the seismic vulnerability of buildings. It is particularly useful for large-scale assessments by agencies and organizations. RVS can be carried out by professionals with a basic understanding of construction and structural design, such as civil engineers, architects, or contractors [10]. The methodology is based on correlating structural typology, such as frame buildings or masonry structures, with their expected seismic performance [11].

RVS assigns a basic structural score to buildings, which is adjusted using modifiers to account for specific vulnerabilities, including vertical irregularities, soil type, and building age [12]. The assessment does not require complex structural analysis, making it a time-efficient screening method. Each building is typically assessed in 30 to 45 minutes, though additional time is required for deeper assessments [10].

The basic score is influenced by regional seismic design practices and ground shaking levels, with buildings receiving higher scores indicating greater resistance to earthquakes. Lower scores highlight buildings that may need further evaluation or retrofitting [10]. RVS results are used to classify buildings based on their seismic risk, prioritizing those for further analysis or mitigation [13].

Damage grades, which are linked to RVS scores, help determine the extent of potential earthquake damage. The system employs a classification of damage from Grade 1 (slight) to Grade 5 (severe), based on the European Macroseismic Scale [9]. RVS is applied to conventional building types but does not cover non-building structures like bridges or towers. It is often used for high-risk building types such as unreinforced masonry or nonductile concrete structures [10].

3. Methodology

The methodology for this study involved the rapid visual screening (RVS) of buildings in Dir City to assess their seismic vulnerability. Spectral acceleration values for Dir City were derived from FEMA-154, with Ss = 1.1123g and S1 = 0.4104g, indicating high seismicity [10]. The soil type was classified as Soil Type B, based on a Vs30 value greater than 760 m/s [14]. For each building, essential details were recorded, including address, owner information, dimensions, number of stories, story height, foundation type, structural system, seismic design code (set to 2005), and any observed irregularities. The buildings were categorized by their structural systems: RC frame with URM infill, confined masonry, stone masonry, and unreinforced masonry.

Geologic hazards such as surface fault rupture, landslides, and liquefaction were assessed, with landslide vulnerability identified in some buildings. Irregularities, both plan and vertical, were noted, along with any exterior falling hazards like parapets and chimneys.

The data collection forms were filled with relevant observations, and the seismic vulnerability of buildings was evaluated using the modified FEMA basic scores for each building type. Concrete frame buildings with URM infill (C3) used the standard FEMA scores, while adjustments were made for URM and confined masonry buildings to reflect local construction practices. The final basic scores for each building type were recorded and used to assess seismic performance.

4. Results and Discussions

A total of 100 buildings in Dir City were surveyed, and their coordinates were plotted on OSM map using QGIS as shown in Figures 1. The surveyed buildings were categorized based on locality, age, and occupancy type, including residential, commercial, governmental, and religious buildings. Table 1 summarizes the distribution and age of buildings, while

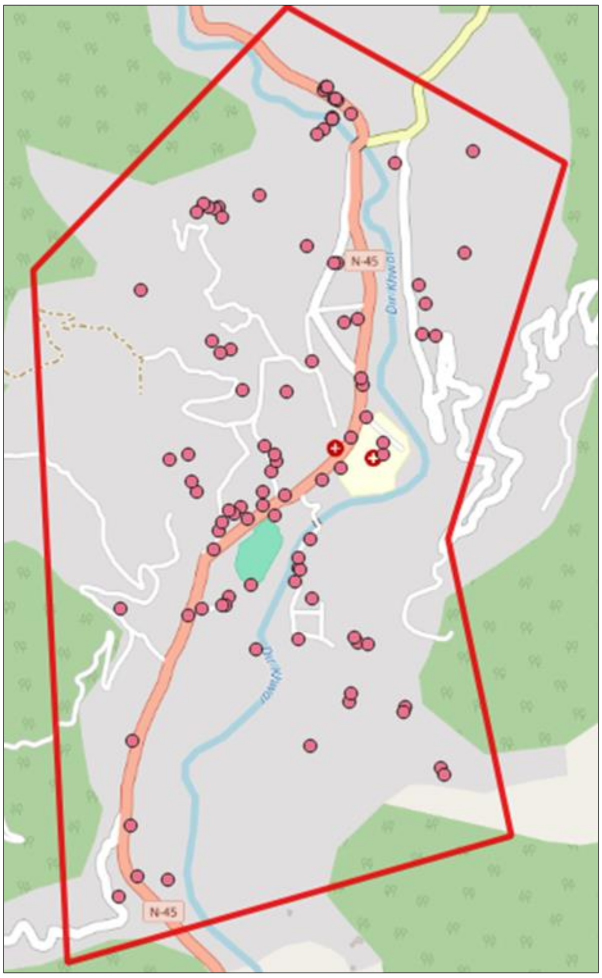

Figure 1 OpenStreetMap (OSM) showing surveyed building locations in Dir City

Table 1 Building Quantity and Age Breakdown

Locality	**Number of Buildings**		**Age of Buildings**			
	Numbers	Percentage	≤10	10 - 25	25 - 40	>40
Rehan Kot Payyan	13	13	6	2	2	3
Kalshow	12	12	7	4	0	1
Main Dir Bazar	12	12	3	7	0	2
Pharao Sha	12	12	5	4	3	0
Kas	9	9	7	2	0	0
Jasmin Town	10	10	1	7	2	0
Shao	10	10	2	2	3	3
Bijli Ghar	8	8	1	3	1	3
Rehan Kot Bala	7	7	6	0	0	1
College Colony	7	7	0	0	5	2
Total	100	100	37	31	16	15

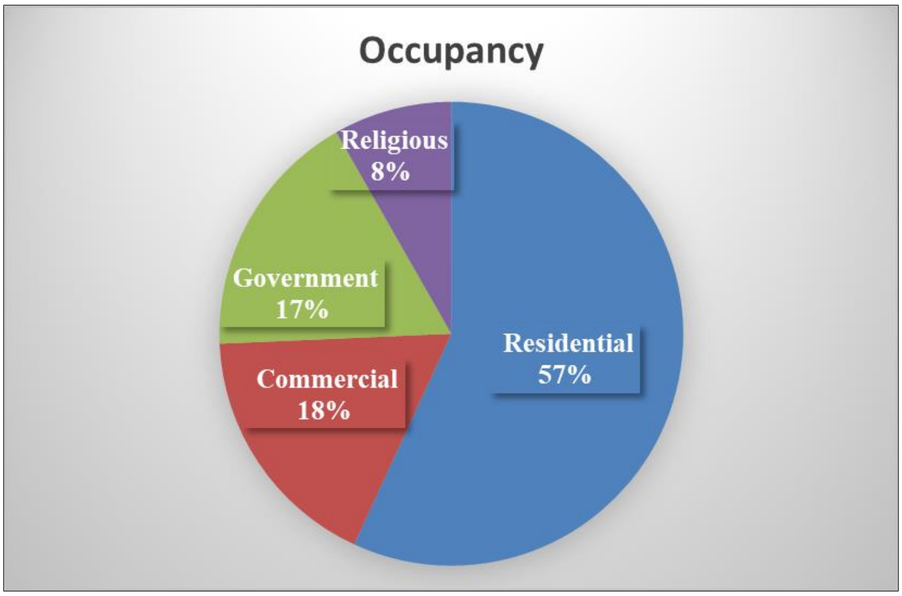

Figure 2 Occupancy of Surveyed Buildings

The survey covered a total of 100 buildings across various localities (mohallas) in Dir City, with a uniform distribution ensuring comprehensive coverage. These buildings, categorized by age and occupancy type, represent a wide range of structural characteristics across the city. The selection process aimed for a diverse sample, including residential, commercial, governmental, and religious buildings, ensuring a balanced representation of the city's built environment as shown in Figure 2. The distribution spans different age groups, with buildings ranging from newly constructed to those over 40 years old, reflecting a mix of older and newer structures in need of seismic assessment.

Buildings were further analyzed based on structural and geometric characteristics, such as structure type (engineered, semi-engineered, and non-engineered) and story height. Floor and roof types, seismic bands (plinth, lintel, and roof), and site slope were also recorded. Tables 2 depict the structural type and story height distribution of surveyed buildings. The structural systems included confined masonry, stone masonry, reinforced concrete frames, and unreinforced masonry (Figure 3).

Table 1 Structure Type and Story Height

Locality	**Structure Type**			**Story Height**			
	Engineered	**Semi Engineered**	**Non-Engineered**	**≤9**	**9 -10**	**10-11**	**>11**
Rehan Kot Payyan	1	2	9	1	3	7	2
Kalshow	1	1	10	1	6	3	2
Main Dir Bazar	9	1	3	2	3	5	2
Pharao Sha	4	1	7	0	4	6	2
Kas	2	1	6	1	5	2	1
Jasmin Town	1	2	7	0	4	5	1
Shao	0	0	10	3	5	2	0
Bijli Ghar	0	1	7	2	1	2	3
Rehan Kot Bala	0	0	7	2	3	2	0
College Colony	3	4	0	0	2	4	1
Total	21	13	66	12	36	38	14

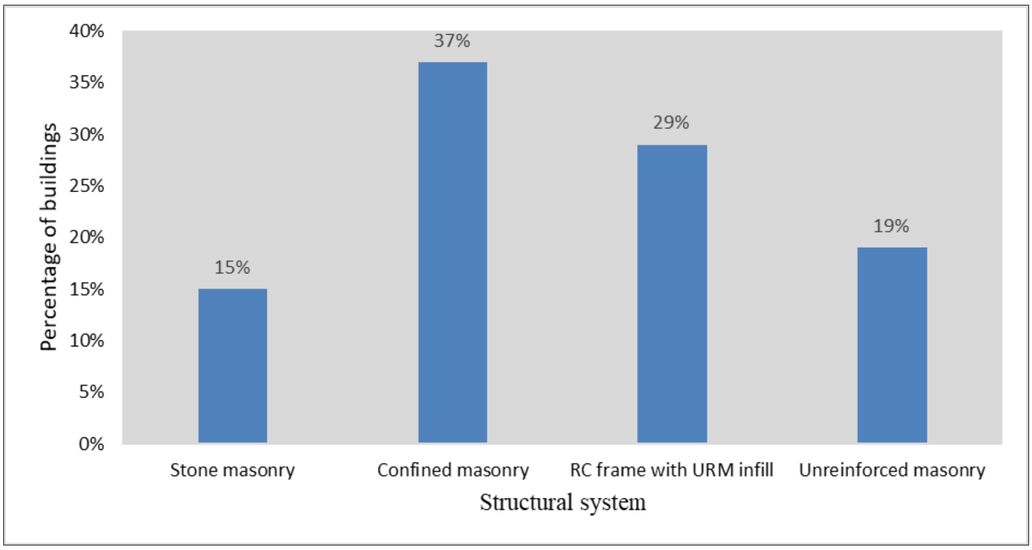

Figure 3 Percentage of Buildings Vs Structural System

The survey of Dir City buildings shows a diverse mix of structural types and story heights, reflecting varying seismic vulnerabilities. The majority (66%) of buildings are non-engineered, followed by semi-engineered (13%) and engineered (21%) structures. This suggests a reliance on traditional construction, which may not be resilient during earthquakes. Most buildings (36%) are between 9 and 10 stories tall, with some exceeding 11 stories (14%), indicating potential seismic risks due to height.

The variety of structural systems, including confined masonry, stone masonry, and reinforced concrete frames, highlights the diverse construction practices. The survey's uniform distribution across localities ensures a representative sample, providing a clear view of the city's seismic vulnerabilities. These results stress the importance of improving seismic resilience, particularly for non-engineered buildings.

	
Figure 4 Cracks in Wall of a Residential Building at Muhala Shao, Dir City	**Figure 5** Damage in Lawari House Boys Hostel Dir College

Visual inspections identified seismic vulnerabilities like cracks, leaning walls, and irregularities in plan or elevation as presented in Figures 4 to 8. The visual inspections revealed several seismic vulnerabilities, including cracks, leaning walls, and structural irregularities in both plan and elevation, as shown in Figures 4 to 8. These issues are indicative of potential weaknesses that could compromise the structural integrity of the buildings during an earthquake. Cracks and deflection observed in some buildings are concerning, as they can signal early signs of structural failure or poor construction practices. The presence of leaning walls further exacerbates the seismic risk, as they may not effectively resist lateral forces during an earthquake.

	
Figure 6 Collapse of a Room in Residential Building at Muhala Kalshow, Dir City	**Figure 7** Dampness a Residential Building at Muhala Shao, Dir City

Figure 81 Cracks in Lecturers Hostel Dir College, Dir City

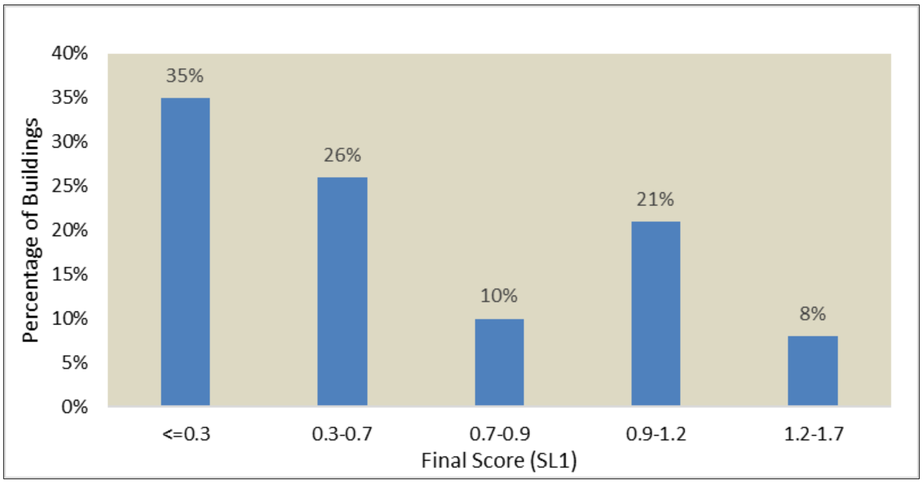

Figure 9 Percentage of buildings Vs Final Score (SL1)

As shown in Figure 9 the results show that 35% of the buildings have a final score of 0.3 or lower, indicating a relatively low seismic risk. A further 26% have scores between 0.3 and 0.7, 10% fall within the 0.7 to 0.9 range, and 21% have scores between 0.9 and 1.2. The remaining 8% of buildings have scores ranging from 1.2 to 1.7, suggesting a higher vulnerability to seismic events. These findings emphasize the need for targeted risk mitigation measures, particularly for the buildings with higher seismic risk scores.

5. Conclusions and recommendations

- 100 buildings in Dir City were surveyed, revealing significant seismic vulnerabilities, particularly in non-engineered buildings (66%), which pose a high risk due to poor earthquake resistance design.
- Structural irregularities, such as plan and vertical irregularities, are common, especially in residential buildings, which require prioritization for retrofitting.
- 17% of buildings have sustained damage, highlighting the need for urgent repairs.
- Most buildings have story heights between 9 and 11 feet, RCC foundations, and varying roof types, which influence seismic resilience.
- The government should enforce strict building regulations, especially for structures on slopes, and launch retrofitting programs for non-engineered buildings. Regular inspections and public awareness campaigns are essential.
- Financial incentives for retrofitting and establishing emergency preparedness plans are crucial.
- Residents should facilitate building assessments, retrofit properties, and ensure compliance with seismic standards. Emergency kits and family plans should be prepared.
- Researchers should conduct in-depth screenings, material studies, and explore modern technologies like seismic isolation systems, while collaborating with local communities and authorities.

Compliance with ethical standards

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Conflict of Interest

The authors declare that they have no conflicts of interest related to this research, its findings, or its publication.

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