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RAPID VISUAL SCREENING METHOD FOR RC BUILDING STRUCTURES

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Abstract

The destruction caused by recent earthquakes worldwide highlights the urgent need to assess buildings, especially those in medium-high-seismic-prone areas. Over the past few decades, advances in earthquake engineering have led to new methods to evaluate the hazard levels in buildings. Several seismic evaluation methods have been developed across the world. One such method, which is both rapid and cost-effective, is Rapid Visual Screening (RVS). In this paper, a detailed investigation has been done on the developed RVS methodologies in the field. Seismic evaluation guidelines from, the USA, Canada, Japan, and New Zealand, are reviewed from the perspective of their applicability. Each method is briefly outlined, highlighting its key features, applications, and contributions to seismic vulnerability assessment of RC building structures. According to most of the guidelines used worldwide, the work of various researchers was also presented.

Keywords: rapid visual screening (RVS), RC structues, assessment, methodolgies, scale, rapid, preliminary, detailed

1. Introduction

It is well known that as a consequence of earthquakes there is ground motion experienced on the surface resulting from the transmission of energy waves released from source and then undergoing certain modifications while travelling through soil layers as the energy reaches the earth surface. Many of these are of small intensity and do not cause significant damage to structures. However, there are cases when earthquakes of larger intensity in the urban areas cause considerable damage to the buildings and sometimes even a loss of life. During the last few decades, the urban areas have experienced very rapid population growth due to economic factors, such as the decrease in economic opportunities in rural areas, resulting in migration to urban areas. As a result of this migration, rapid construction in urban areas often leads to the spread of poorly designed and constructed buildings. Additionally, the older buildings were built to the relevant standards at the time of their construction and may not comply with the requirements of the latest building codes and standards. These buildings are at greater risk of considerable damage during a future earthquake, which can pose significant risks to human life and result in substantial economic losses in densely populated areas. Meanwhile, reinforced concrete (RC) buildings are among the most populated construction types in many developing countries. Most developing countries have emphasized the need to assess the seismic vulnerability of buildings in urban areas as an essential component of a comprehensive earthquake risk management policy. There are many methods available for seismic assessment of structures, which need a lot of time, cost, effort, a complex technical background, and procedure. Alternative methods have been developed to filter and prioritize buildings for a comprehensive, time- and resource-saving evaluation. These range from the most complex procedures to simpler ones. Amongst the simplified ones, Rapid Visual Screening (RVS) methodologies have been recently developed and proposed and their application is particularly useful in regions characterized by high seismicity or where a significant part of buildings are not designed according to seismic provisions. Rapid visual screening (RVS) is the basic key to measuring the seismic capacity of buildings. RVS helps to quickly categorize buildings into risk levels based on factors such

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as building height, structural system, age, condition, and irregularities, and it provides a framework for identifying those at higher risk of significant damage during an earthquake. By identifying vulnerable buildings early, RVS enables authorities to focus their efforts on structures that need urgent attention, ensuring that the most at-risk buildings are prioritized for retrofitting or detailed evaluation.

2. Approaches to seismic vulnerability assessment

Over the past few decades, RVS has become an essential approach for quickly identifying vulnerable buildings, particularly in areas with a large number of older structures or those that do not meet modern seismic standards. The Rapid Visual Screening, (RVS) methodology has undergone several adaptaions and improvements, over the years to increase its accuracy and applicability. Fig. 1 illustrates the chronological evolution of widely used RVS methods for assessing seismic vulnerability which can be broadly divided into two categories:

a) Instrumental and quantitative data-based techniques

These methods rely on sophisticated instruments (e.g., accelerometers) to gather detailed quantitative data on the building's seismic performance.

b) Methods combining quantitative and qualitative data

This category includes the RVS method which uses a combination of visual inspection (qualitative data) and basic measurements (quantitative data) to assess a building's seismic vulnerability.

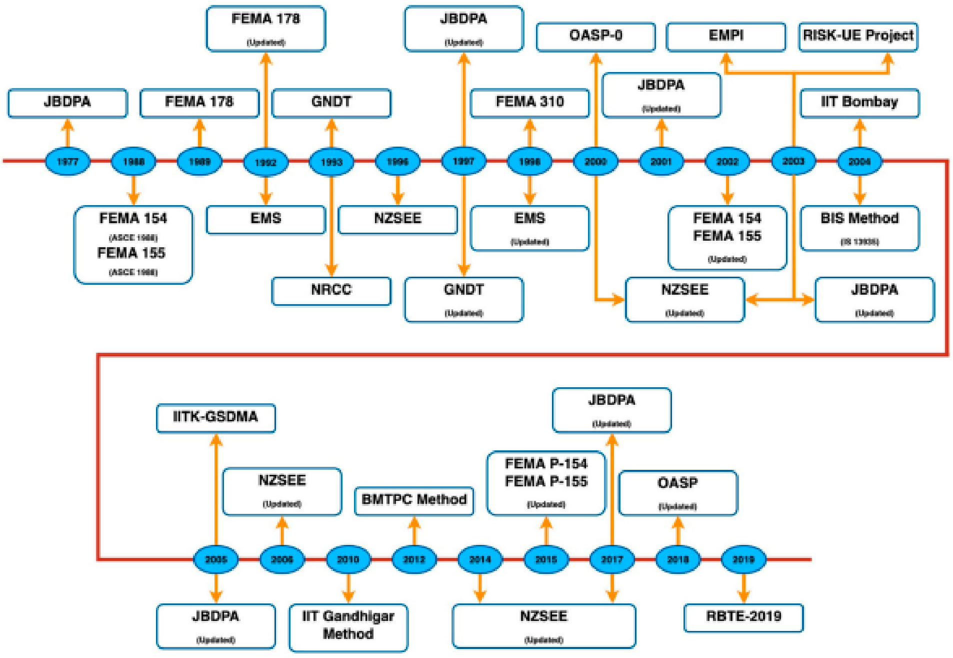

Figure 1. Timeline graphic of the development of the RVS methods

JBDPA: Japan Building Disaster Prevention Association
ASCE: American Society of Civil Engineering
GNDT: Gruppo Nazional per la Difesa dai Terremoti (National Earthquake Protection)
NZSEE: New Zealand Society for Earthquake Engineering
EMPI: Earthquake Master Plan of Istanbul
BMTPC: Building Materials and Technology Promotion Council
FEMA: Federal Emergency Management Agency
EMS: European Macro-seismic Scale
NRCC: National Research Council of Canada
OASP: Earthquake Planning and Protection Organization
IITK-GSDMA: Indian Institute of Technology Kanpur – Gujarat State Disaster Mitigation Authority

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2.1 Application scales of seismic vulnerability assessment methodologies

The choice of methodology primarily depends on the number of buildings under assessment and the level of detail required. Based on the scale of applications the assessment procedures can be classified into three groups, as is illustrated in Fig. 2: a) single building scale, b) building stock scale, and c) large scale.

Figure 2. Different scales of the seismic vulnerability assessment procedures: (a), (b) & (c)

At the single building scale, the assessment focuses on evaluating the seismic vulnerability of individual structures. This method provides the most detailed analysis of a building's structural integrity and its ability to withstand seismic forces. It typically requires in-depth inspection, detailed design reviews, and sometimes the development of complex numerical models, including finite element analysis. This level of assessment is often used for high-value or high-risk buildings, where the cost of failure would be catastrophic.

At the building stock scale, the assessment aims to evaluate the seismic vulnerability of a group of buildings within a specific urban zone or district.

The approach begins by identifying sample buildings that represent the main building typologies within the area. These buildings act as representative models for the broader building stock, considering various factors such as the construction material, structural system, and the age of the buildings.

The second step in this process involves applying the vulnerability values from the sample buildings to the other structures in the zone by referring to their characteristics. This method allows for a more generalized but still relatively accurate assessment of a larger number of buildings, and it is useful for understanding the overall seismic risk in a particular area.

In large-scale applications, the methodology is employed to assess seismic vulnerability across an entire city or region. This involves the assessment of a large number of buildings over a wide area, often using simplified methods, such as Rapid Visual Screening (RVS), to evaluate large building stocks quickly. Large-scale assessments are generally used for city-wide seismic risk mapping and urban planning, where the goal is to prioritize interventions and resources for retrofitting or improving building codes across a broad geographic area [1].

3. Review of RVS documents

Rapid Visual Screening (RVS) methodology was first developed by "Applied Technology Council" in the late 1980's and published in FEMA 154 in 1988 by the United States as a standard guideline methodology for rapid vulnerability assessment. Several national seismic codes were further developed by various other countries worldwide, each of them being specific to local factors of construction methods and design philosophies.

The common RVS methodologies adopted by various countries across the globe include: RVS by the USA (FEMA), Rapid Evaluation method by the New Zealand Society of Earthquake Engineering (NZSEE), RVS by Canada developed by the National Research Council (NRC), Japanese method developed by the Japanese Building Disaster Prevention Association (JBDPA), Greek method by Earthquake Planning and Protection Organization (OASP), Indian approach based on FEMA 154

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developed by IIT Kanpur, Turkish method developed by the Structural Engineering Research Unit (TERU), and the Italian method by the National Earthquake Defense Group (GNDT) all of which serve as approximate seismic vulnerability assessment techniques. These methodologies typically involve a three-level procedure: rapid, preliminary, and detailed assessments.

Rapid Visual Screening (RVS) is the initial stage of the assessment process, aimed at quickly evaluating a large number of buildings to determine their level of seismic risk. This stage involves visual inspections of buildings to identify key structural and non-structural vulnerabilities that may affect their performance during an earthquake. Following RVS, buildings identified as having significant seismic vulnerabilities undergo a more detailed preliminary assessment. PVA involves more comprehensive evaluations, including structural analysis and assessment of specific vulnerabilities identified during the RVS stage. Buildings requiring further consideration based on RVS and PVA results are subject to a detailed vulnerability assessment. DVA involves in-depth structural analysis, often utilizing advanced engineering techniques and computer modeling, to assess the building's behavior under seismic loading.

Throughout the years, numerous studies have been conducted to develop a more accurate and efficient Rapid Visual Screening (RVS) approach, primarily in seismically active regions.

One such study by Moustafa Moufid Kassem et al. (2020) [2], presents a comprehensive review of seismic vulnerability assessment methodologies. This review provides a detailed examination of the most common empirical and analytical techniques, summarizing findings from various research works. It also discusses the history and basic concepts of vulnerability assessment, screening procedures, the development of screening techniques, and the advancements in technology.

In another study, Mohd Danish et al. (2014) review the Rapid Visual Screening (RVS) method, highlighting its speed and cost-effectiveness. The study explains how the RVS score is calculated and assessed for various purposes related to seismic risk mitigation. It emphasizes the importance of RVS as a tool for identifying buildings that require further simplified vulnerability assessments and for identifying critical structures that need more detailed evaluations. This approach helps prioritize buildings for retrofitting or additional analysis, ultimately reducing seismic risks [3].

3.1. The method of the U.S.A. by the Federal Emergency Management Agency

The RVS methods that were developed for the seismic assessment of buildings in the United States consist of FEMA 154 and FEMA 155 which was first published in 1988 and revised in 2002. In January 2015, FEMA issued a third edition of procedures for FEMA P-154 and FEMA P-155.

The FEMA P-154 Rapid Visual Screening (RVS) method incorporates two levels of screening forms, Level 1 and Level 2, tailored for each seismicity region, which can be classified as moderate, moderately high, high, and very high.

- Level 1 screening form in the first section of the data collection form includes public information about the building, such as address, location, usage, and construction date, along with scores for various parameters based on the building type.

- Level 2 screening form is more detailed, including additional screening measures (SMs) for evaluating the final score (FS), and it requires a more qualified screener. While it is optional, it provides a more comprehensive assessment. At the end of the Level 2 screening, some nonstructural screening properties are also considered.

This two-tiered approach allows flexibility in the level of detail and expertise required, making it easier to comprehensive seismic risk assessments depending on needs and available resources.

The FEMA P-154 method provides forms for different seismicity regions, with the appropriate form selected based on seismic classification as shown in Fig. 3.

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Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA P-154 Data Collection Form

Level 1
HIGH Seismicity

PHOTOGRAPH

Address: ______ **Zip:** ______
Other Identifiers: ______
Building Name: ______
Use: ______
Latitude: ______ **Longitude:** ______
S_S: ______ S_1: ______
Screener(s): ______ **Date/Time:** ______

No. Stories: Above Grade: ____ Below Grade: ____ **Year Built:** ____ ☐ EST
Total Floor Area (sq. ft.): ____ **Code Year:** ____
Additions: ☐ None ☐ Yes, Year(s) Built: ____

Occupancy: Assembly, Commercial, Emer. Services, ☐ Historic, ☐ Shelter, Industrial, Office, School, ☐ Government, Utility, Warehouse, Residential, # Units: ____

Soil Type: ☐A Hard Rock ☐B Avg Rock ☐C Dense Soil ☐D Stiff Soil ☐E Soft Soil ☐F Poor Soil **DNK** *If DNK, assume Type D.*

Geologic Hazards: Liquefaction: Yes/No/DNK Landslide: Yes/No/DNK Surf. Rupt.: Yes/No/DNK

Adjacency: ☐ Pounding ☐ Falling Hazards from Taller Adjacent Building

Irregularities: ☐ Vertical (type/severity) ____ ☐ Plan (type) ____

Exterior Falling Hazards: ☐ Unbraced Chimneys ☐ Heavy Cladding or Heavy Veneer ☐ Parapets ☐ Appendages ☐ Other: ____

COMMENTS:

SKETCH

☐ Additional sketches or comments on separate page

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}

FEMA BUILDING TYPE	Do Not Know	W1	W1A	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM	MH
Basic Score		**3.6**	**3.2**	**2.9**	**2.1**	**2.0**	**2.6**	**2.0**	**1.7**	**1.5**	**2.0**	**1.2**	**1.6**	**1.4**	**1.7**	**1.7**	**1.0**	**1.5**
Severe Vertical Irregularity, V_{L1}		-1.2	-1.2	-1.2	-1.0	-1.0	-1.1	-1.0	-0.8	-0.9	-1.0	-0.7	-1.0	-0.9	-0.9	-0.9	-0.7	NA
Moderate Vertical Irregularity, V_{L1}		-0.7	-0.7	-0.7	-0.6	-0.6	-0.7	-0.6	-0.5	-0.5	-0.6	-0.4	-0.6	-0.5	-0.5	-0.5	-0.4	NA
Plan Irregularity, P_{L1}		-1.1	-1.0	-1.0	-0.8	-0.7	-0.9	-0.7	-0.6	-0.6	-0.8	-0.5	-0.7	-0.6	-0.7	-0.7	-0.4	NA
Pre-Code		-1.1	-1.0	-0.9	-0.6	-0.6	-0.8	-0.6	-0.2	-0.4	-0.7	-0.1	-0.5	-0.3	-0.5	-0.5	0.0	-0.1
Post-Benchmark		1.6	1.9	2.2	1.4	1.4	1.1	1.9	NA	1.9	2.1	NA	2.0	2.4	2.1	2.1	NA	1.2
Soil Type A or B		0.1	0.3	0.5	0.4	0.6	0.1	0.6	0.5	0.4	0.5	0.3	0.6	0.4	0.5	0.5	0.3	0.3
Soil Type E (1-3 stories)		0.2	0.2	0.1	-0.2	-0.4	0.2	-0.1	-0.4	0.0	0.0	-0.2	-0.3	-0.1	-0.1	-0.1	-0.2	-0.4
Soil Type E (> 3 stories)		-0.3	-0.6	-0.9	-0.6	-0.6	NA	-0.6	-0.4	-0.5	-0.7	-0.3	NA	-0.4	-0.5	-0.6	-0.2	NA
Minimum Score, S_{MIN}		*1.1*	*0.9*	*0.7*	*0.5*	*0.5*	*0.6*	*0.5*	*0.5*	*0.3*	*0.3*	*0.3*	*0.2*	*0.2*	*0.3*	*0.3*	*0.2*	*1.0*

FINAL LEVEL 1 SCORE, $S_{L1} \geq S_{MIN}$:

EXTENT OF REVIEW
Exterior: ☐ Partial ☐ All Sides ☐ Aerial
Interior: ☐ None ☐ Visible ☐ Entered
Drawings Reviewed: ☐ Yes ☐ No
Soil Type Source: ____
Geologic Hazards Source: ____
Contact Person: ____

LEVEL 2 SCREENING PERFORMED?
☐ Yes, Final Level 2 Score, S_{L2} ____ ☐ No
Nonstructural hazards? ☐ Yes ☐ No

OTHER HAZARDS
Are There Hazards That Trigger A Detailed Structural Evaluation?
☐ Pounding potential (unless S_{L2} > cut-off, if known)
☐ Falling hazards from taller adjacent building
☐ Geologic hazards or Soil Type F
☐ Significant damage/deterioration to the structural system

ACTION REQUIRED
Detailed Structural Evaluation Required?
☐ Yes, unknown FEMA building type or other building
☐ Yes, score less than cut-off
☐ Yes, other hazards present
☐ No

Detailed Nonstructural Evaluation Recommended? *(check one)*
☐ Yes, nonstructural hazards identified that should be evaluated
☐ No, nonstructural hazards exist that may require mitigation, but a detailed evaluation is not necessary
☐ No, no nonstructural hazards identified ☐ DNK

Where information cannot be verified, screener shall note the following: EST = Estimated or unreliable data OR DNK = Do Not Know

Legend: MRF = Moment-resisting frame; BR = Braced frame; RC = Reinforced concrete; SW = Shear wall; URM INF = Unreinforced masonry infill; TU = Tilt up; MH = Manufactured Housing; LM = Light metal; FD = Flexible diaphragm; RD = Rigid diaphragm

Figure 3. Data collection form for high seismicity region (FEMA, 2015)

The classification of levels of seismicity is based on the spectral response acceleration values, as shown in Table 1, where S_S the spectral response acceleration parameter for a 5%-damped maximum

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considered earthquake (MCER) at a period of 0.2 seconds, and S_1 is the spectral response acceleration parameter for a 5%-damped MCER at a period of 1 second, assuming Soil Type B.

Table 1. Range and median $MCER$ spectral response acceleration values in each seismic region

Seismicity Region	Range of Response Values for Each Region	Median Response Values for Each Region	Range of Response Values for Each Region	Median Response Values for Each Region
	$S_{S(g)}$	$S_{1(g)}$	$S_{S,\ avg\ (g)}$	$S_{1,\ avg\ (g)}$
Low(L)	S_S<0.25g	S_1<0.1g	0.2	0.08
Moderate (M)	0.25g≤S_S <0.5g	0.1g≤S_1<0.2g	0.4	0.16
Moderately High (M)	0.5g≤S_S <.1g	0.2g≤S_1<0.4g	0.8	0.32
High (H)	1g≤S_S<.1.5g	0.4g≤S_1<.0.6g	1.2	0.48

The assessment begins by selecting a suitable Basic Score for each building, which is derived from the building's general characteristics, such as its construction type and age. This Basic Score represents the initial evaluation of the building's seismic performance before accounting for specific vulnerabilities or mitigation measures. A lower Basic Score indicates higher vulnerability.

The classification of damage is then based on the Final Score, which incorporates additional screening measures and detailed evaluation. The Final Score, as outlined in Table 2, helps determine the extent of potential damage and the necessary steps for improving the building's seismic resilience.

Table 2. Structural scores with damage potential

Rapid Visual Screening Score	Damage Potential
S<0.3S	High probability of Grade 5 damage; Very high probability of Grade 4 damage
0.3<S<0.7	High probability of Grade 4 damage; Very high probability of Grade 3 damage
0.7<S<2	High probability of Grade 3 damage; Very high probability of Grade 2 damage
2.0<S<2.5	High probability of Grade 2 damage; Very high probability of Grade 1 damage
S>2.5S>2.5	Probability of Grade 1 damage

The Final Score (FS) is a crucial metric in assessing a building's seismic performance, determined by summing the Basic Score and adjustments from all applicable Score Modifiers. The Final Score ranges from 0 to 7, where: 0 indicates a potential for collapse and 7 signifies better expected seismic performance. The building categorization can be divided into the following ranges based on the final score (FS):

- **Acceptable Seismic Performance (2 < FS ≤ 7):** Buildings within this range are considered to have a level of seismic safety that is considered acceptable.

- **Seismically Hazardous (0 ≤ FS ≤ 2):** Buildings in this range are considered to be at risk and require further detailed assessment to understand the potential risks in case of seismic events. These buildings may not meet current seismic safety standards and could pose a significant risk in the event of an earthquake.

By evaluating and adjusting scores through this method, the Rapid Visual Screening (RVS) process offers a comprehensive assessment of a building's seismic vulnerability. This approach helps prioritize buildings for more detailed evaluations and necessary seismic upgrades, enhancing the overall safety and resilience of the built environment [4].

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The FEMA P-155 supports the RVS process, which is a preliminary assessment method used to quickly evaluate the seismic performance of buildings and identify those that require more detailed evaluation. For buildings identified as needing further evaluation, FEMA P-155 provides guidelines for conducting more comprehensive assessments and designing appropriate retrofits. The goal of FEMA P-155 is to help reduce the risk of earthquake damage and enhance the resilience of buildings, contributing to overall community safety and preparedness [5]. The steps of RVS survey for seismic vulnerability assessment (FEMA, 2015) are illustrated as in Fig. 4.

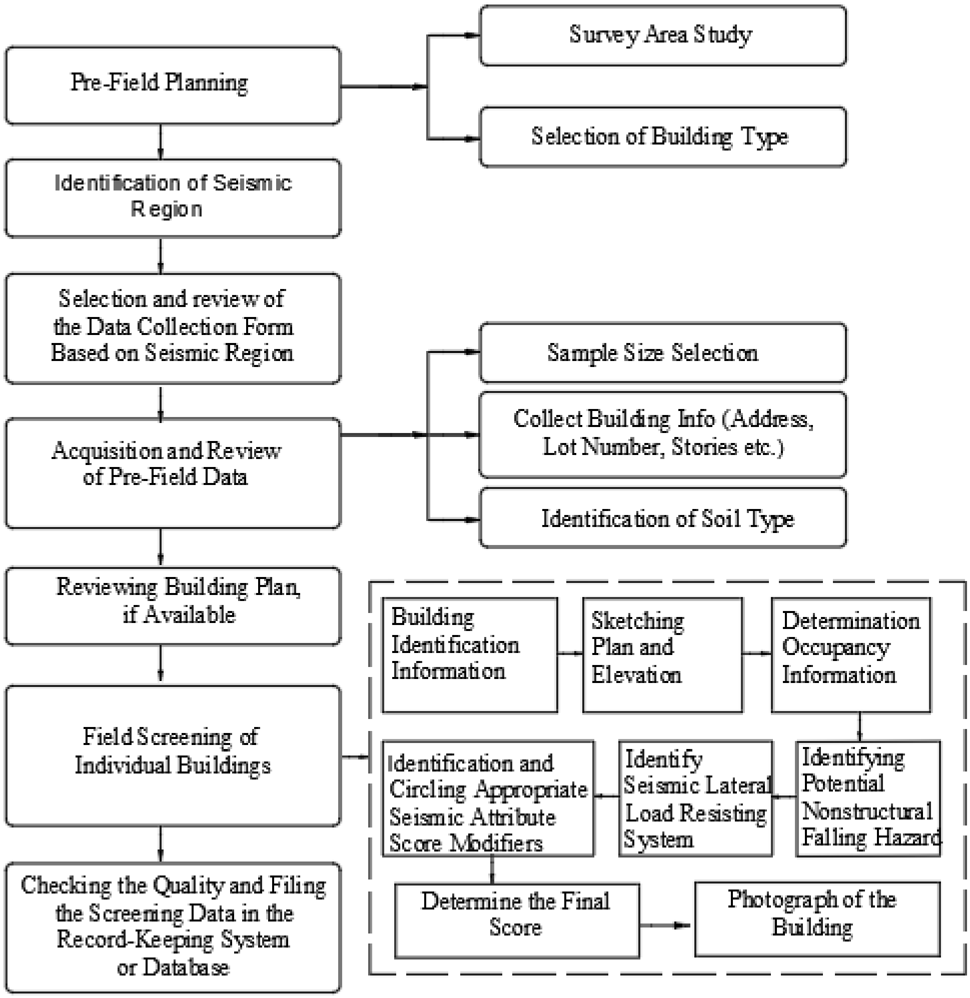

Figure 4. Steps of RVS survey for seismic vulnerability assessment (FEMA, 2015)

The RVS methods that were developed for the seismic assessment of buildings in the United States, have been widely used for seismic assessments by various researchers, as illustrated in studies such as those by Apostolska Roberta et al. (2017) [6,7], who conducted a comprehensive two-level, multi-group approach to assess the seismic performance of existing buildings in Karposh, a significant municipality in Skopje, Macedonia. The study began with rapid visual screening (level 1) on 161 buildings. For two case studies, various steps from the level 2 activities were implemented. The results indicated that the multidisciplinary approach led to a realistic assessment of the structural integrity of the buildings in relation to potential earthquakes.

Additionally, Nechevska-Cvetanovska Golubka et al. (2014) [8,9], introduced a methodology for geo-referenced inventory and monitoring of existing structures, with a focus on seismic stability and safety in the municipality of Karposh, Skopje. The methodology was applied to 161 buildings, using FEMA 154 level 1 rapid visual inspection steps. Three selected buildings were then analyzed further using FEMA 154 level 2 methods to assess seismic safety and stability.

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The review of RVS methods, including FEMA P-154 Level 1, FEMA P-154 Level 2, and the Indian and Bangladesh methods, was used to assess the seismic safety of 26 low-rise RC buildings in Mandalay, Myanmar, in a study by Moe Myat Myat Aung et al. (2021) [10]. Based on the results, the FEMA P-154 methods gave the highest risk estimates, which were found to be overestimated and are therefore not recommended. The Indian method was recommended for low-rise buildings, while the Bangladesh method was found to be more suitable for assessing high-rise buildings.

Furthermore, Sameh A. El-Betar et al. (2016) [11] applied a seismic evaluation to two case studies: one representing GLD buildings and the other representing buildings designed according to Egyptian codes. The study used Level 1 FEMA P-154 score modifiers and conducted pushover analysis to investigate the buildings' vulnerability. Simplified parameters were used to determine the safety index, and both structural and non-structural factors were considered in the evaluation.

3.2. Japanese Seismic Index Method by the Japanese Board of Disaster Prevention Association

The Japanese Board of Disaster Prevention Association (JBDPA) developed three-stage screening procedures for assessing the seismic vulnerability of buildings in Japan. This procedure was developed in 1977 and underwent revisions in 1990 and 2001. In the first screening stage, the seismic assessment is conducted with a simplified approach. The ultimate strengths of the vertical resisting members are used to quantify the structure's response behavior during lateral seismic loading. The second screening stage, a more comprehensive evaluation of seismic building capacity is conducted. This level considers not only the strength but also the ductility of the resisting members. While the third screening stage, represents the most detailed and comprehensive assessment. It considers not only the strength and ductility of columns and walls but also the strength and ductility of beams for evaluating the structural performance during the earthquake movements.

In the Japanese standard, the seismic performance of a building is expressed by the seismic index of the structure (IS-index), where for each story and in each principal horizontal direction of the structure the calculation is done based on the product represented by Eq. (1):

$$IS = EO * SD * T \tag{1}$$

Where, (EO), is basic seismic index, (SD), is irregularity index and (T), is time index.

The basic seismic index of structure (EO) for different screening levels, calculated differently, however, is generally approximated by multiplying the shear modification factor, strength index and ductility index of each story. The irregularity index (SD) is introduced to adjust the basic seismic index by measuring the effects of horizontal and vertical shapes, and the mass and stiffness irregular distribution of the structure following engineering judgment. The time index (T) considers the effects of cracks, deflection, and aging of building. Once the Seismic Index of Structure (IS) is determined, it is compared with the Seismic Demand Index (ISO) using Eq. (2):

$$ISO = ES * Z * G * U \tag{2}$$

Where, (ES) for the first level of assessment is taken as 0.8 and 0.6 for the second and third levels; (Z) represents the seismicity of the region corresponding to the building's location; (G) symbolizes the ground index and (U) the usage index. There are two possibilities in comparing IS and IS0, in the first one, if: IS > IS0, this means it has low vulnerability condition, and for the second one, if IS < IS0 it will correspond to high vulnerability condition [12].

The Japanese seismic assessment procedures, based on the seismic index, are widely used by researchers, such as those outlined by Ercan IŞIK et al. (2015) [13]. In their study, the Japan Seismic Index Method was applied alongside the Canadian Seismic Screening Method and the Turkish First Stage Evaluation Method to assess a building damaged during the 2003 Bingöl earthquake. The building, a three-story structure constructed in the 1990s, sustained significant damage during the May 2003 Bingöl earthquake. Each method was used separately to calculate the building's performance score, and the results were found to be identical.

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3.3. Canada Seismic Screening Method by the National Research Council

The methodology widely used in Canada for screening buildings for seismic investigation is outlined in the "Manual for Screening of Buildings for Seismic Investigation," published in 1993 by the National Research Council (NRC).

The methodology utilizes a scoring system similar to FEMA 154 but focuses on different factors. By considering these additional factors, the NRC approach enables a more comprehensive analysis of the consequences of building failure. Its purpose is to establish a Seismic Priority Index (SPI), which serves as a ranking system for buildings based on their seismic vulnerability.

The Seismic Priority Index is calculated by combining two indices: the Structural Index and the Non-Structural Index. The structural index (SI) considers a range of parameters related to seismicity, soil conditions (ground motions), structure type, structural irregularities, and building importance.

In contrast, the non-structural index (NSI) focuses on life safety against falling hazards in post-disaster scenarios, building importance, and soil conditions. SI is the structural index developed based on the product of five parameters.

These parameters along with their corresponding letters are: (A) seismicity index; (B) soil conditions; (C) type of structure; (D) building irregularities; and (E) importance of the building; (F) Max (F_1, F_2): (F_1) Failing Hazards to life; (F_2) Hazards to vital operations. Each of the parameters is calculated using the coefficient that is given in the Seismic Examination Method of Canada.

In first step, the structural index (SI) is calculated based on the product represented by Eq. (3):

$$SI = A * B * C * D * E * F \tag{3}$$

The non-structural index (NSI) which is the product of three parameters (B), (E), and (F) is calculated based on Eq. (4):

$$NSI = B * E * F \tag{4}$$

Where, F is the maximum value between F_1 for falling hazards to life and F_2 for hazard to vital operations. The formula for calculating the Seismic Priority Index (SPI), which is the sum of the Structural Index (SI) and the Non-Structural Index (NSI) is calculated based on Eq. (5):

$$SPI = SI + NSI \tag{5}$$

The score obtained by using the survey classifies the seismic vulnerability classes of the buildings as “low”, “medium”, and “high” seismic assessment stages. Then, the obtained results are the primary criteria that contributed to this screening score with the limit values given in Table 3:

Table 3. Priority levels for buildings in Canada Seismic Screening Method (Çelik, 2007)

Score type	Limit values	Priority Level
SPI	<10	Low priority buildings
SPI	10-20	Middle priority buildings
SPI	>20	High priority buildings
SPI	>30	Very hazardous buildings
SI/NSI	1.0-2.0	Sufficient seismic safety

If the SPI value of the evaluated building is less than 10, it is classified as “low”; if it is in the range from 10 to 20, it is classified as “medium”; and if the value is more than 20, then it is classified as being of the “high” seismic vulnerability class in terms of the priority of a further detailed assessment. A building constructed in compliance with the National Building Code of Canada (NBCC) is intended to have an SPI index score of 2.0. By considering these factors and calculating the SPI, this methodology

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provides a systematic approach to prioritize buildings for further investigation or retrofitting efforts aimed at improving their seismic stability [14].

In the study by Ibrahim Baran Karasin et al. (2016) [15], the Canadian Seismic Screening Method was applied to assess the seismic risk of 37 RC buildings in Ahlat, located in the Lake Van Basin, an area known for its high seismic activity in Turkey. According to the Canadian seismic regulations, the evaluation categorized the buildings as follows: 14% as low priority, 41% as medium priority, 35% as high priority, and 10% as very risky. This evaluation represents the first stage, aiming to determine the risk priority of the buildings and guide further detailed analysis.

3.4. Rapid evaluation method by the New Zealand Society for Earthquake Engineering

The seismic assessment procedures in New Zealand (2017) are based on guidelines provided by the New Zealand Society for Earthquake Engineering (NZSEE) which incorporates elements from the FEMA methodology.

The NZSEE recommends a two-stage seismic risk assessment procedure, consisting of an initial assessment phase (IAP), which is the rapid evaluation stage and a detailed seismic assessment phase (DSA), which consists of two parts: one for potential earthquake-prone buildings (EPBs) and one for non-EPBs only. The IAP procedure presents an initial evaluation phase of the existing buildings based on the new building design standards (NBS).

The New Building Standard (NBS) is derived based on the characteristic features, such as the design year, the previous retrofitting interventions, the building importance, the fault distance, the site soil properties, and the vertical and plan irregularities integrated into the building area.

The % NBS value is calculated using this information given in Table 4, providing an initial indication of the building's seismic performance.

Table 4. Priority levels for buildings in Canada Seismic Screening Method (Çelik, 2007)

% NBS	Building Status	Seismic Risk Assessment
%NBS < 33	Vulnerable	Requires detailed seismic assessment and possible retrofitting
33 ≤ %NBS ≤ 67	Moderate Risk	Requires a more sophisticated assessment than RVS to determine seismic performance
%NBS > 67	Acceptable Seismic Performance	Considered capable of withstanding future earthquakes: no immediate action needed

If the % NBS is less than 33, the building is considered vulnerable, requiring a more detailed assessment. If it's greater than 67, the building is deemed capable of withstanding future earthquakes. For % NBS values between 33 and 67, the structural system should be examined in a method that is more sophisticated than RVS.

The earthquake rating evaluation is given in Eq. (5):

$$NBS = (Ultimate\ Capacity\ Seismic)/ULS\ (Seismic\ Demand) * 100 \tag{5}$$

The DSA can be used to verify the accuracy of the results obtained from the Initial Assessment Procedure (IPA). If the IPA indicates a need for further evaluation, the DSA provides a more detailed and comprehensive analysis to confirm the initial findings [16].

The seismic assessment procedures in New Zealand (2017) are based on guidelines widely used in countries with high seismic risk, as discussed by Kapetana, P. et al. (2007) [17]. Their study provides an overview of various rapid visual screening methods developed in seismic-prone regions such as the

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USA, Greece, New Zealand, India, and Canada. These methods were applied to a sample of 456 reinforced concrete buildings in Athens, Greece, for which structural characteristics and damage levels from the 1999 Athens earthquake were already known. The earthquake caused 93 building collapses, 201 buildings sustained severe damage, 69 experienced moderate damage, and 93 had light damage. Each building was assessed using the scoring systems of the applied methods, resulting in eight different scores for each building. The study aimed to evaluate the reliability of these methods in identifying potentially seismically hazardous buildings.

4. Conclusion

Many structures in the current building stock, including reinforced concrete (RC) buildings, were constructed without considering seismic design standards, or with lower seismic design criteria, making them vulnerable to potential earthquakes. This paper highlights key factors that should be considered when selecting an appropriate seismic vulnerability assessment method for buildings. The Rapid Visual Screening (RVS) method is an effective tool for quickly assessing the seismic vulnerability of existing buildings. It provides a cost-effective and efficient way to identify RC structures and other structures that may need further detailed evaluation or retrofitting to reduce their seismic risk. By utilizing a set of predefined criteria, the RVS method helps prioritize buildings for more in-depth seismic analysis, ensuring that limited resources are directed toward the most critical structures at risk. This paper also provides a review of some of the most significant contributions to the field of vulnerability assessment.

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