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FIRST-LEVEL SEISMIC RISK ASSESSMENT OF REINFORCED CONCRETE PUBLIC BUILDINGS CONSIDERING HILLTOP AND SLOPE EFFECTS IN SAMSUN, TÜRKIYE

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Abstract. Rapid seismic risk assessment methods are critical for mitigating disasters in seismically active regions. This study presents the first-level seismic assessment methodology applied to reinforced concrete buildings within Samsun Province, Türkiye. The evaluation relies on a multi-parameter scoring system that accounts for structural typology, building age, and various architectural irregularities. By analyzing key parameters—such as soft stories, heavy overhangs, short columns, and pounding effects—this method provides a rapid, efficient framework for identifying high-risk structures. The findings provide a basis for urban resilience planning and prioritization of buildings requiring detailed seismic evaluation.

Keywords: Rapid Seismic Assessment, Reinforced Concrete, Samsun, Building Performance Score, Structural Irregularities

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1. Introduction. Türkiye is situated in one of the most seismically active regions in the world, making proactive structural evaluations a matter of public safety. While detailed structural simulations offer the highest accuracy, they are time-consuming and economically unfeasible for regional or city-wide inventories. Consequently, "first-level" or rapid visual screening methods are widely adopted to quickly categorize the vulnerability of existing building stocks. [2,3].

This paper examines the specific parameters and scoring methodology utilized in the seismic risk screening of reinforced concrete buildings within Samsun Province, Türkiye. Located within a region influenced by several active tectonic structures, Samsun Province requires systematic monitoring of its building stock. [5]

2. Methods. Since the examined structures are public buildings, their address information is obtained directly from the relevant institution along with the official inspection request. The target zone for the street survey is delineated on the map. Architectural elevation photographs of the investigated building are captured and appended to the Data Collection Form for Reinforced Concrete Buildings.

The construction year of the building is of critical importance for the fieldwork, as it provides substantial insights into the seismic code in force at the time of construction, as well as the contemporary construction techniques employed, such as the utilization of deformed reinforcing bars, and the proper execution of confinement techniques.

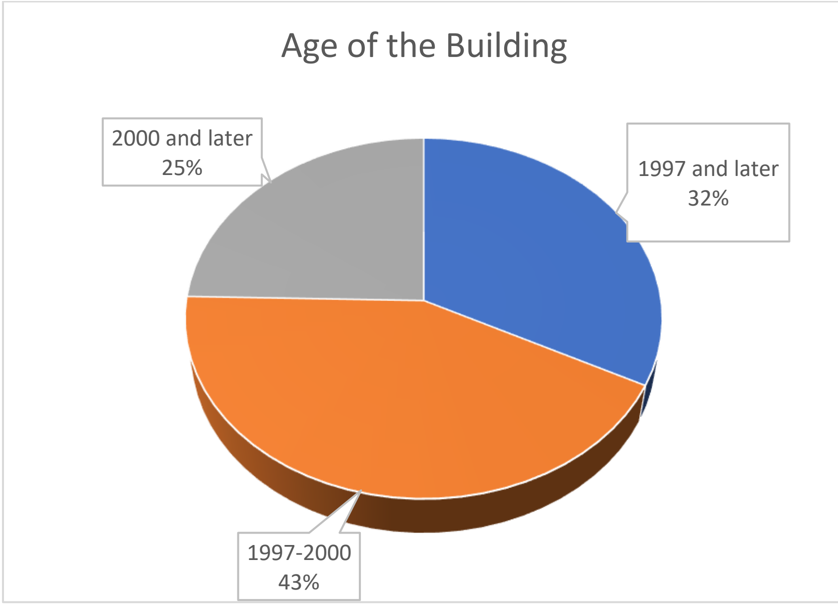

Fig.1. Distribution chart of building age

The structural systems of the investigated buildings were classified into two categories: Reinforced Concrete Frame (RCF) and Reinforced Concrete Frame-Wall (RCFW). [7]

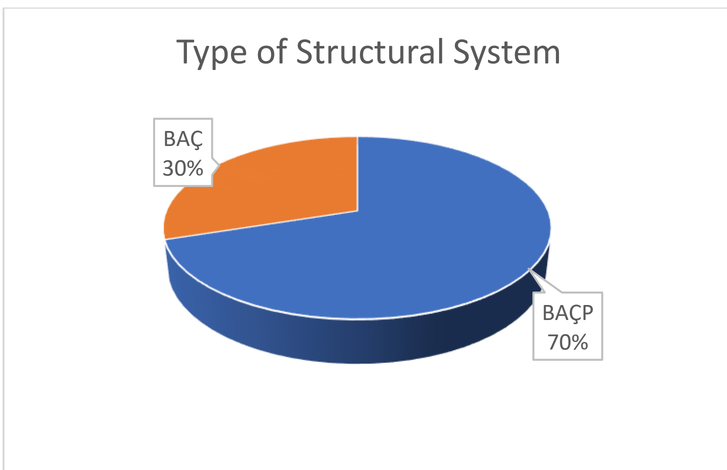

Fig.2. Distribution chart of structural system types of the buildings

Since the structures examined in this study are public buildings, a basement floor is present in the majority of them to accommodate the boiler room. For this reason, it has been observed that in buildings constructed prior to 1997, as well as those built in 1997 and thereafter, the basement floors feature reinforced concrete shear walls, or the basement frame is supported by vertical structural elements with an aspect ratio (long side to short side) of at least 7, as specified in the 2007 and 2018 Specifications for Buildings to be Built in Seismic Zones.

The total number of stories of a building is counted as the total number of floors situated above the foundation, including the basement and attic floors.

The assessment, conducted in compliance with the implementing regulation of the Law No. 6306 on the Transformation of Areas Under Disaster Risk, is applicable to buildings with 1 to 7 stories. Therefore, reinforced concrete public buildings with up to 7 stories were selected for this study.

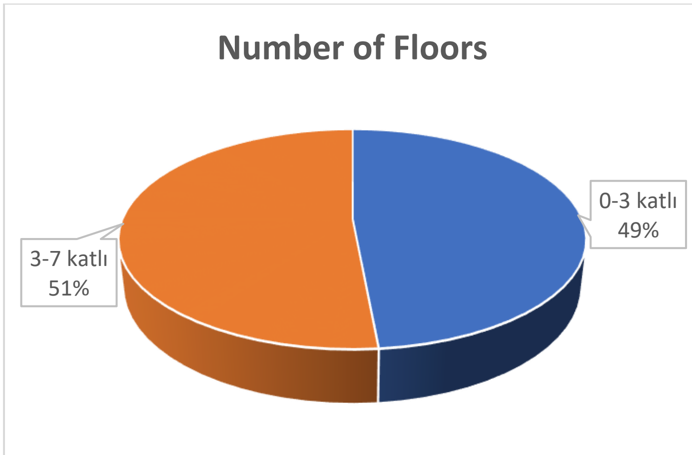

Fig.3. Distribution chart of the number of building stories

The quality of workmanship and materials utilized during the construction of a building, along with the diligence shown in its maintenance, directly influence the visual quality of the structure. In observational assessments, the visual quality of a building can be classified as good, moderate (fair), or poor. Structural quality and the risk of damage that may occur during a potential earthquake are closely interrelated. For a building with poor visual quality, the material strength under seismic loads is also expected to be lower than anticipated (Deprem Şurası, 2004) [4,5].

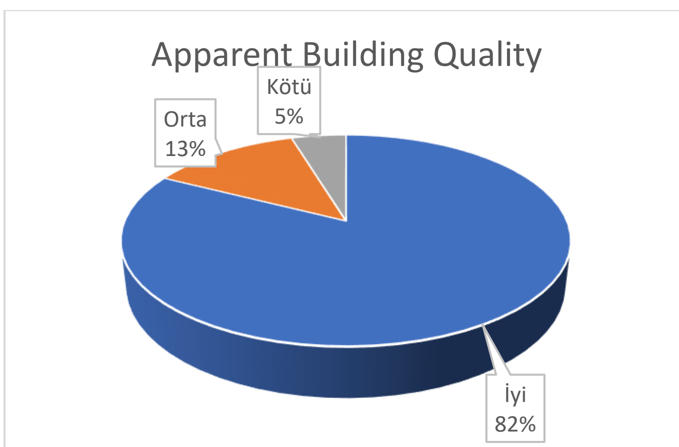

Fig.4. Distribution chart of the visual quality of the buildings

According to the form provided in the implementing regulation of the Law No. 6306 on the Transformation of Areas Under Disaster Risk, the selected buildings are classified into two categories observationally and categorized into three groups based on their visual quality: good, moderate, and poor.

Since this study focuses on public buildings across the province of Samsun, 82% of the structures were evaluated as "good" in terms of visual quality, attributed to the regular execution of their annual maintenance and repairs.

Fig.5. A school building with regularly maintained exterior facades

Based on investigations conducted around the structures, buildings that exhibited defects such as settlement in the surrounding parapets in heavily utilized areas like schoolyards, and whose observational evaluations were made regarding their construction year and workmanship, were classified as "moderate" at a rate of 13%. Furthermore, buildings that displayed cracks due to live loads at the expansion joint zones between structural junctions and reinforced concrete fire escapes or interior staircases, visible cracks at wall and column-beam joints, and deflections in structural floor slabs were evaluated as "poor" at a rate of 5%.

Considering the building age and the construction techniques employed (such as the non-utilization of ready-mixed concrete and ribbed rebars, or the usage of unwashed marine sand), public buildings constructed in 1997 and earlier are expected to be in a poorer condition than those built in 2000 and thereafter. However, since the supervision processes during the estimated cost estimation, tendering, and construction phases are executed by the technical personnel within public institutions, it has been observed that these buildings are in a better state in terms of visual quality and workmanship compared to the surrounding residential buildings of the same vintage.

Fig.6. Abandoned lodging buildings

Stories constructed without infill walls on the ground floors or with a height greater than that of other stories to generate revenue—such as for commercial spaces, parking lots, restaurants, showrooms, or banks—even when the upper stories remain structurally adequate. These modifications, made on ground floors to create larger spaces driven by economic considerations, lead to failure at the ground floor level despite the structural integrity of the upper stories. This is attributed to the fact that the vast majority of lateral displacement during an earthquake occurs within these specific stories, causing crushing at the column ends and resulting in heavy damage. The lateral stiffness of a soft storey is substantially lower than that of stories with infill walls. A weak storey irregularity also arises when the height of the ground floor is greater than that of the upper floors in the floor plans. This condition creates a vertical stiffness discontinuity, leading to a higher concentration of damage in these stories during seismic events.

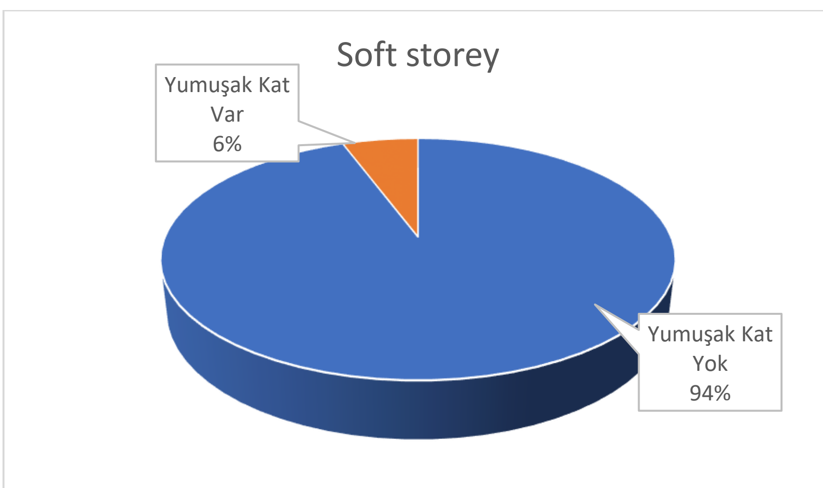

Fig.7. Distribution chart of soft storeys

Since the structures examined in this study are public buildings, their ground floors are not utilized for commercial purposes; consequently, it was observed that 94% of the buildings were constructed in compliance with standard floor plans and storey heights. In contrast, it was noted that in certain public buildings such as police stations and hospitals, which require the accommodation of specially equipped vehicles, the ground floors were constructed with greater heights to serve as vehicle parking or washing bays. This architectural configuration led to the formation of a soft storey irregularity in 6% of the investigated buildings.

Fig.8. A public building with a ground floor utilized as a garage

Overhangs are structural components that extend from floor slabs within the parcel boundaries, featuring at least one free or supported end, and whose dimensions are specified by implementation zoning plans or regulations. In other words, the ground footprint of the building differs from the floor plan areas of the upper stories. Overhangs are categorized into two types: open overhangs and enclosed overhangs.

Enclosed overhangs can be constructed on the street facades of parcels, provided they remain within the parcel boundaries, projecting a maximum of 1.50 meters beyond the building setback line. These overhangs must stay within the parcel limits for street facades and may similarly project up to 1.50 meters into yard setbacks.

Open overhangs, on the other hand, are projections constructed on the street facades of parcels, provided they remain within the parcel boundaries, extending a maximum of 1.50 meters from the building setback line. They may project 1.50 meters into rear and side yard setbacks, provided they do not approach closer than 3 meters to the parcel boundaries. However, in practice, cases are frequently encountered where open or enclosed overhangs are constructed facing adjacent neighbors without any street frontage, a condition that strictly violates zoning regulations.

Overhangs that do not comply with regulatory frameworks disrupt the structural frame system and induce mass irregularities in buildings. Consequently, the required load transfer mechanism between structural components cannot be properly established, and buildings with heavy overhangs sustain extensive damage during seismic events.

In this study, it was observed that public buildings constructed prior to 1997 were built in accordance with standardized type projects; as a result, they do not feature heavy overhangs that would disrupt the structural frame or prevent the load-bearing system from resisting seismic and other loads. Similarly, investigations conducted on public buildings built after the revised 1997 seismic code, and particularly those constructed after 2000, revealed no planning designs incorporating heavy overhangs.

The short column is a concept associated with the discrepancy between the designed column height and the actual effective column length. In buildings, particularly along exterior walls, when infill walls are not constructed continuously up to the upper floor slab, short column effects emerge during an earthquake within the clear portions of the columns where no partition wall is built. In structures with functional basement stories, openings are often left in the exterior walls to install strip windows and utilize natural light. If these walls do not extend through the full clear height of the column and are not structurally isolated from the frame to which they are connected, severe damage can occur in the columns during seismic events (Celep, Z. 2005).

In a structure, short columns exhibit a significantly more rigid behavior compared to other columns. Elements with high stiffness attract greater seismic forces because they absorb a larger portion of the seismic energy during an earthquake. Consequently, because short columns are subjected to exceptionally high shear and bending moment effects, shear failures develop along the clear length of the column.

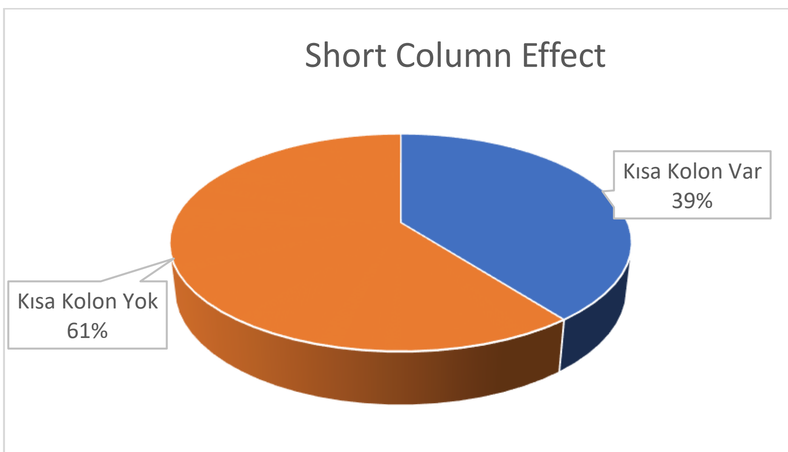

Fig.9. Distribution chart of the short column effect

Since the structures examined in this study are public buildings with high occupancy rates—such as hospitals, schools, and dormitories—facilities including boiler rooms, indoor parking lots, and storage rooms are constructed on the ground and basement floors. Due to the installation of strip windows for natural lighting in these areas, the short-column effect was observed in 71% of the investigated buildings.

Fig.10. A school building with strip windows in the basement floor

An urban settlement pattern in which adjacent buildings share one or more common side walls is referred to as an adjacent building layout (row housing system). In such configurations, neighboring reinforced concrete structures are susceptible to mutual damage resulting from seismic-induced vibrations and impact effects during earthquakes.Furthermore, another structural challenge in adjacent layouts arises when the floor slab elevations of the buildings differ, causing the floor slab level of one building to align with the clear column height of the neighboring structure. Especially during a potential earthquake, if the joint spacing is insufficient, the floor slab of the neighboring building can fracture the column of the adjacent structure as a result of seismic oscillation. Another phenomenon observed in adjacent layouts is the pounding (hammering) effect. The pounding effect can be defined as a phenomenon where, in cases where an adequate seismic joint spacing has not been provided between two adjacent structures based on structural calculations, the building with higher stiffness against overturning strikes the less rigid building as a result of its lateral displacement under seismic action, thereby inducing structural damage. The Specifications for Buildings to be Built in Seismic Zones (DBYBHY; 2007, 2018) emphasize specific precautions regarding this issue. Apart from the effects of temperature fluctuations and foundation translations and rotations induced by differential ground settlements, the code explicitly prescribes the criteria for seismic joint clearances to be maintained between existing old structures and newly planned buildings solely for seismic actions.

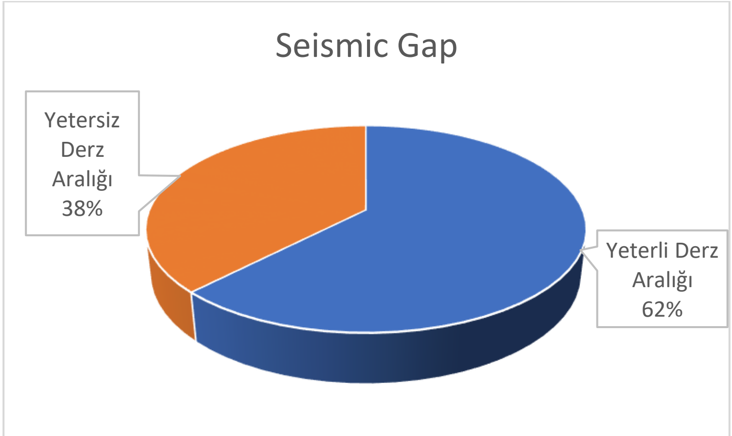

Fig.11. Distribution chart of joint spacings

Since the public buildings examined in this study—comprising schools, hospitals, nursing homes, dormitories, and police stations—are planned within their own parcels incorporating yards and parking spaces based on their occupancy types, an adjacent building layout is not applicable to these structures.

However, because the regional development characteristic is predominantly an adjacent layout, particularly in the downtown area of the İlkadım district in Samsun province, apartment-style lodging buildings belonging to various institutions in this zone were investigated regarding their joint spacings. Accordingly, it was observed that 62% of these buildings were constructed with adequate joint spacing; however, structures located in the relatively older settlements of the district in terms of urban zoning failed to satisfy the required joint clearance adequacy.

Fig.12. Adjacent building layout in Samsun city center

Buildings located on hilltops or on slopes exceeding 30° amplifies the seismic actions it will be or has been subjected to. This condition, which can be easily identified through observational assessment during the street survey method, must be taken into consideration when calculating the structural seismic score (Işık and Tozlu, 2015).

Public structures are planned not merely as standalone service buildings, but integrated with parking areas, yard spaces, additional service facilities, and outbuildings. Consequently, because multiple sections or buildings utilized for different purposes must be situated on single or multiple parcels, the land selection process for construction is executed by rigorously considering terrain conditions to determine the most optimal site. Therefore, it was observed that for the public buildings examined in this study, plots with a natural ground slope exceeding 30° were not selected.

Fig.13. A school building planned with its own yard

Vertical irregularity—namely, irregularity within the load-bearing system—emerges as a result of columns lacking continuity along the building height and varying floor areas across stories. Plan irregularity consists of structural axes that are not parallel to each other, forming broken-axis beams. In such cases, columns and shear walls are irregularly distributed in the plan configuration. Due to excessive opening ratios introduced in floor slabs for staircases or elevator shafts, the transfer of seismic loads to the structural system components becomes restricted. Since the structural statics do not comprise uniform frames, lateral loads cannot be regularly transferred from column to column; consequently, the forces change direction within the structure. Buildings featuring plan irregularities exhibit a high vulnerability to torsional effects.

The observations recorded under the "Heavy Overhangs" parameter are also valid for the "Vertical and Plan Irregularities" parameter. Public structures built prior to 1997 were constructed in accordance with standardized type projects, such as lodging facilities, dormitories, hospitals, and 8-classroom schools. In these low-rise type buildings, no plan or vertical irregularities were observed; furthermore, it was noted that bridging large spans for areas such as conference halls and gymnasiums without proper column and beam support was meticulously avoided. For public buildings constructed after 1997, the cross-sections of the structural system components were selected in strict compliance with the revised and updated seismic codes. Notably, investigations carried out on public structures built after 2000 revealed no evidence of plan irregularities.

Fig.14. A lodging building constructed in accordance with standardized public building type projects

3. Calculation of Building Performance Score. Following the completion of the outdoor visual inspections of the selected structures, and once the parameter values are determined and recorded into the Data Collection Form for Reinforced Concrete Buildings, the Building Performance Score is calculated. This score determines the prioritization of the investigated buildings for detailed seismic risk assessments. By following the methodology detailed in the appendix of the implementing regulation of the Law No. 6306 on the Transformation of Areas Under Disaster Risk, the calculation of vulnerability parameters—which serves as the preliminary stage of the performance score calculation—was executed for 406 public buildings.

According to the fundamental approach and methodology for calculating the building performance score outlined in the implementing regulation of the Law No. 6306 on the Transformation of Areas Under Disaster Risk, the risk zone is primarily determined based on the seismicity of the region where the structure is situated and the local soil type.

The conducted study encompasses the entire province of Samsun, and the districts of Samsun are located within I. II. and III degree seismic zones according to the earthquake risk map.
Accordingly:

Table 1. Selection of hazard zones for Samsun Province

District Name	Seismic Zone
19 Mayıs	III
Alaçam	III
Asarcık	I
Atakum	II
Ayvacık	I
Bafra	III
Canik	II
Çarşamba	II
Havza	I
İlkadım	II
Kavak	I

Ladik	I
Salıpazarı	II
Tekkeköy	II
Terme	III
Vezirköprü	I
Yakakent	III

Table 2. Selection of hazard zones based on soil class

Seismic Hazard Zone	Earthquake Zone According to DBYBHY	Soil Classification According to DBYBHY
I	1	Z3 / Z4
II	1	Z1 / Z2
II	2	Z3 / Z4
III	2	Z1 / Z2
III	3	Z3 / Z4
IV	3	Z1 / Z2
IV	4	All Soil Classes

After the hazard zones are determined for all districts, these data are utilized alongside Table 3 to obtain the Base Score and Structural System Score for each building. All structures investigated in this study are categorized as either RC-F (Reinforced Concrete Frame) or RC-FW (Reinforced Concrete Frame with Shear Walls). For buildings classified as RC-F, the additional structural system score is taken as 0 in the calculations, whereas for buildings classified as RC-FW, the additional system scores are determined based on their respective hazard zones [9].

Table 3. Base and Structural System Score Table

Total Number of Stories	Base Score by Hazard Zone				Structural System Score (SSS)	
	I	II	III	IV	RCF	RCFW
1–2	90	120	160	195	0	100
3	80	100	140	170	0	85
4	70	90	130	160	0	75
5	60	80	110	135	0	65
6–7	50	65	90	110	0	55

For the reinforced concrete buildings investigated in this study, the identified vulnerability parameters—such as Soft storey, Heavy Overhangs, Short Column, Hilltop/Slope Effect, and Plan Irregularity—are evaluated using Table 5. If no vulnerability parameters are detected, the parameter value is entered as "0" according to Condition 1 in Table 4. Conversely, if one or more vulnerability parameters are identified in the inspected building, the evaluation is conducted according to Condition 2, and the value for each parameter is taken as "1". Regarding the assessment based on the Apparent Quality values in Table 4., the vulnerability parameter value is taken as "0" for buildings whose apparent structural quality is considered "good"; similarly, for buildings evaluated as having "moderate" and "poor" apparent quality, the parameter values are adopted as "1" and "2", respectively.

Table 4. Vulnerability Parameter Values (O_i)

Deficiency Parameter No.	Deficiency Parameter	Condition 1		Condition 2	
		Presence	Parameter Value	Presence	Parameter Value
1	Soft storey	Absent	0	Present	1
2	Heavy Overhang	Absent	0	Present	1
3	Apparent Construction Quality	Good	0	Moderate (Poor)	1 (2)
4	Short Column	Absent	0	Present	1
5	Hill/Slope Effect	Absent	0	Present	1
6	Plan Irregularity	Absent	0	Present	1

The total vulnerability score of the building was determined by multiplying the identified vulnerability parameter values for the baseline structures—namely Soft storey, Heavy Overhangs, Short Column, Hilltop/Slope Effect, and Plan Irregularity—by the corresponding value matching the total number of stories in the Vulnerability Parameter Score OP_i table presented in Table 5. [2,7]

Table 5. Vulnerability Parameter Score (OP_i)

Total Number of Storeys	Structural Irregularity Penalty Scores (OP)										
	Soft Storey	Poor Visual Quality	Heavy Overhangs	Storey-Level Compatibility / Isolated Building Condition				Vertical Irregularity	Plan Irregularity / Torsional Effects	Short Column	Hilltop / Slope Effect
				Same Storey Level	Same Storey Level	Different Storey Level	Different Storey Level				
				Intermediate Position	Corner Position	Intermediate Position	Corner Position				
1–2	-10	-10	-10	0	-10	-5	-15	-5	-5	-5	-3
3	-20	-10	-20	0	-10	-5	-15	-10	-10	-5	-3
4	-30	-15	-30	0	-10	-5	-15	-15	-10	-5	-3
5	-30	-25	-30	0	-10	-5	-15	-15	-10	-5	-3
6–7	-30	-30	-30	0	-10	-5	-15	-15	-10	-5	-3

In accordance with Equation (1) provided in Annex-A of the implementing regulation of the Law No. 6306 on the Transformation of Areas Under Disaster Risk, the structural performance score was calculated by determining the corresponding regulatory values of the vulnerability parameters.

$$PP = TP + \sum_{i=1}^{n} O_i * OP_i + YSP \quad (1)$$

The terms in Equation (1), which is utilized to calculate the Building Performance Score, are defined below:

PP: Building performance score
TP: Base score
O_i: Vulnerability parameter value
OP_i: Vulnerability parameter score
YSP: Structural system score

In this study, the structural performance scores of the 406 investigated buildings were calculated, and a risk prioritization was established based on the final performance score values obtained through the First-Stage Evaluation Method. Due to the high number of buildings inspected and the occurrence of multiple structures sharing the identical Performance Score, a risk ranking grouping was implemented based on the Performance Scores. According to this approach:

Table 6. Risk Prioritization Evaluation Intervals

Performance Score Range	**Risk Priority Value**
0-30	1
31-50	2
51-70	3
71-100	4
101- ~	5

The structures are categorized into Risk Priority Values ranging from 1 to 5 based on their Performance Score intervals.

4. Conclusions. This study presented a first-level seismic risk assessment of reinforced concrete public buildings in Samsun Province, Türkiye, incorporating structural irregularities and hilltop/slope effects within a standardized scoring framework. The results indicate that the proposed rapid screening methodology is effective for identifying and prioritizing buildings requiring detailed seismic evaluation, thereby supporting efficient seismic risk management and decision-making at the urban scale [9].

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Data Availability. The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Conflict of Interest. The authors declare that they have no competing interests or conflicts of interest related to this work.
Ethical Approval. This article does not involve studies with human participants or animals. Therefore, ethical approval was not required.
Informed Consent. Not applicable.

References

[1] S. Özdemir, *Seismic Evaluation Methods and Applications of Public Buildings* [in Turkish], M.S. thesis, Samsun, Türkiye, 2019.
[2] A. Kasimzade, M. Erdik, T. Kundu, H. Sucuoğlu, and P. Clemente, Eds., *Earthquake Resistant Design, Protection, and Performance Assessment in Earthquake Engineering*, vol. 54. Cham, Switzerland: Springer Nature, 2024. DOI: https://doi.org/10.1007/978-3-031-65407-7
[3] A. A. Kasımzade, E. Şafak, E. C. Ventura, F. Naeim, and Y. Mukai, *Seismic Isolation, Structural Health Monitoring, and Performance Based Seismic Design in Earthquake Engineering: Recent Developments*. Cham, Switzerland: Springer, 2018. ISBN: 978-3-319-93156-2.
[4] A. A. Kasimzade *et al*., "Economic evaluation of 2000 Baku earthquake impact in view of building features," *Construction Economics and Management*, vol. 32, no. 3, pp. 191–206, 2025.
[5] A. A. Kasimzade *et al*., "System identification for non-destructive assessment of structures: Lessons learned," in *Communications in Computer and Information Science*, vol. 2225. Cham, Switzerland: Springer Nature, 2025, pp. 235–250. DOI: https://doi.org/10.1007/978-3-031-73417-5_18
[6] A. A. Kasimzade and E. Nematli, "New structural seismic isolation system for tower structures," in *Geotechnical, Geological and Earthquake Engineering*, vol. 54. Cham, Switzerland: Springer Nature, 2024. DOI: https://doi.org/10.1007/978-3-031-65407-7_1
[7] A. A. Kasimzade *et al*., "Novel approach on mathematical modelling and numerical evaluation of the seismic protection of structural dynamic systems," *Mathematical Methods in the Applied Sciences*, 2024.
[8] A. A. Kasımzade *et al*., "The contribution of natural seismic base isolation on the durability of traditional Japanese structures," in *Geotechnical, Geological and Earthquake Engineering*, vol. 54. Cham, Switzerland: Springer Nature, 2024. DOI: https://doi.org/10.1007/978-3-031-65407-7_3
[9] A. A. Kasimzade *et al*., "The new criterion on performance-based seismic design with application to high-rise building," in *Geotechnical, Geological and Earthquake Engineering*, vol. 54. Cham, Switzerland: Springer Nature, 2024. DOI: https://doi.org/10.1007/978-3-031-65407-7_11