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NON-DESTRUCTIVE AND SEMI-DESTRUCTIVE TESTING FOR SEISMIC RISK ASSESSMENT OF PUBLIC BUILDINGS: FIELD FINDINGS FROM SAMSUN, TÜRKIYE

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Abstract. This study evaluates the seismic risk of 406 reinforced concrete public buildings located across 17 districts in Samsun Province, Türkiye, within the framework of Law No. 6306. A multi-level assessment approach combining rapid visual screening and selected non-destructive and semi-destructive testing techniques was implemented. These included reinforcement detection using Ferroscan technology, localized concrete cover removal, and Schmidt rebound hammer testing. The buildings were classified into five risk categories based on structural performance scores, resulting in 14 buildings identified as first-degree high risk and 48 as second-degree risk requiring priority intervention. The remaining structures were distributed across lower risk categories, indicating varying levels of vulnerability. A regional database was developed to support continuous monitoring and risk prioritization of public infrastructure. The findings suggest that, under updated seismic code provisions introduced in 2019, several of the assessed buildings may exhibit higher vulnerability due to revised soil-structure interaction parameters and increased seismic demand definitions.
Keywords: Seismic Risk Assessment, Rapid Visual Screening, Law No. 6306, Non-Destructive Testing, Public Buildings

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1. Introduction. Ensuring the post-disaster operational continuity of critical public infrastructure (hospitals, schools, police stations) is vital for life safety and public order in earthquake-prone regions like Türkiye. Outdated building codes and rapid urbanization have left a large portion of the existing reinforced concrete (RC) inventory potentially vulnerable. To systematically address this challenge, the Turkish Government enacted Law No. 6306 for structural assessment and urban transformation.

Since detailed, code-based destructive testing for every structure is economically and temporally unfeasible, multi-level screening frameworks are essential. This study applies rapid visual screening combined with targeted non-destructive testing (NDT) across 406 public buildings in Samsun Province to establish a regional risk-priority matrix for emergency planning [1,3].

2. Methods. Since detailed destructive testing of all buildings was not feasible, a hierarchical assessment strategy was adopted. Initial evaluations were performed using rapid visual screening in accordance with Law No. 6306 guidelines. To improve accuracy, targeted non-destructive and semi-destructive tests were conducted, including reinforcement detection using a Hilti Ferroscan PS 200 device, localized concrete cover removal, and in-situ Schmidt rebound hammer testing. Reinforcement detailing was investigated at selected structural elements per floor, while concrete quality was assessed at ground and basement levels to minimize variability effects [2].

Fig.1. A law enforcement building featuring exterior thermal insulation cladding

For the seismic assessment of the existing reinforced concrete structures, reinforcement detection was carried out on three randomly selected columns per floor in each building, using a rebar scanner (Hilti Ferroscan PS 200) as a non-destructive testing method. This procedure enabled the determination of reinforcement diameters along with the required confinement ratios within the critical zones of columns and beams [5].

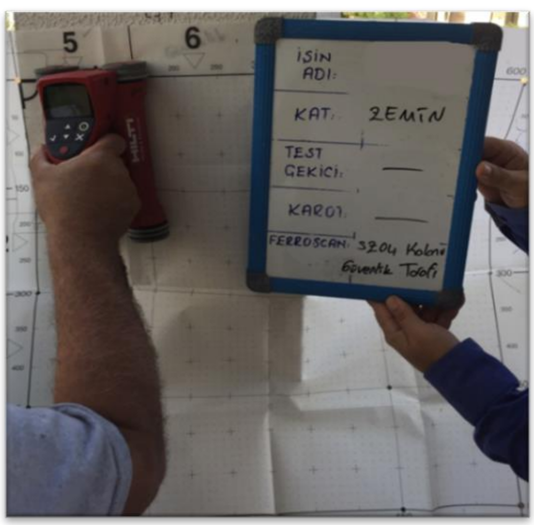

Fig.2. Rebar detection in columns utilizing a Ferroscan

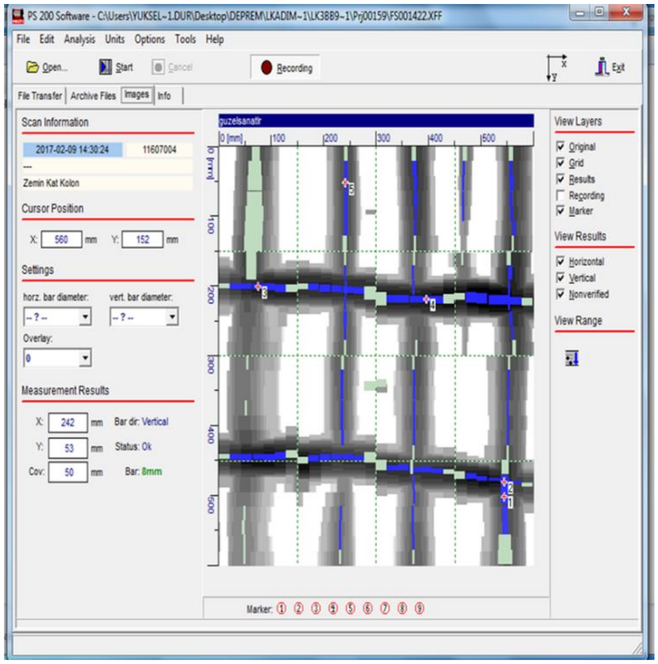

Fig.3. Software visualization of reinforcement detected with Ferroscan

In buildings with a basement, concrete chipping was performed on the basement columns, whereas in buildings without a basement, it was carried out on columns accessible from the exterior facades to evaluate the corrosion state of the reinforcement.

Fig.4. Concrete chipping process in columns

As a result of the concrete chipping process, it was concluded that the reinforcement diameters utilized in the columns were adequate, and the corrosion rates occurring in the reinforcement were within reasonable levels. The inspection revealed that stirrup confinement was not implemented at the column ends only in the reinforced concrete buildings constructed in 1997 and earlier; the stirrup spacing varied between 20 and 30 cm along the column length, and consequently, the transverse reinforcement elements were found to be insufficient.

Fig.5. Concrete chipping process in columns

In the now-defunct residential buildings where concrete chipping was performed for reinforcement detection, results suggest that plain (smooth) rebar was used in some columns, and the reinforcement diameters selected during construction were incompatible with the column dimensions. Furthermore, within the critical confinement zones located at the end regions of columns and beams, observations indicate that the poorly cast concrete underwent segregation as a result of insufficient concrete curing and faulty workmanship, and the concrete quality was low.

Conversely, inspections of buildings constructed in 2000 and later revealed that transverse reinforcement in confinement zones generally consisted of ribbed Ø8 bars or larger, Additionally, the confinement spacings in the randomly selected columns were found to be no greater than 1/3 of the column cross-sectional dimension or 100 mm, and no less than 50 mm.

Fig.6. Corrosion in column reinforcement

When the seismic behavior of reinforced concrete structures is examined, it is known that an increase in concrete grade and quality leads to a decrease in the number of plastic hinges formed in columns, maximum plastic sectional rotation values, and relative story drift values (Uçar, 2007). For this reason, an in-situ concrete strength test was performed on all inspected buildings using an N-type Schmidt rebound hammer. The columns and shear walls to be tested were selected from the ground or basement floors. On the columns and shear walls designated for measurement, a 20*20cm area was cleared of paint, plaster, and mortar; the old reinforced concrete surfaces were scraped down by approximately 1 cm to reach the raw concrete, after which 10 rebound measurements were taken at 10 distinct points across 10 different structural elements. After determining the average rebound number, the corresponding concrete strength for that structural element was read from the calibration chart. These data were then entered into a Concrete Test Hammer Excel spreadsheet prepared by the technical personnel of the Samsun Provincial Directorate of Environment and Urbanization, enabling a comparative determination of concrete strengths based on cube and cylinder compressive strengths, factoring in concrete age and impact angle.

Particularly in buildings constructed prior to 1997, surface cleaning was meticulously performed before testing, taking into account that concrete surface carbonation—which is anticipated to reach depths of up to 15 mm—could cause misleading surface hardening. Furthermore, in addition to the carbonation effect, when considering the quality of construction techniques, inadequate workmanship, and the low rate of ready-mix concrete utilization in buildings constructed in 1997 and earlier, it was anticipated that concrete curing, aggregate granulometry, and segregation could cause varying strength results within the same structural element. Consequently, these test results were not utilized for a definitive seismic risk determination [6].

Table 1. Sample test report of the concrete rebound hammer

Schmidt Rebound Hammer Test Report										
Date of Testing	11 January 2019									
Building Name (Owner)	Chatalarmut Primary School									
Year of Construction	1997									
Test Location	Block B, Ground Floor									
Visual Inspection	Conducted									
Tested Element	Column	Column	Column	Column	Column	Column	Column	Column	Column	Column
Number of Blows (R-Q) 1	30	30	34	30	34	30	34	34	30	34
2	30	30	34	30	34	30	34	34	30	34
3	30	30	34	30	34	30	34	34	30	34
4	30	30	34	30	34	30	34	34	30	34
5	30	30	34	30	34	30	34	34	30	34
6	30	32	36	32	36	32	36	36	30	36
7	32	32	36	32	36	32	36	36	32	36
8	32	32	36	32	36	32	36	36	32	36

9	32	32	36	32	36	32	36	36	32	36
10	32	32	36	32	36	32	36	36	32	36
Total	308	310	350	310	350	310	350	350	308	350
Average	31.00	31.00	35.00	31.00	35.00	31.00	35.00	35.00	31.00	35.00
Correction for Impact Direction	0	0	0	0	0	0	0	0	0	0
Concrete Age Factor (Days)	8071	8071	8071	8071	8071	8071	8071	8071	8071	8071
Time Factor	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Wmax(kg/cm²) Cube	154	154	194	154	194	154	194	194	154	194
Wmin(kg/cm²)Cube	116	116	154	116	154	116	154	154	116	154
Wmax+0.85 Cylinder	131	131	165	131	165	131	165	165	131	165
Findings	148,00 (kg/cm²)									

Summary of District Field Inspections. A ground condition assessment was conducted for the 406 public buildings, and findings were integrated into the first-stage evaluation methods to complete the Public Buildings Pre-Evaluation Form. The district-specific risk distributions revealed distinct regional trends:

- *19 Mayıs & Alaçam: Evaluated public buildings achieved consistently high performance scores (110–150), uniformly classifying them under Risk Priority Level 5 (low seismic risk requiring no urgent intervention).*
- *Asarcık, Atakum, & Ayvacık: Displayed highly heterogeneous risk profiles spanning Risk Priority Levels 1–5. Vulnerabilities were strongly correlated with construction quality variations and local soil conditions.*
- *Bafra: Performance scores ranged from 55 to 150 (Risk Priority Levels 1–5), driven by variations in structural system contributions and localized negative design parameters.*
- *Canik & Yakakent: Exhibited a concentrated, moderate risk profile restricted to Risk Priority Levels 3–4, indicating relatively uniform structural configurations with minor geometric irregularities.*
- *Çarşamba: Showed extensive variability across Risk Priority Levels 1–5. The structural vulnerabilities were primarily governed by localized geometric variations and configuration deficiencies.*
- *Havza, İlkadım, Ladik, & Vezirköprü: Displayed non-uniform distributions across Risk Priority Levels 1–5 (or 1–4). Vulnerabilities were heavily influenced by severe structural system deficiencies, vertical irregularities, soft-story defects, and hill/slope topographical effects.*
- *Kavak & Tekkeköy: Revealed moderate, spatially variable vulnerability profiles predominantly falling within Risk Priority Levels 2–5, governed by structural system contributions and slope irregularities.*
- *Terme: Exhibited a predominant concentration at Risk Priority Level 5, indicating a uniformly low and stable seismic vulnerability across its public building stock.*

3. Conclusions. In this study, as the initial phase of disaster mitigation efforts prior to the occurrence of a disaster with devastating impacts such as an earthquake, a total of 406 reinforced concrete public buildings within the provincial borders of Samsun were investigated. The structural evaluations were conducted between 2017 and 2018 based on rapid visual screening methods performed from the exterior facades of the buildings, in accordance with the implementing regulation of the Law No. 6306 on the Transformation of Areas Under Disaster Risk, which came into force in 2013. The spatial distribution of the examined buildings across the districts is as follows: 11 in 19 Mayıs, 3 in Alaçam, 8 in Asarcık, 30 in Atakum, 11 in Ayvacık, 3 in Bafra, 2 in Canik, 67 in Çarşamba, 45 in Havza, 45 in İlkadım, 24 in Kavak, 23 in Ladik, 13 in Salıpazarı, 11 in Tekkeköy, 44 in Terme, 56 in Vezirköprü, and 2 in Yakakent.

As a result of the study, the investigated structures were first ranked based on their building performance scores and subsequently categorized according to their risk levels. Through this classification, the number of risky buildings requiring high-priority intervention was determined.

Table 2. Distribution of the number of buildings based on risk levels by district

District Name	*Number of Buildings*	*Risk Levels (Number of Buildings)*				
		1st Degree	*2nd Degree*	*3rd Degree*	*4th Degree*	*5th Degree*
19.May	2					2
Alaçam	3					3
Asarcık	8	2	1	1	3	1
Atakum	30	2	3	3	12	10
Ayvacık	11	1	1	4	4	1
Bafra	21			2	3	16
Canik	2			1	1	
Çarşamba	67	3	3	7	20	34
Havza	45	2	10	14	19	
İlkadım	45	1	3	9	16	16
Ladik	23		6	8	9	
Vezirköprü	56	2	13	17	24	
Kavak	24		6	8	10	
Salıpazarı	13	1	1	2	5	4
Tekkeköy	11		1	3	3	4
Terme	44			4	7	33
Yakakent	2			1	1	
Total	**406**	**14**	**48**	**84**	**137**	**124**

As a result of the evaluation, 14 buildings were identified as first-degree high-risk structures and 48 buildings identified as 2nd-degree high risk in the districts of Asarcık, Atakum, Ayvacık, Çarşamba, Havza, Ladik, Kavak, and Vezirköprü were reported as " High seismic risk requiring immediate intervention." For these structures, the Existing Public Buildings Pre-Evaluation Form was prepared, and the relevant institutions were informed accordingly. Furthermore, 84 buildings were classified as 3rd-degree risk and 137 buildings as 4th-degree risk. The deficiencies observed in these structures were detailed, reported as "Resolvable with mitigation measures," and the Existing Public Buildings Pre-Evaluation Form was issued to notify the respective administrations regarding the seismic retrofitting of the buildings.

Within the scope of the investigation, no visible defects were found in 124 buildings, and these structures were categorized as 5th-degree risk based on their building performance scores.

The Existing Public Buildings Pre-Evaluation Form was also issued for these assets, and the relevant authorities were informed that periodic annual maintenance and repair operations would be sufficient for these buildings.

Since the study spans a two-year period encompassing 2017 and 2018, the investigated structures were evaluated under the implementing regulations in force as of 2017. However, significant amendments introduced as of 2019—both in the Seismic Code and the implementing regulation of Law No. 6306—have enabled more realistic soil effect calculations through a more detailed handling of the soil class-seismic hazard relationship and the introduction of the seismic hazard map concept [4]. This clearly demonstrates that the existing reinforced concrete buildings, which were identified as risky even under the more conservative and limited approaches prior to 2019, could be evaluated as substantially weaker in terms of resisting seismic ground motions and surviving a potential earthquake compared to calculations based on the previous codes. Therefore, to mitigate potential casualties and economic losses, the risky public buildings particularly located in districts within the 1st-degree seismic zone—such as Asarcık, Ayvacık, Havza, Ladik, Kavak, and Vezirköprü- must be evacuated, followed by the execution of necessary demolition and redesign processes [7].

Furthermore, considering the post-disaster chaos experienced after past devastating earthquakes in Türkiye, ensuring that critical public facilities such as police stations, hospitals, dormitories, and public housing units remain operational immediately after an earthquake is of paramount importance for both the continuity of public order and the safety of citizens. Consequently, priority must be given to public infrastructure in seismic risk assessments conducted within the current building stock, and indispensable measures must be implemented promptly. In this direction, within the scope of this study, the rapid visual screening methodology was utilized to rank the performance scores of the public building stock across Samsun Province prior to the generation of regional seismic risk maps. Ultimately, a comprehensive database was established to enable the annual monitoring of the examined public structures and to provide information regarding these buildings to the relevant institutions and organizations whenever necessary [8,9].

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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.

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