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Seismic Vulnerability of Masonry School Buildings: The Case of Algiers and Blida, Algeria

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Abstract

School architecture, which emerged in the early 19th century, developed to structure education within environments specifically suited to learning, becoming one of the most widespread public building types worldwide. In northern Algeria, particularly in Algiers and Blida—high-seismicity regions—numerous schools were constructed in unreinforced masonry between the 19th and early 20th centuries, prior to the introduction of seismic design codes, making them highly vulnerable. This study identifies and geolocates these buildings, classifies them according to geometric and morphological configurations, and assesses their seismic vulnerability using nonlinear static (pushover) analysis with TREMURI software. Results highlight seismic response across diverse typologies, identify critical structural zones, and demonstrate the influence of architectural form on seismic performance. The study provides an evaluation framework to guide retrofit interventions and inform conservation and seismic risk mitigation strategies for masonry school heritage in earthquake-prone regions.
Keywords: School architecture heritage; Unreinforced masonry (URM); Seismic vulnerability assessment; Pushover analysis; Algeria.

1. Introduction

A school building embodies an enduring architectural structure in both urban and rural landscapes. It ranks among the most widespread and frequently visited public buildings worldwide. In educational architecture, its distinctive identity makes it an indelible landmark for every student. According to Chitour (1999), education in Algeria existed well before the French colonization that began in 1830. Teaching was organized in highly popular Quranic schools, attached to mosques (Youbi et al., 2024).
After 1870, the French educational model was massively established in Algeria. European students and a minority of indigenous people gained access to high-performing public schools, both primary and secondary (Chitour, 1999), as well as to religious institutions. Secondary schools (lycées) were built in the main cities, such as Algiers, Oran, and Blida (Aissaoui, 2026).

Figure 1. Interior and exterior view of the Emir Abdelkader High School (formerly the Grand Lycée d'Alger), the first secondary school built in Algeria (1860). Source: CDHA.

1.1 North Algeria: A Zone of Strong Seismicity

Northern Algeria has historically been subjected to significant seismic activity, resulting in widespread destruction and substantial loss of life. Among the most devastating events, some earthquakes reached a magnitude of 7.3 on the Richter scale according to the Research Center in Astronomy, Astrophysics and Geophysics (CRAAG). In this region, seismic events are predominantly shallow, generally occurring within the first 20 kilometers of the Earth's crust (Yelles-Chaouche et al., 2022).

This seismic activity is primarily generated by reverse and strike-slip fault mechanisms, governed by a NW-SE to NNW-SSE (Bezzeghoud et al., 2022) compressional stress regime induced by the oblique collision between the African and Eurasian tectonic plates (Yelles-Chaouche et al., 2022) (Stich et al., 2003). Despite their shallow nature, the combination of significant magnitude and proximity to densely populated areas make these earthquakes particularly destructive (Toni et al., 2024), with considerable potential for casualties and structural damage (Table 1).

Table 1: Some of historical and recent earthquakes in northern Algeria. Source: CRAAG.

Date	Region	Magnitude	EMS	Deaths	Injuries
1716	Algiers	7.5	X	8000	
1825	Blida	7.5	X-XI	3000	/
1867	Mouzaia	7.5	X-XI		
1891	Gouraya				
1954	Chlef (Ex Orléansville)	6.8	X	1250	3000
1980	Chlef (Ex El Asnam)	7.3	X	5000	9000
1988	Al Affroun	5.4	VII		
1989	Tipasa	6.0	VIII		
2003	Zemmouri	6.8		2278	11450
2013	Blida region	5.1	V	/	/
2018	Blida region	5.4		/	/
2020	Mila	4.9		/	/
2021	Béjaia	6.0		/	04
2022	Oran	5.1		/	/

The updated Algerian Seismic Regulations, RPA 2024 (CGS, 2024) classifies Algerian territory into seven seismic zones of progressively increasing hazard, ranging from Zone 0, characterized by low seismicity, to Zones V and VI, which correspond to the highest levels of seismic risk (Figure. 2). According to this classification, the wilayas of Algiers and Blida are located in Zone VI, placing them among the most seismically exposed regions in the country.

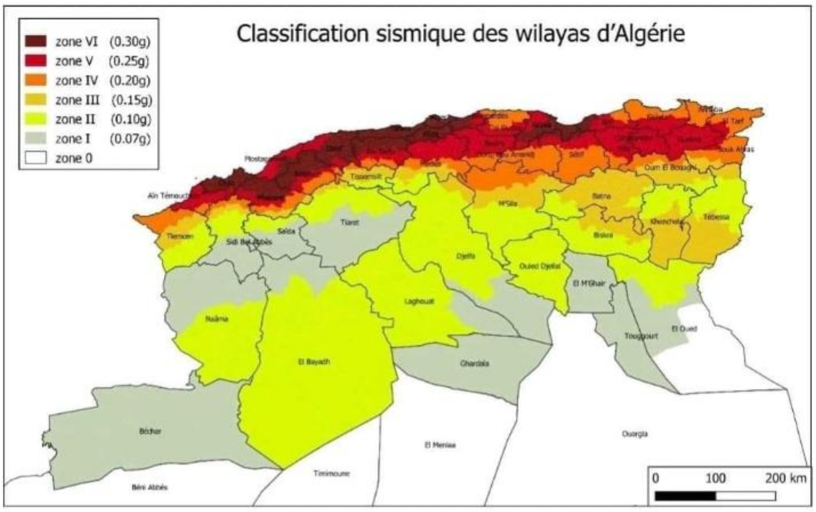


Figure 2. Seismic zoning of Algeria. Source: RPA version 2024.

1.2 Seismic Vulnerability of Existing Building

Historic buildings constructed in unreinforced masonry—namely those constructed prior to the introduction of seismic design regulations—generally exhibit a degree of structural vulnerability (Penna et al., 2019) (Mohammedi et al., 2021). Nevertheless, certain monumental constructions, built with appropriate craftsmanship and quality materials, have demonstrated considerable resistance to seismic ground motion.

Compared with other construction materials, masonry demonstrates a nonlinear behavior even under low seismic loading. In addition to its limited tensile strength (D'ayala & Novelli, 2014), its fragility is mainly attributed to its physical and mechanical properties, as well as to the nature of its components (such as mortar, cement, and bonding elements) (Mosoarca et al., 2020)

1.3 School Architecture in Algiers and Blida: A Heritage to Be Preserved

School architecture reflects the value that society places on education and youth (Cuentas et al.,2024). The majority of masonry school buildings were erected between the 19th and 20th centuries. These spaces, dedicated to learning and intellectual life, are deeply embedded in history — not only in the history of education, but also in that of architecture and the nation as a whole.

During the 19th and early 20th centuries, buildings were constructed using unreinforced masonry (URM), primarily with locally sourced materials (such as cut stone, rubble masonry, and bricks), and without consideration of seismic risk. The emphasis was placed on prevailing architectural styles rather than on the capacity of structures to withstand horizontal forces that may occur during an earthquake (Park et al., 2009).

Throughout the colonial era, a variety of school buildings were constructed, ranging from primary to secondary and high school levels, and reflecting architectural expressions characteristic of major European cities, including neo-classical, neo-Moorish, and eclectic styles (Khelifa-Rouaissia & Boulkroune, 2017). These educational buildings can be grouped into two broad categories:

- Establishments built as schools (primary schools; secondary schools; high schools)
- Establishments converted into schools after formerly being used for other functions (barracks; hospital; convent)

The objective of this study is to identify and locate these school buildings, then to categorize them according to their geometric configurations, while simultaneously conducting an assessment of their seismic vulnerability.

2. Materials and Methods

2.1 Identification and Classification of School Building

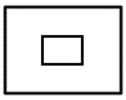
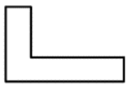
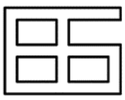
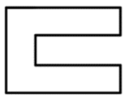
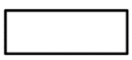
Following a survey conducted in two major cities in northern Algeria—Algiers and Blida—a total of 74 school buildings were identified (Table 2). These structures, officially listed by the Ministry of National Education, were constructed between 1830 and 1930 using unreinforced masonry (URM). Most were built with no consideration for seismic risk because, at that time, no regulations had been put into place (Henni chebra et al., 2024).

Table 2: Classification, by town and by level, of masonry school buildings. Source: (Developed buy authors).

Cities	**ALGIERS**	**BLIDA**
Primary school	41	7
Middle school	8	4
High school	12	2

The study places particular emphasis on high schools due to their high occupancy levels, where ensuring occupant safety is a primary concern. (Table 3) illustrates the range of geometric configurations identified in these buildings.

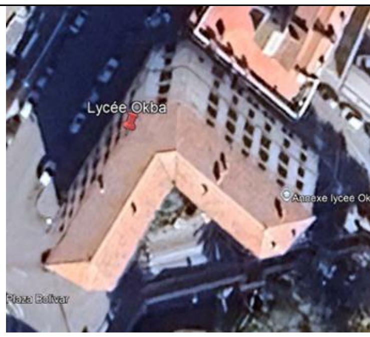
Table 3: High schools inventory classified by geomatic form. Source: (Developed buy authors).

	Geometrical shape		**High school**
(a)		O-shaped	03
(b)		L-shaped	02
(c)		checkerboard shape	03
(d)		U-shaped	01
(e)		Bar-shaped	02
(j)		H-shaped	01

The selection of the case study was based on several criteria, namely: (a) its location in a high seismicity zone; (b) its construction period between 1830 and 1930; (c) its construction materials and techniques, consisting of unreinforced

masonry (URM) of brick or stone; (d) the complex and unfavourable geometric configuration of the building (H, L, and U shapes) (Table 3); (e) the availability of architectural drawings; and (f) its status as a historical establishment
Considering all the selection parameters, the Okba Ibn Nafaa High School in Algiers and El Feth High School in Blida meet all the requirements for conducting this study, particularly with regard to their geometric configurations (Table 4) that do not comply with seismic code provisions, as well as the significant number of daily occupants they accommodate.

Table 4: The two specimens selected for seismic vulnerability assessment. Source: (Developed buy authors).

	City	Geometrical form	Satellite view
Okba Ibn Nafaa High School	Algiers	L-shaped	
El Fath High school	Blida	H-shaped	

2.2 Presentation of the Case Studies

The following table provides a comprehensive overview of the two selected high schools along with their structural characteristics (table 5), both of which are constructed of unreinforced masonry (URM).
The Okba Ibn Nafaa High School was originally purpose-built as an educational facility, known as the 'Boys' Superior School', and was subsequently converted into a high school following Algeria's independence.
In contrast, the El Feth High School was initially erected as a religious building, serving as a convent for nuns, before being repurposed as a hospital during the Second World War, and ultimately transformed into a high school.
Beyond their remarkable historical backgrounds, both case studies represent an architectural style that left a lasting mark on 19th-century built heritage.

Table 5: General overview of the case studies. Source: (Developed buy authors).

Hich school	Main façade	Structural characteristics		
		Load-bearing walls	Wall thickness	Floor system
Okbaa Ibn Nafaa (Built around 1920)		Rubble stone Cut stone	External walls: 60 cm Internal walls: 40 cm	Jack arch floor Steel joists Solid brick infill
El Fath (Built around 1860)		Rubble stone Hollow brick with 6 holes	External walls: 55 cm Internal walls: 38 cm	Jack arch floor Woden floor

2.3 Equivalent frame modeling of unreinforced masonry (URM)

Several analytical approaches have been proposed in the literature to model masonry structures at different scales (Mosoarca et al., 2020) (Siano et al., 2018). Among these, the macro-element (Figure 3) approach stands out as particularly well-adapted to the heterogeneous and discontinuous nature of masonry (Lagomarsino et al., 2013) (Pinasco et al., 2025). By capturing the interactions between its constituent components — stone, brick, and mortar — and accounting for an initial elastic response followed by a softening phase, this method produces results that align well with experimental evidence (Canditone et al., 2025).

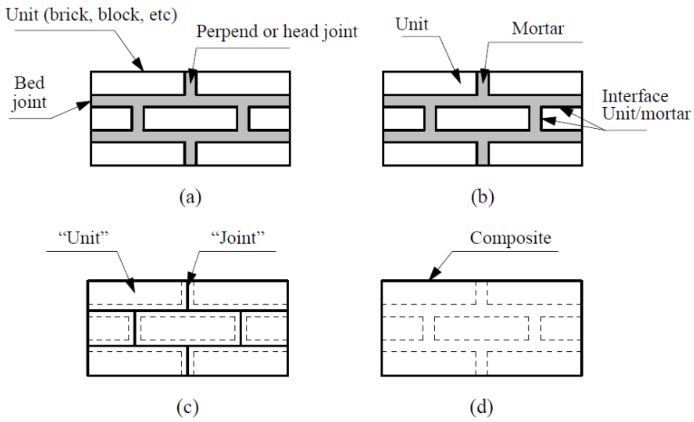


Figure 3. Modelling techniques in masonry (a) Masonry sample; (b) detailed micro-modeling; (c) simplified micro-modeling; (d) macro-modeling. Source: (Asteris et al., 2014).

The equivalent frame models were generated using the TreMuri software after inputting all geometric and mechanical data for the two case studies. This process resulted in two models of varying levels of complexity.

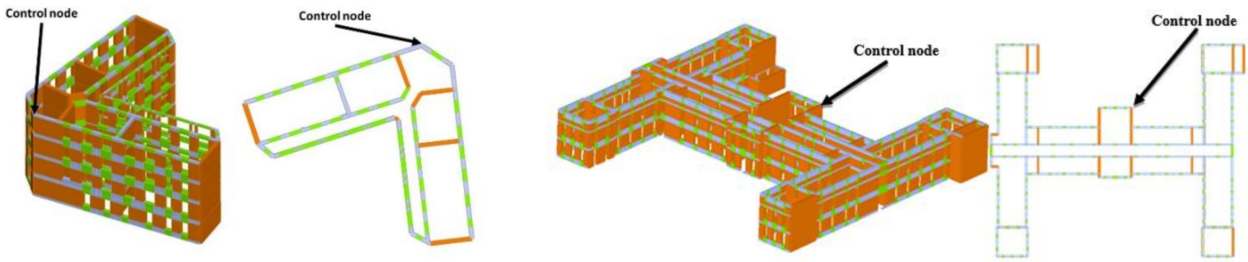


Figure 4. Equivalent frame model generated using TreMuri software: on the left (Okba Ibn Nafaa High School), on the right (El Feth High School). Source: (Developed by authors).

2.4 Pushover Analysis

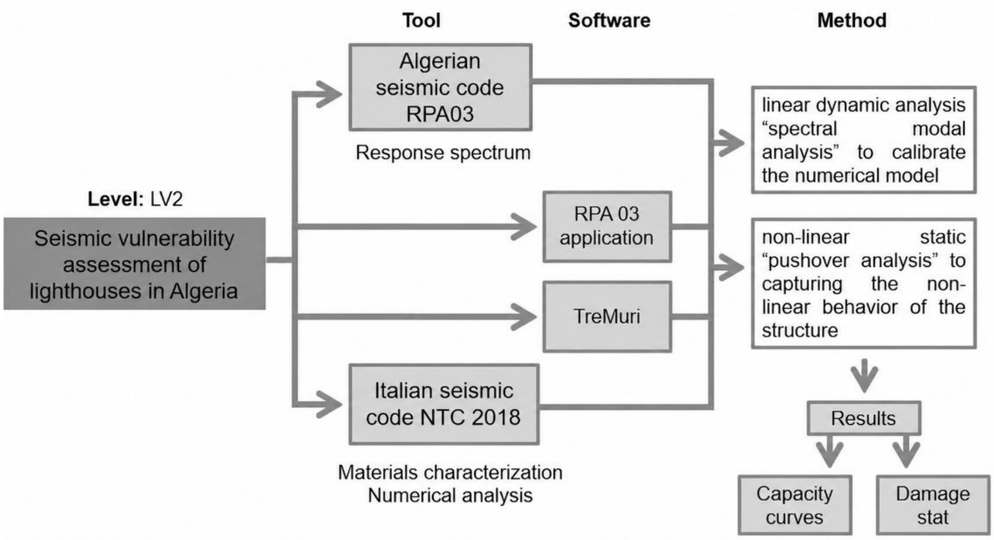


Figure 5. methodology of assessment employed. Source: (Developed by authors).

The seismic vulnerability assessment proposed in this study is conducted at Level 2 (LV2) analysis and combines complementary analytical tools and methods within a multi-code framework. As illustrated in (Figure 5), the methodology is based on two regulatory references and a dedicated numerical platform.

The Algerian Seismic Code (RPA 2003) provides the elastic response spectrum used to perform a linear dynamic analysis, namely a spectral modal analysis, for the calibration of the numerical model and the verification of its dynamic characteristics with respect to the seismic demand prescribed by the national regulations. In parallel, the Italian seismic code NTC 2018 is employed for material characterization and for defining the parameters governing the nonlinear analyses, owing to its comprehensive provisions for the assessment of existing unreinforced masonry structures.
Numerical simulations are carried out using the TreMuri software platform, which implements a macro-element approach specifically developed for masonry structures. Two computational modules are employed within the assessment framework: the RPA 2003 application for code-compliant spectral analyses and TreMuri for nonlinear static analyses. The core of the structural assessment relies on nonlinear static (pushover) analysis, which enables the evaluation of the structural response beyond the elastic range and the identification of the principal failure mechanisms under increasing lateral loading. (Amari et al., 2020)
The results are expressed through capacity curves, representing the relationship between base shear and roof displacement, and damage-state distributions derived from the nonlinear analyses. These outputs provide the basis for evaluating the seismic performance of the lighthouse structures and for characterizing their seismic vulnerability (Negulescu et al., 2014).

Once the structural model is established, a pushover analysis can be performed. The seismic action is represented through response spectrum data, which in this case are derived in accordance with the provisions of the Algerian seismic code RPA 2024 (CGS, 2024).
After defining these parameters, the structural analysis is carried out. The Italian standard NTC 2018 (Ministero delle Infrastrutture e dei Trasporti, 2018) specifies 24 analysis procedures, differentiated by the loading direction (along the x and y axes, in both positive and negative senses) and the type of loading pattern (modal or uniform), while also accounting for structural eccentricity.

3. Results

3.1 Okba Ibn Nafaa High School

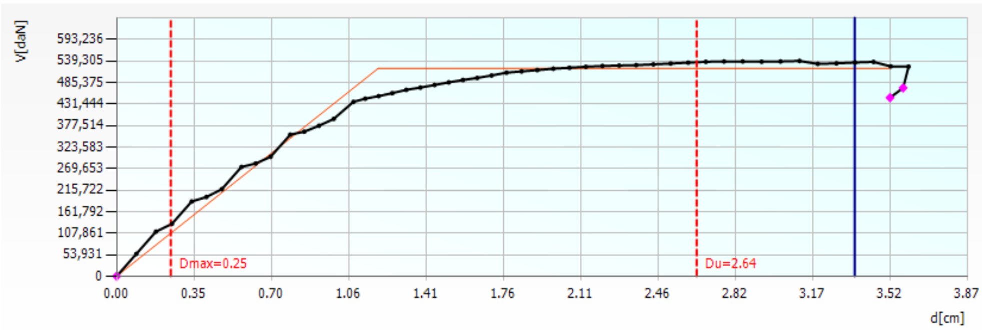


Figure 6. Capacity curves, corresponding equivalent bilinear curves, and maximum available displacement Du. Pushover in the +X direction. Source: (Developed by authors).

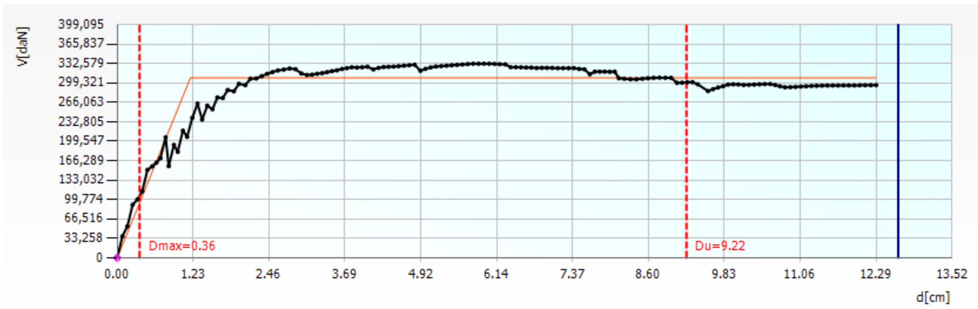


Figure 7. Capacity curves, corresponding equivalent bilinear curves, and maximum available displacement Du. Pushover in the -Y direction. Source: (Developed by authors).

The pushover capacity curve obtained along the +X direction shows a characteristic nonlinear response consistent with unreinforced masonry structures (Figure 6). Bilinearized using the N2 method, the curve indicates a high initial stiffness up to a displacement of approximately 1.06 cm, followed by an approximate resistance plateau of 485–539 kN, reflecting a gradual stiffness degradation. The identified characteristic displacements include Dmax = 0.25 cm, corresponding to the expected displacement under the reference seismic action, and Du = 2.64 cm, representing the ultimate displacement before collapse.
The capacity curve illustrated in (Figure 7) highlights key characteristic points, including the maximum elastic displacement (Dmax = 0.36 cm) and the ultimate displacement (Du = 9.22 cm), both represented by vertical red lines. The structure initially exhibits high stiffness up to a displacement of approximately 1.23 cm, corresponding to the elastic behavior phase. Beyond this stage, the curve shows a nonlinear progression, with the maximum resistance reaching about 332 kN at a displacement of 4.92 cm. This peak is followed by a gradual degradation in resistance between 4.92 cm and 8.60 cm, after which the response stabilizes at approximately 290 kN.

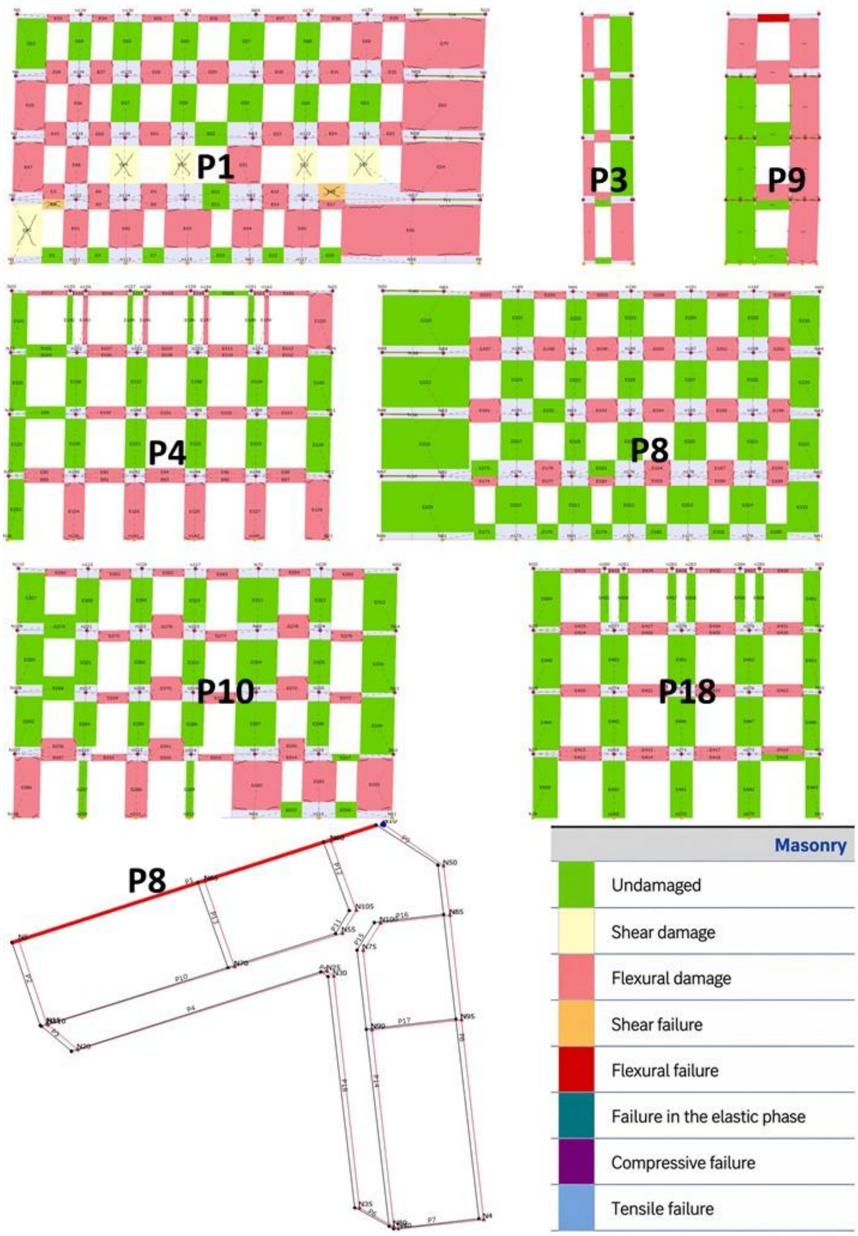


Figure 8. Wall damage state of Okba Highschool – Pushover analysis (positive X-direction). Source: (Developed by authors).

The post-pushover damage distribution along the +X direction (Figure 8) reveals a characteristic pattern of damage across the load-bearing wall system. Wall P1 exhibits predominantly flexural damage, concentrated in peripheral zones and at structural junctions, consistent with the bending demand induced by horizontal loading in the +X direction. Wall P3, oriented perpendicularly to the push direction, presents a combined flexural and shear damage pattern, particularly pronounced at the base level.

A significant concentration of damage is observed at the ground floor level of walls P4 and P8, a phenomenon typical of seismic loading conditions where lateral forces — and consequently internal stresses — are generally highest at the base. Wall P8, oriented parallel to the loading direction, exhibits flexural damage primarily at its extremities, while walls P9 and P10, oriented more perpendicularly, display a more complex mixed flexural-shear damage pattern.

The predominance of undamaged zones (green) across the wall system, particularly evident in wall P18, demonstrates that, despite localized damage, a substantial portion of the structure retains its load-bearing capacity. This observation is consistent with the post-elastic deformation capacity identified on the previously analyzed pushover capacity curve. Furthermore, the upper panels of walls P4, P8, and P10 generally sustain less damage than their lower counterparts, reflecting the expected deformation mode of such structural typologies, where lateral displacements increase with height while stress demands remain highest at the base.

The overall damage distribution is consistent with the typical seismic behavior of unreinforced masonry structures under horizontal lateral loading, wherein flexural failure mechanisms predominate in walls oriented parallel to the loading direction — such as P8 — while shear failure mechanisms govern the response of walls oriented perpendicularly — such as P3 and P9.

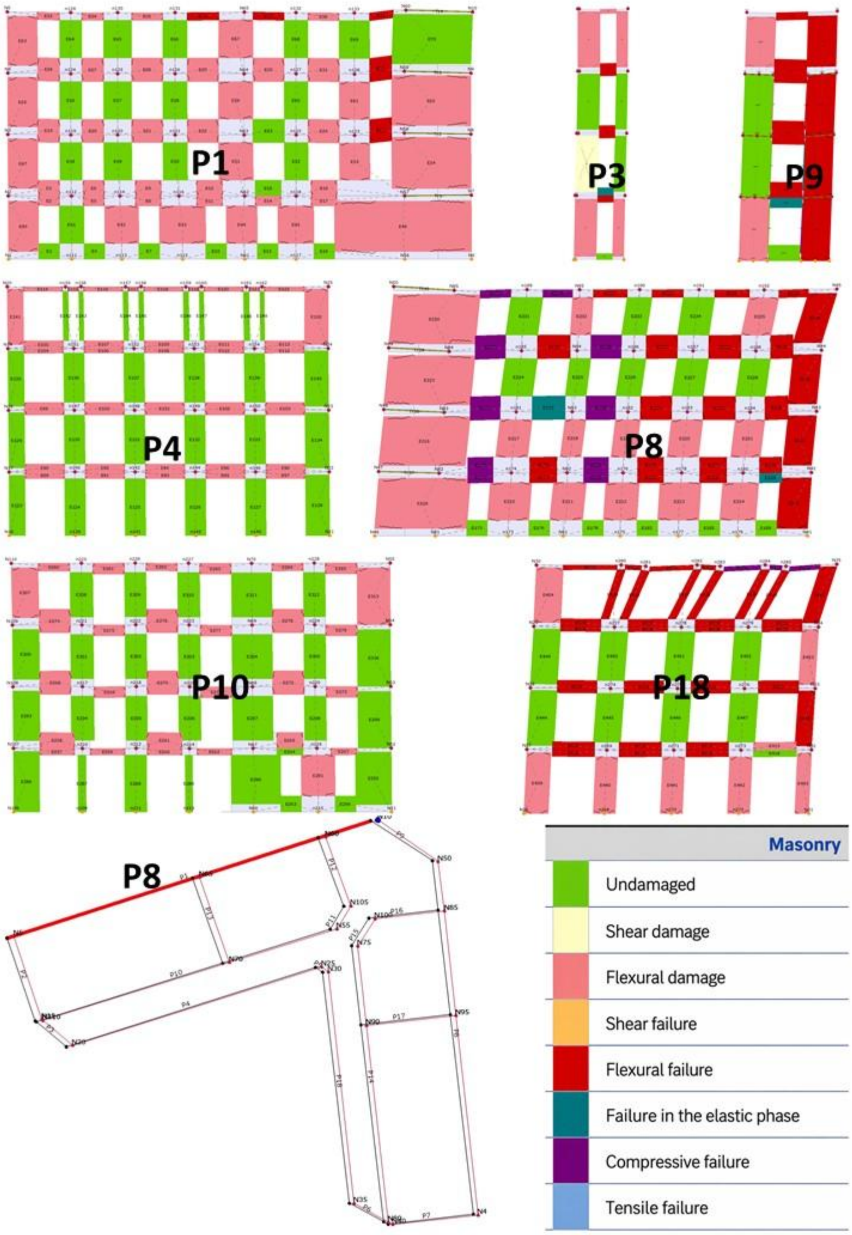


Figure 9. Wall damage state Okba Highschool – Pushover analysis (negative Y-direction). Source: (Developed by authors).

The post-pushover damage distribution along the −Y direction (see figure 9) reveals heterogeneous failure mechanisms distributed throughout the structure, reflecting the complex response of the masonry system under lateral loading.

Wall P1 exhibits predominantly flexural damage (pink) across numerous elements, with partial preservation of vertical members (green) in the central zone. This pattern suggests that P1, oriented perpendicularly to the loading direction, is subjected to significant out-of-plane bending demands.

Wall P3, narrow and oriented parallel to the push direction, displays an alternation of undamaged zones and flexurally damaged regions, along with localized shear damage (light yellow) at the base level, indicating a mixed in-plane response to horizontal solicitation.

Wall P9 presents a critical damage state, with extensive shear failure (orange) and flexural failure (red) concentrated particularly in the upper stories, alongside a zone of failure within the elastic phase (turquoise). This concentration of severe damage identifies P9 as a major vulnerability point under −Y directional loading.

Walls P4 and P10 exhibit a similar and comparatively favorable damage pattern, characterized by a large proportion of undamaged piers (green) and flexural damage limited primarily to spandrel elements, suggesting adequate lateral resistance in this loading direction.

In contrast, wall P8 presents severe and complex damage involving multiple simultaneous failure modes: compressive failure (purple) in certain piers, combined with shear (orange) and flexural (red) failures in other piers and spandrels, indicating a critical and multi-modal structural response likely attributable to torsional effects or structural discontinuities.

Wall P18 sustains extensive damage dominated by shear failure (orange) across nearly all piers, reflecting a significant vulnerability to lateral shear forces in the −Y direction.

Overall, the damage distribution highlights the particular vulnerability of walls P8, P9, and P18 under −Y lateral loading, while walls P4 and P10 demonstrate comparatively greater resistance. The occurrence of compressive failure in P8 suggests the presence of excessive stress concentrations, potentially induced by torsional coupling or geometric irregularities within the structural layout.

3.2 El Feth High School

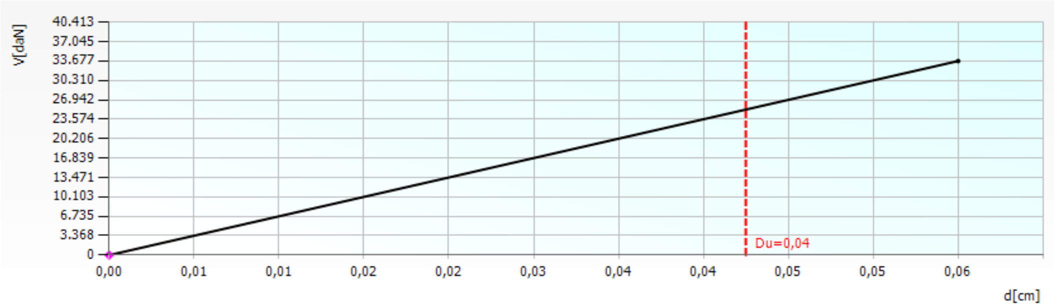


Figure 10. Capacity curves, corresponding equivalent bilinear curves, and maximum available displacement Du. Pushover in the +X direction. Source: (Developed by authors).

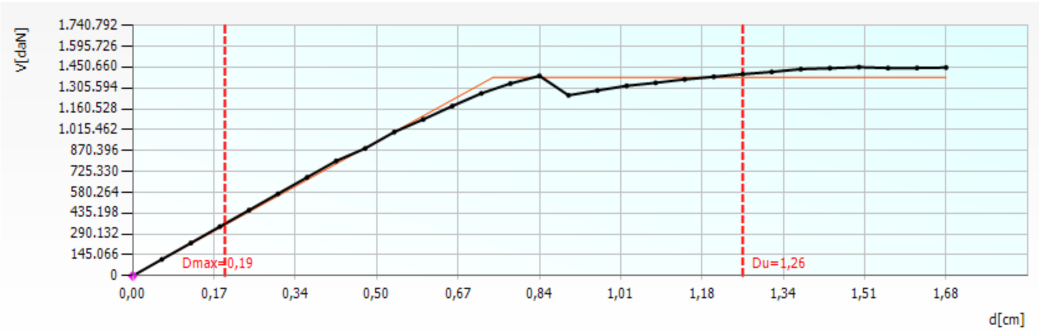


Figure 11. Capacity curves, corresponding equivalent bilinear curves, and maximum available displacement Du. Pushover in the -Y direction. Source: (Developed by authors).

The analysis (Figure 10) reveals that the seismic demand displacement (Dmax = 0.39 cm) substantially exceeds the ultimate displacement capacity (Du = 0.04 cm), indicating that the structure is unable to withstand the reference seismic action without reaching collapse in this direction. Furthermore, the ultimate displacement is located within the elastic range of the curve, indicating a very limited deformation capacity and a highly brittle structural behavior under seismic loading.

The capacity curve presented in (Figure 11) illustrates the structural behavior of the building during the pushover analysis along the −Y direction. The analysis shows that the maximum displacement (Dmax = 0.19 cm) remains significantly lower than the ultimate displacement (Du = 1.26 cm), with Dmax = 0.19 cm < Du = 1.26 cm. This relationship indicates that the structure possesses a substantial reserve of capacity in this direction.

Figure 12. Wall damage state of El Feth Highschool – Pushover analysis (positive X-direction). Source: (Developed by authors).

Figure 12 illustrates the in-plan damage distribution across the principal walls of the building following pushover analysis in the +X direction. The predominance of undamaged zones (green) confirms that the structure, characterized by significant lateral stiffness in this direction, has globally performed satisfactorily under the applied horizontal loading demands.

The observed damage is concentrated primarily at the spandrel level, where flexural failure (red zones) and flexural damage (pink zones) are localized predominantly at member extremities. This damage configuration is characteristic of unreinforced masonry buildings, in which spandrels — as the structurally weaker horizontal elements — deform preferentially, thereby dissipating a portion of the seismic energy input and preserving the overall structural integrity.

The piers, as the critical vertical load-bearing members essential to the building's lateral stability, exhibit considerably less damage, with only isolated zones affected by flexural damage. This relative preservation of vertical structural members is favorable to the maintenance of the building's load-bearing capacity under seismic conditions.

The overall damage pattern, largely confined to horizontal non-load-bearing elements (Pilipovićet al., 2026), suggests a comparatively satisfactory structural response to lateral loading in the +X direction, notwithstanding the absence of ring beams (tie beams).

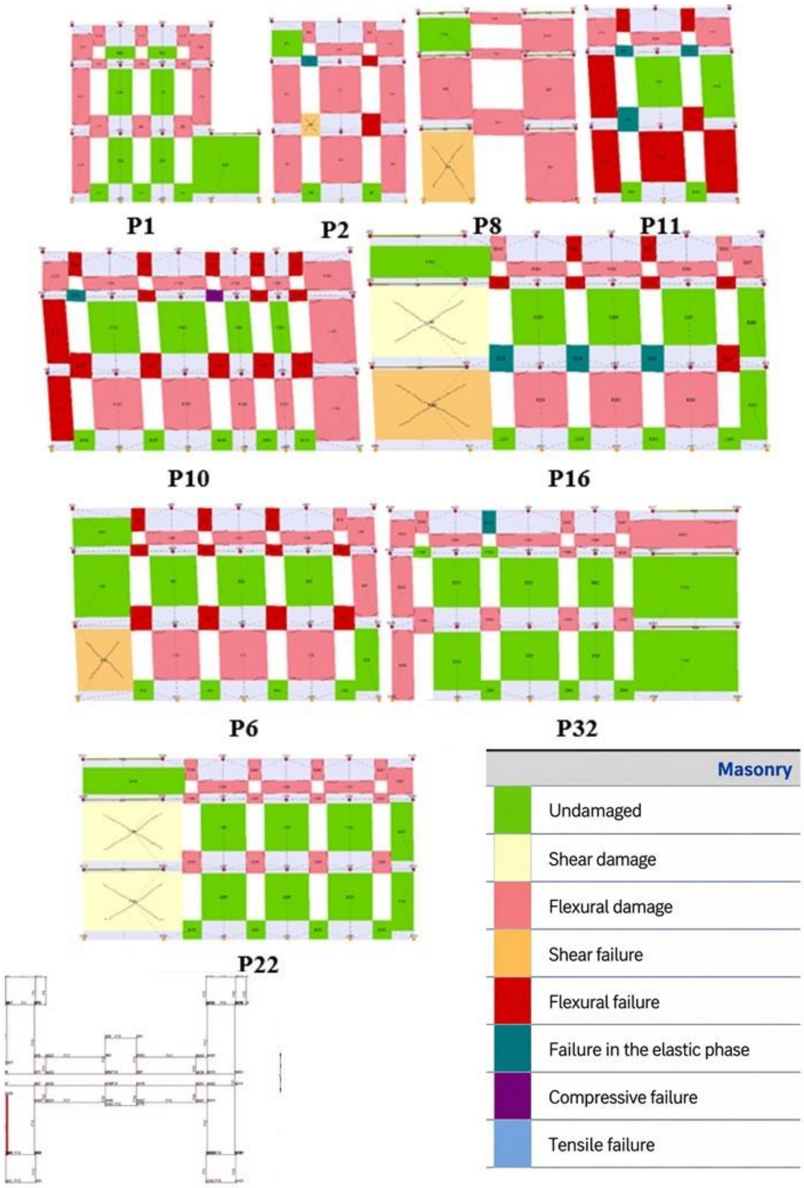


Figure 13. Wall damage state of El Feth Highschool – Pushover analysis (negative Y-direction). Source: (Developed by authors).

The in-plan damage analysis along the −Y direction (Figure 13) reveals a comparatively more critical structural behavior. Despite a residual capacity reserve identified on the pushover curve (Dmax < Du), the walls exhibit significant and diversified damage patterns.

Walls P1 and P32 display predominantly flexural damage (pink zones) localized at the level of spandrels and piers, yet retain a relative structural integrity. In contrast, walls P11, P10, P16, and P6 exhibit flexural failure (red zones) of greater concern, affecting essential load-bearing members.

A particularly alarming phenomenon is the onset of shear failure (orange zones) in the spandrels of walls P8, P16, P6, and P22, accompanied by shear damage zones (yellow), indicating early-stage shear degradation. These failure mechanisms directly compromise the vertical load-bearing capacity of the structure.

4. Discussion

4.1 Okba Ibn Nafaa High School

The evolution of the capacity curve (Figure 5) highlights the progressive degradation mechanism of the building, with a slight reduction in resistance observed at large displacements (beyond 3.17 cm). This unexpected post-elastic deformation capacity, despite the absence of tying elements, suggests that the quality of the original construction — particularly wall thickness and lime mortar cohesion — may have contributed to an inherent, albeit limited, seismic resilience.

The capacity curve (Figure 6) indicates that the maximum elastic displacement (Dmax = 0.36 cm) remains significantly lower than the ultimate displacement (Du = 9.22 cm), demonstrating an important post-elastic deformation capacity of the structure in the −Y direction. This sustained load-bearing capacity beyond peak resistance suggests a progressive, rather than sudden, failure mechanism — a favorable characteristic that may allow occupant evacuation before total collapse.

4.2 El Feth High School
The absence of ductility demonstrated in Figure 10, which is characteristic of unreinforced masonry structures, prevents any effective energy dissipation during an earthquake. The relatively constant slope of the curve up to the failure point confirms the brittle behavior of the structure making the structure highly susceptible to brittle failure even under moderate seismic events.
Figure 11 indicates that the structure possesses a substantial reserve of capacity in this direction. Unlike the analysis along the +X direction presented previously, the building exhibits a more favorable behavior here, with a comfortable safety margin. The curve shows several distinct phases: an initial elastic phase up to approximately 0.5 cm of displacement, followed by a progressive nonlinear behavior phase until the plateau reached around 1.40 cm.
The plateau reflects the progressive yielding of certain structural elements, enabling a degree of energy dissipation that contributes to a more favorable seismic response in the −Y direction.
The results obtained from the pushover analysis of the two schools demonstrated that the selected buildings, characterized by complex geometric configurations such as 'L'-shaped and 'H'-shaped layouts, exhibit significant vulnerability under horizontal seismic loading. In the absence of seismic joints, these re-entrant corners become critical weak zones, leading to stress concentration and amplifying the structural susceptibility to seismic damage.

5. Conclusions
Nonlinear static analysis, also known as pushover analysis, represents a well-established and practically applicable assessment method for existing buildings. In this study, the method was applied to unreinforced masonry structures in order to evaluate their response under seismic loading. The obtained results provide valuable insights for specialists and can serve as a reliable basis for future structural rehabilitation and seismic strengthening interventions.
The assessment carried out using the TreMuri software focused on a study corpus composed of two high schools located in the north-central region of Algeria, specifically in Blida and Algiers. This evaluation enabled us to characterize and assess the seismic behavior of these URM structures under seismic loading.
The results of our analysis demonstrate that the behavior of these buildings varies significantly depending on their geometric configuration, the arrangement of their load-bearing elements, and the intrinsic properties of the materials composing the structures. Indeed, the two school buildings — El Feth and Okba Ibn Nafaa — exhibit markedly different structural responses, as observed in the El Feth and Okba Ibn Nafaa high schools. Beyond dimensional considerations, “H”-shaped and “L”-shaped configurations prove to be particularly vulnerable in the absence of seismic joints.
These irregularities, both in plan and in elevation, may induce structural torsion phenomena, leading to significant damage that can extend to structural failure or partial collapse. These observations corroborate our initial hypothesis and justify the selection of the analyzed specimens based on their distinct geometric configurations.
Although very old, — with Lycée El Feth being more than 150 years old (Henni chebra et al., 2024) and Lycée Okba Ibn Nafaa over a century old — these school buildings remain functional and in good condition. Located in a highly seismic region, the structures nevertheless demonstrated a favorable dynamic behavior, revealing unexpected seismic-resistant properties despite having been designed without any seismic regulations. This longevity may be attributed to the robustness of construction practices and material quality prevalent during the colonial period, prior to the formalization of seismic design codes.
This study nevertheless presents several limitations. On the one hand, the initial quality of the materials and their current state of preservation cannot be accurately assessed due to the lack of available data, archival documentation, and investigative resources. On the other hand, although pushover analysis remains a relevant assessment method, it does not fully capture out-of-plane failure mechanisms, which are particularly relevant for masonry walls with limited floor-to-wall connections.
In conclusion, this research has provided new insights into a little-known and vulnerable architectural heritage. The assessment of the seismic vulnerability of historic masonry school buildings is not merely a technical challenge, but also part of a broader approach aimed at preserving an architectural heritage rich in meaning and collective memory.

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