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Residents' Responses to Water Shortages in Algeria's AADL Housing: Implications for Environmental ,Architectural, and Social Resilience"

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Abstract

This study investigates the impact of informal water-storage practices in AADL housing developments in Algeria, where residents install large-capacity water tanks on rooftops, balconies, stairways, and entrances to cope with recurrent water shortages. The research aims to evaluate the structural, architectural, and social implications of these unauthorized interventions. A qualitative methodology based on field observations and expert assessments was applied across several collective housing sites. The findings indicate that uncontrolled tank installations increase seismic vulnerability by introducing irregular structural loads, while also degrading urban aesthetics, damaging shared spaces, and generating social conflicts among residents. The study identifies significant deficiencies in current water-management strategies within collective housing programs. It concludes that integrating collective underground water-storage systems combined with decentralized distribution mechanisms could improve water accessibility, enhance structural safety, and preserve architectural coherence. The research contributes to sustainable and resilient housing strategies adapted to the Algerian urban context.
Keywords: Water management ;Sustainable housing ;AADL program ;Urban resilience ; Algeria.

1. Introduction

Algeria has been facing increasing water stress due to a combination of climatic variability, rapid urbanization, and growing domestic demand. Periodic droughts, declining groundwater levels, and uneven distribution of water infrastructure have intensified water shortages, particularly in large urban housing developments.

In the context of recurrent water shortages affecting collective housing developments in Algeria, residents of public housing programs such as the AADL estates have increasingly adopted informal strategies to secure domestic water supply. Among the most widespread practices is the installation of large-capacity water tanks on rooftops, balconies, stairways, and building entrances. Although these interventions respond to an essential daily need, they progressively transform the architectural and structural configuration of residential buildings, generating new technical, environmental, and social challenges that were not anticipated in the original housing design.

Originally conceived according to standardized reinforced concrete (RC) shear-wall systems, particularly the "Table Banche" construction method, AADL buildings were designed to ensure structural efficiency, rapid execution, and seismic resistance under predefined loading conditions. However, the addition of unauthorized water reservoirs introduces significant localized loads and mass irregularities that can adversely affect the seismic behavior of these structures. In seismic regions such as Algeria, the concentration of elevated masses on balconies and rooftops increases structural vulnerability by amplifying overturning moments, torsional effects, and dynamic instability during earthquakes.

Beyond structural concerns, the uncontrolled proliferation of individual storage tanks contributes to the degradation of the architectural quality and visual coherence of collective housing environments. The occupation of shared spaces such as staircases, terraces, and entrances alters the intended urban image of residential complexes and accelerates façade deterioration through leakage, humidity, and material degradation. Furthermore, these informal practices often generate social tensions between residents due to unequal access to water resources and the privatization of common areas.

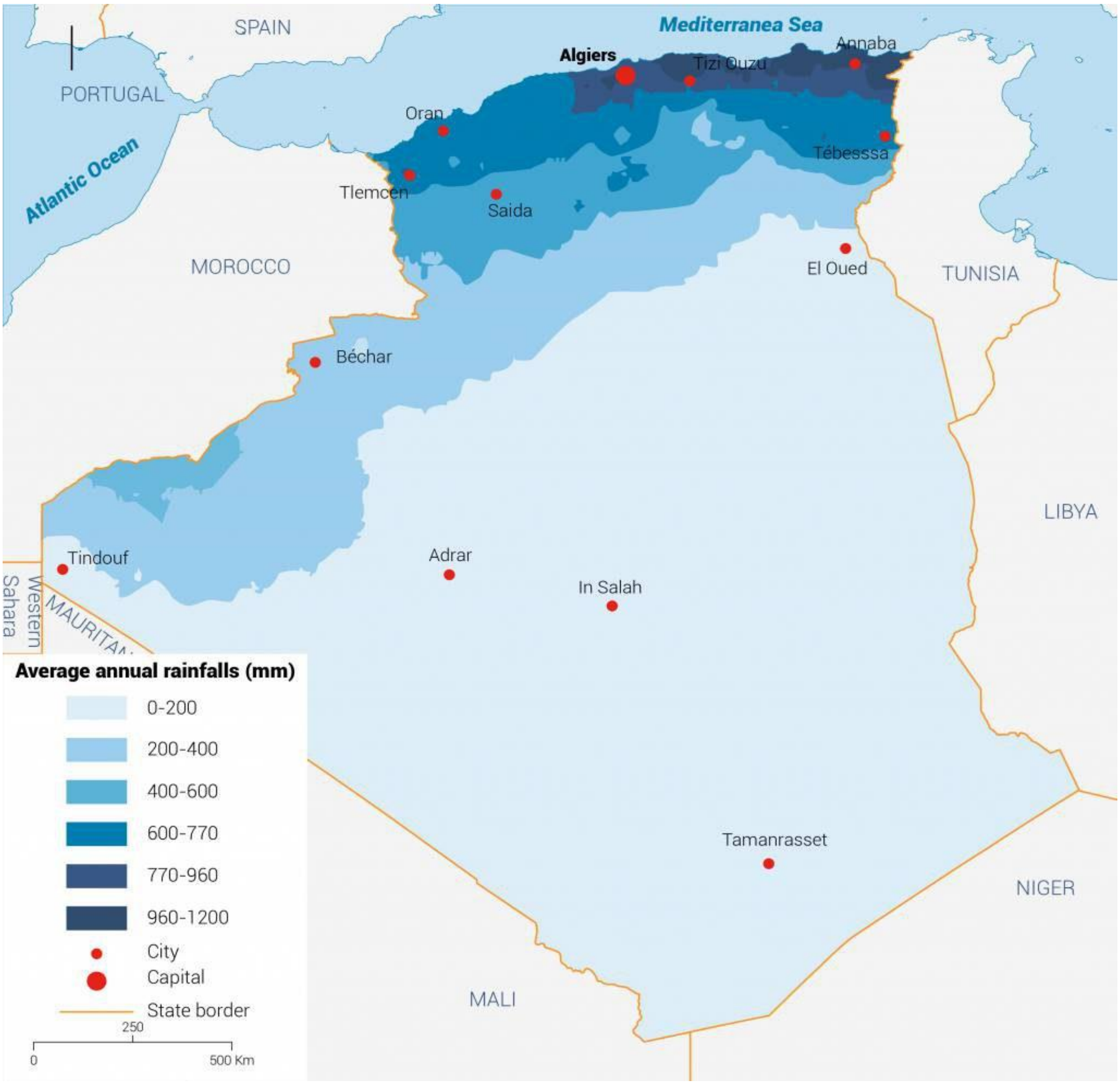

Figure 1. Algerian average annual rainfalls (mm) Source:(Authors).

These issues reveal a broader gap in the water management strategies adopted within the AADL housing program. As Algeria advances toward more resilient and sustainable urban development policies, there is an increasing need to rethink domestic water storage within collective housing projects. In this perspective, integrating collective underground storage systems into future residential designs appears as a viable alternative capable of ensuring equitable water distribution while preserving structural safety, architectural integrity, and social cohesion. Such an approach would not only improve the resilience of housing estates in the face of water scarcity and seismic risk, but also contribute to the long-term sustainability and habitability of contemporary urban environments in Algeria.

Figure 2. The AADL housing program (Developed by the Authors).

The scientific literature addressing informal water-tank installations in collective housing highlights the need for a multidisciplinary approach integrating structural, socio-technical, and hydraulic dimensions. From a seismic engineering perspective, several studies have demonstrated that the addition of concentrated masses on upper floors significantly alters the dynamic response of reinforced concrete (RC) buildings. Bulent Aykas et al. (**2012**) showed that irregular mass distribution amplifies lateral displacements and increases P-Delta effects, thereby intensifying overturning moments during seismic events. Similarly, S. C. Dutta, Sudhir K. Jain, and C. V. R. Murty (**2009**) demonstrated that elevated water masses generate additional seismic demand due to increased inertia forces. Regarding shear-wall systems commonly used in “Table Banche” buildings, Michael N. Fardis (**2009**) emphasized that, despite their high lateral stiffness, these structures remain highly sensitive to torsional irregularities. This vulnerability becomes more critical when heavy loads are distributed asymmetrically. In this context, Giuseppe Mazza and Labernarda (**2020**) demonstrated that eccentric mass distribution shifts the Center of Mass away from the Center of Rigidity, generating torsional forces capable of compromising the global seismic performance of RC buildings.

Beyond structural considerations, several scholars have examined the socio-technical reasons behind residents’ preference for individual water-storage systems over centralized infrastructure. Karen Bakker (**2010**) argued that fragmented urban water infrastructures encourage inhabitants to adopt individual resilience strategies due to declining trust in collective management systems. This perspective was further developed by Michelle Kooy, Pruitt, and Sianipar (**2019**), who described “self-supply” practices as a direct response to unreliable public water services and inadequate infrastructure governance. In collective housing environments, these practices progressively transform shared spaces and reinforce the privatization of common areas. Furthermore, Jian Ge and Hokao (**2005**) demonstrated that uncontrolled modifications to residential façades generate forms of “visual entropy” that negatively affect urban aesthetics, architectural coherence, and property value.

The hydraulic and energy dimensions of decentralized water storage have also been widely investigated. A. S. Vieira et al. (**2014**) demonstrated that ground-level decentralized storage systems can improve the sustainability and energy efficiency of residential water distribution when properly designed. Likewise, S. Nair, Samuel, and George (**2014**) showed that decentralized pumping systems are technically capable of supplying high-rise residential buildings, provided that the required static head and residual pressure are adequately controlled. Collectively, these studies suggest that underground or ground-level collective storage systems combined with decentralized pumping mechanisms constitute a technically feasible, socially acceptable, and structurally safer alternative for collective housing projects in Algeria.

Figure 3. improvised water reservoirs installed within shared spaces in the AADL housing program (Developed by the Authors).

2. Materials and Methods

The study adopts a dual-track methodology to resolve the technical-social paradox of water storage in high-rise shear-wall buildings. First, a Finite Element Model (FEM) of the R+09 structure was developed to simulate seismic behavior under heavy top-loading conditions. Second, a comparative impact assessment was conducted to evaluate the 'Hybrid Decentralized' model."

A. Structural Simulation Parameters:

- **System:** Reinforced concrete shear walls (Table Banche).
- **Loading:** 36 individual nodes representing 15.0 kN each (1500L full tanks).
- **Analysis:** Linear Static and Dynamic Response Spectrum Analysis.

B. Social-Technical Integration:

- The methodology incorporates the **'User Autonomy Factor'**, acknowledging that centralized pump systems are often rejected due to maintenance distrust. The proposed model relocates the 36 individual tanks to the Ground Floor (GF), maintaining independent plumbing lines for each unit.

We can divide the methodology into four main phases:

1. **Structural Modeling:** Defining the R+09 "Table Banche" building parameters (materials, dimensions, and shear wall thickness).
2. **Load Definition:** Calculating the static and dynamic loads of the 36 full 1500L tanks.
3. **Seismic Analysis:** Defining the seismic zone and the response spectrum used for the simulation.
4. **Socio-Technical Comparison:** Establishing the criteria for the social "Trust" factor vs. technical "Safety" factor.

Phase 1: Structural Modeling & Design

In this part, we describe the building's "bones." Since you are using the **Table Banche** system, the stiffness comes from the reinforced concrete walls.

- **Material Properties:** Concrete grade (e.g., C25/30) and Steel grade (e.g., FeE500).
- **Structural System:** Bearing walls (voiles porteurs) with cantilevered balconies.
- **Software:** Mentioning the software used (e.g., ETABS, SAP2000, or Robot Structural Analysis).

Phase 2: Loading Scenarios

To make the study robust, we compare two distinct models:

- **Model A (Current Practice):** 4 tanks per floor on balconies from the 1st to the 9th floor.
- **Model B (Proposed Hybrid):** 36 tanks located at the Ground Floor (GF), each with an independent pumping line.

Table 1: The methodology divided into four main phases.

Phase	Description	Key Objective
Phase 1: Data Acquisition	Define R+09 "Table Banche" dimensions and 1500L tank specifications.	Establish the Baseline Model.
Phase 2: Seismic Modeling	Apply response spectrum analysis (e.g., $Cs = 0.3g$) to the structure.	Quantify V_b and M_o.
Phase 3: Socio-Technical Analysis	Evaluate resident trust, maintenance autonomy, and space usability.	Identify social constraints.
Phase 4: Comparative Evaluation	Compare "Tanks on Balconies" vs. "Hybrid Ground Floor" models.	Validate the optimal system.

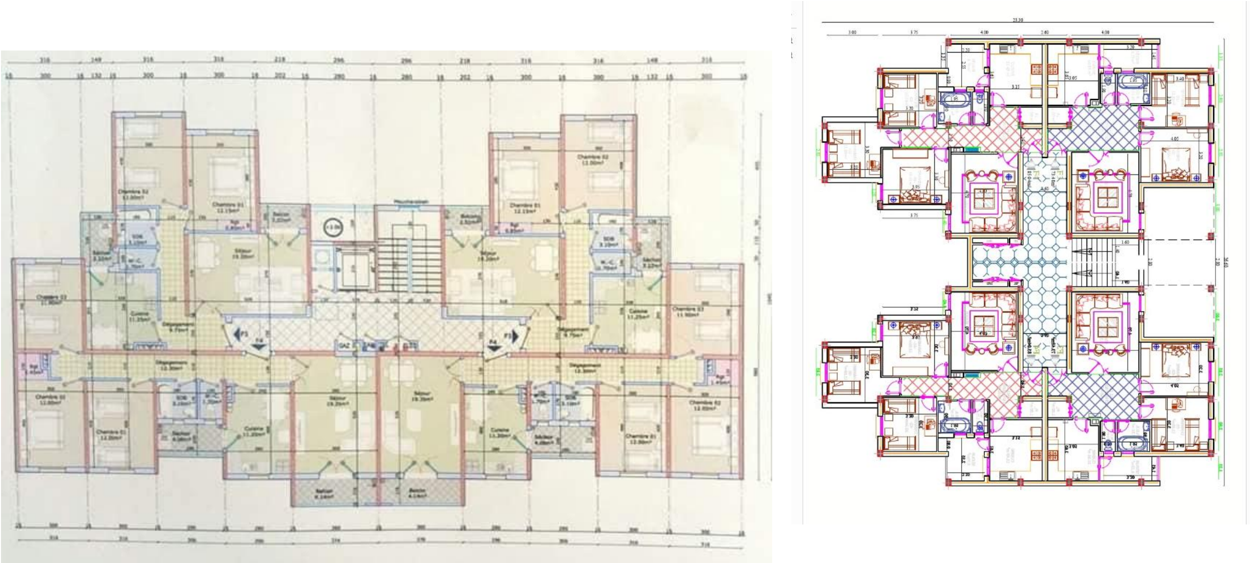

Figure 3. Plan roof in the AADL housing program
(Developed by the Authors).

3. Results

Placing the tanks on balconies radically changes the load distribution compared to a flat roof arrangement. In a "**Formwork Table**" structure (tunnel formwork system or load-bearing walls), balconies are often cantilevers or slabs supported on two or three sides. Adding a point load **of 1000L (10 kN) or 1500L (15 kN)** to the end of a balcony creates a significant bending moment. Here are the steps we will follow for our calculations:

1. Load Characterization

We need to calculate the additional surface load on the balcony slab. Volume (V): 1.5 m³ (for 1500L). Weight (W): Approximately 1500 kg or 15 kN. Surface Area .A standard tank occupies approximately 1.2 m² × 1.2 m².

2. Structural Impact on Cantilever Slabs We will analyze how this load increases the negative moment (Ma) at the balcony's connection to the load-bearing wall.

1. Load Characterization

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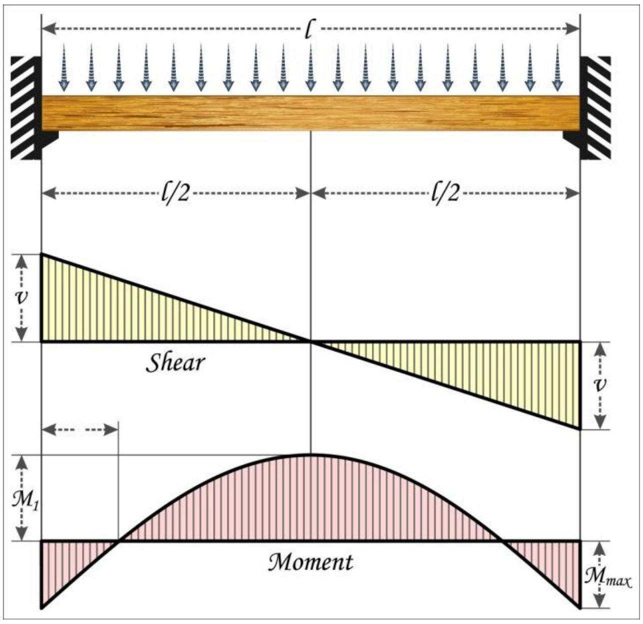

Figure 4. Structural Impact on Cantilever Slabs (Developed by the Authors).

Figure 5. The tanks Placed on balconies (Developed by the Authors).

3-Vertical Load Takedown
Since there are 9 stories, we need to check if the load-bearing walls of the ground floor can support the accumulation of these eccentric loads.
Let's start with a quick check of the balcony's capacity:
For a typical balcony in a residential building, the live load specified by standards (such as Eurocode 2) is generally 3.5 kN/m².

4-Integrating seismic effects:
Integrating seismic effects into your study is essential, as water tanks located on balconies significantly alter the building's dynamic response. In a high-rise structure **(R+09),** these masses act as oscillating loads that can amplify the forces felt by the structural walls.
To analyze the **Vertical Load Takedown** under seismic conditions for a **9-story (R+09)** building with **Table Banche** (shear wall) technology, we must account for the added mass of the water tanks on the balconies.
In seismic engineering, the vertical load isn't just a static weight; it becomes a dynamic force. When an earthquake occurs, vertical ground acceleration (Av) can momentarily increase or decrease the effective weight of the tanks, putting extreme stress on the balcony-to-wall connection.
To analyze, we need to transition from **static loads** to **Dynamic Seismic** Analysis :
Let's begin the technical drafting with the **Seismic Coefficient (*Cs*).**
In seismic design, we calculate the Design Base Shear (*V*), which represents the total lateral force the building must resist at its base. The formula is:
V = Cs \times W
Where:

- ***V*** is the Base Shear.
- ***Cs*** is the Seismic Response Coefficient (determined by soil type and building importance).
- ***W*** is the Effective Seismic Weight (Total dead load + a portion of the live load).

If we add **36 tanks** of **1500L** each, we are adding approximately **540 kN (54 tons)** to the structure.

4.1. The "Sloshing Effect"
When an earthquake occurs, the water inside the tanks doesn't move as a solid block. It "sloshes," creating two types of forces:

- **Impulsive Mass (Mi):** The portion of water that moves with the tank wall.
- **Convective Mass (Mc):** The portion of water that creates waves, exerting a delayed force on the tank.

4.2. Eccentricity and Torsion :
Since the tanks are on balconies (the perimeter of the building), they increase the **Mass Eccentricity**. This can lead to **Torsional Effects**, where the building doesn't just sway back and forth but also twists around its vertical axis.

4.3. Vertical Acceleration :
Balconies are sensitive to vertical seismic components. A tank filled with 1500L increases the risk of the balcony slab failing due to a "punching" effect or sudden shear force during an upward or downward jolt.
The table 2 tracks the accumulation of load from the top floor down to the foundation.

Table 2: the accumulation of load from the top floor down to the foundation.

Level	Description	Gravity Load (G+Q) [kN]	Seismic Vertical Force (Fv,i) [kN]
Roof (R+09)	4 Tanks + Slab	Pstatic	±(Av×Mass)
Floor 08	Accumulation	∑Pstatic	∑Fv,i
...	...	...	...
Ground Floor	Total Base Load	∑i=09Gi+ψQi	Base Shear Contribution

4.4. Structural Calculation
The total vertical design load (N_{Ed}) at any level during a seismic event is often defined by the combination:

$$N_{Ed} = \sum G_{k,j} + \gamma_{I} .\ A_{Ed} + \sum \psi_{2,i}\ x\ Q_{k,i}$$

Equation 1. The total vertical design load (NEd)

Where:

- $G_{k,j}$: Permanent loads (Structure + Empty Tanks).
- A_{Ed}: Design seismic action (Mass of water \times Seismic acceleration).
- $\upsilon_{2,i}$: Quasi-permanent coefficient for live loads (Water).

In a **Table Banche** system, these loads are transferred directly through the vertical concrete walls. Because the tanks are on the **balconies**, they create a **Moment (M)** that must be added to the **Axial Force (N)**.
Assuming all 36 tanks are 100% full (1500L each) provides the most conservative "worst-case scenario" for your study. In structural engineering, this is known as the **Ultimate Limit State (ULS)**.
When an earthquake hits, these full tanks contribute significantly to the **Base Shear** (Vb) of the building. Since they are located on balconies, they also create a **Torsional Moment** because the center of mass (CM) shifts away from the center of rigidity (CR).
To visualize the vertical load distribution for your article, we can use a **Load Accumulation Diagram**. This graph shows how the axial force (N) in the shear walls increases floor by floor.
Vertical Load Takedown Analysis
Let's look in the table 3 the accumulation of the axial force in a single corner shear wall supporting these balconies.

Table 3: the accumulation of the axial force in a single corner shear wall supporting these balconies.

Level	Floor Load (G+Q)	Tank Load (Ptank)	Cumulative Vertical Load (Ncum)
9th Floor	120kN	15kN	135kN
8th Floor	120kN	15kN	270kN
...	...	...	...

The choice of cistern location (ground floor vs. terrace/balcony) is a central issue in earthquake engineering for load-bearing walls.
Here is a comparative study summarized, highlighting the impact on the dynamic behavior of the structure.

Table 4: Comparative Study: Ground Floor vs. Upper Floors.

Criteria	Water Tanks at Ground Floor (RDC)	Water Tanks at Upper Floors (R+09)
Center of Mass (CM)	Lower; increases global stability.	Higher; increases the building's period of vibration.
Base Shear (Vb)	Minimal impact on lateral seismic forces.	Significant increase in horizontal inertia forces.
Torsional Effect	Negligible (if centered).	High (especially if placed on perimeter balconies).
P-Delta Effects	None.	Increased risk of second-order displacements.
Structural Integrity	No risk to slabs or balconies.	Risk of punching shear and cantilever failure.

2. Seismic Impact Analysis :
When tanks are placed on the **9th floor**, they act as a "pendulum mass" at the top of the structure. During an earthquake, the **top acceleration** is much higher than the ground acceleration.

A. Inertia Forces (F = m x a):
A full 1500L tank on the 9th floor experiences an acceleration amplified by the building's height. If the ground acceleration is **0.3g**, the roof acceleration might reach **0.9g.**

- **Force at RDC: 15 kN x 0.3 ~ 4.5 kN**
- **Force at R+09: 15 kN x 0.9 ~ 13.5 kN**

B. The Sloshing Effect:
In upper floors, the hydrodynamic pressure (sloshing) of the water can synchronize with the building's frequency, leading to **resonance**, which can be catastrophic for the supporting shear walls.

Technically, the best seismic-resistant solution is to place the tanks on the ground floor (ground floor) with a booster system. This keeps the center of gravity low and prevents accidental torsional moments on the concrete walls.

To analyzing the **Total Seismic Weight** (W) and the **Overturning Moment**.
Let's look at the comparative study between placing tanks at the **Ground Floor (GF)** versus the **9th Floor (R+09)** through the lens of seismic physics

1. **Comparative Analysis Table**

We can summarize in the table 5 the impact of tank placement on structural behaviour:

Table 5: The impact of tank placement on structural behaviour.

Technical Parameter	Ground Floor (GF) Placement	9th Floor (R+09) Placement
Fundamental Period (T)Stays low	the building remains stiff.Increases	the added mass at the top slows the vibration.
Story Drift Minimal displacement.Maximum displacement at the top, increasing P	Delta effects.	Story Drift Minimal displacement .Maximum displacement at the top, increasing P
Torsional Irregularity	None; mass is centered at the base.	High; creates a "Twisting" force on the shear walls.
Hydrodynamic Pressure	Absorbed by the ground/foundation.	Creates "Sloshing" forces against the balcony slabs.

2. The Physics of the "Top Floor" Scenario
When an earthquake hits, the building acts like an inverted pendulum. The **Lateral Force** (***F_x***) at any level $_x$ is proportional to its height and its mass.

For the 9th floor: $F_9 = \left(\frac{\text{w9xh9}}{\sum w_i hi}\right)^* Vb$ **Equation 2.** The weight of the 9th floor

Where:

- **w_9** is the weight of the 9th floor (including those 4 full 1500L tanks).
- **h_9** is the total height of the building (~30 meters).

By putting the tanks on the balconies of the 9th floor, you are multiplying the **Seismic Demand** on the entire structure compared to putting them at the base.

3. Structural Vulnerability of "Table Banche" Balconies
In **Table Banche** construction, the balcony is often a cantilevered extension of the floor slab.

- **Static Stress:** The tank creates a constant downward pull.
- **Seismic Stress:** The vertical acceleration (Av) can effectively "double" the weight of the water for a split second, potentially exceeding the **Shear Capacity** of the concrete connection.

4. Discussion
Based on the comparative structural analysis of a **9-story (R+09)** shear wall building, the research demonstrates a significant disparity in seismic performance depending on the location of water storage units.

4.1. Dynamic Impact of Tank Placement
The study confirms that placing **36 full 1500L tanks** on perimeter balconies significantly degrades the building's seismic response. This configuration creates a high **Center of Mass (CM)**, leading to:

- **Increased Base Shear (Vb):** Higher inertia forces due to amplified accelerations at upper levels (R+09).
- **Torsional Irregularity:** Significant eccentricity between the CM and the **Center of Rigidity (CR)**, inducing twisting moments in the "Table Banche" walls.
- **Local Vulnerability:** Extreme bending moments at the cantilevered balcony connections, risking brittle failure during vertical seismic oscillations.

4.2. The Recommended Solution: Ground Floor Integration
The most adequate system from a seismic standpoint is the **Ground Floor (GF) centralized storage** equipped with a variable-speed pressure booster system.

- **Mass Stabilization:** Keeping the water weight at the base eliminates additional inertia forces at height.
- **Structural Optimization:** It removes the need for costly reinforcement of balcony slabs and prevents the accumulation of parasitic torsional stresses.
  Total Overturning Moment (*Mo*).
  Assuming the building height is ***H = 27 m*** and the total seismic force of the tanks is ***F_s***:

Table 6: Comparison of Overturning Effects According to Water Tank Location in an R+09 Building.

Scenario	Total Added Mass (kg)	Height of Mass (m)	Resulting Overturning Moment (kNxm)
Tanks at R+09	54,000	27	High Impact
Tanks at Ground Floor	54,000	0	Zero Impact

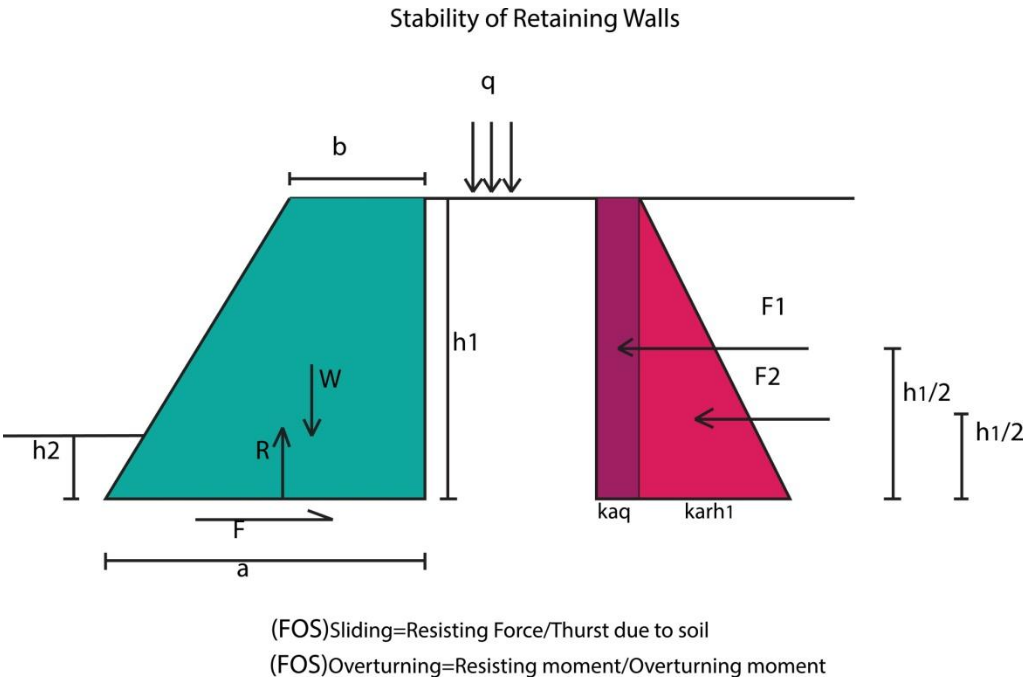

Figure 6. Stability of retaining wall (Developed by the Authors).

Numerical simulations reveal that elevated water storage on perimeter balconies induces significant torsional eccentricity and amplifies the base overturning moment by a factor related to the building's height. Consequently, a centralized ground-level storage system is recommended to preserve the structural ductility and seismic resilience of R+09 shear-wall buildings."

"Beyond the seismic vulnerability, the placement of large reservoirs on balconies converts a private amenity into a structural and visual burden, degrading both the architectural value of the property and the quality of life for its inhabitants."

the **Social and Aesthetic** costs are what residents and urban planners notice first. We call this the "Visual Entropy" of a building—when a structure begins to look disorganized because of unplanned additions.

Moving from the technical structural analysis to a broader socio-aesthetic evaluation adds a vital layer to this research. this is often categorized as **Impact Assessment** or **Sustainability Analysis**.**Comparative Study: Socio-Aesthetic & Functional Impacts**

let's explore **the social and aesthetic** impact of tank placement through a few specific lenses:

1. **Urban Aesthetics and Visual Identity**: We can discuss how the "visual clutter" of individual tanks on balconies disrupts the clean architectural lines of the "Table Banche" (shear wall) design, potentially lowering the perceived value of the neighborhood.
2. **Social Equity and Quality of Life**: We can examine how the loss of private balcony space affects the physical and mental well-being of residents, and how centralized systems (Ground Floor) promote a sense of shared responsibility.
3. **Architectural Preservation and Policy**: We can explore how decentralized storage might lead to long-term structural degradation (like water staining or corrosion) that affects the building's lifespan and its aesthetic integrity.

Table 7: Comparative Assessment of Balcony-Decentralized and Ground-Level Centralized Water Storage Systems in Collective Housing.

Criteria	Balcony Placement (Decentralized)	Ground Floor (Centralized)
Visual Integrity	**Façade Fragmentation:** Individual tanks disrupt the clean, rhythmic lines of the "Table Banche" structure, creating visual "noise."	**Design Preservation:** Maintains the original architectural intent and aesthetic unity of the R+09 building.
Living Space	**patial Reduction:** Each tank can occupy up to **1.5 m² to 2 m²** significantly reducing usable private balcony space.	**Space Optimization:** Residents enjoy full access to their balconies for recreation, ventilation, and natural light.
Social Dynamics	**Potential for Conflict:** Risks of water leakage to lower floors and noise from individual pumps can strain neighbor relations.	**Collective Management:** Promotes a communal utility model, usually managed by a homeowners' association.
Maintenance	**Accelerated Decay:** Moisture buildup around balcony tanks leads to concrete staining and carbonation on the exterior.	**Professional Oversight:** Centralized systems allow for easier, safer, and more efficient professional maintenance.

We can explain that while the structural risks are the primary concern, the **Social and Aesthetic** costs are what residents and urban planners notice first. We call this the "Visual Entropy" of a building—when a structure begins to look disorganized because of unplanned additions.
"Beyond the seismic vulnerability, the placement of large reservoirs on balconies converts a private amenity into a structural and visual burden, degrading both the architectural value of the property and the quality of life for its inhabitants."

4.Social Perspective: The "Centralized Failure" Risk

While a centralized ground-floor system is structurally superior, social factors often dictate decentralized storage. In many urban contexts, residents prioritize **water security through individual autonomy**. The fear of collective system failure or poor maintenance of a shared pump leads inhabitants to install private reservoirs on balconies. This 'social insurance' creates a technical paradox: residents increase their individual water security while simultaneously decreasing the collective seismic safety of the building.

Table 8: Socio-Technical Comparison Between Resident Water Autonomy and Structural Engineering Requirements.

Aspect	The Resident's Perspective (Social Reality)	The Engineering Perspective (Structural)
Trust in Maintenance	Fear that a central pump failure will lead to a total water cutoff for all 36 apartments.	Centralized systems are easier to monitor but require professional management.
Individual Autonomy	Placing a tank on the balcony ensures that a family has water even if the building's main system fails.	Individual autonomy creates a "Top-Heavy" building with high seismi
Maintenance Costs	Residents prefer paying for their own small pump rather than a monthly fee for a shared system.	36 small pumps are less energy-efficient and increase noise pollution across the façade.

5. The Hybrid Solution: Individual Autonomy at Ground Level :

Instead of 36 tanks on 36 balconies, each resident has their own dedicated tank and pump, but they are all located in a secured common area at the Ground Floor (GF).

Table 9: Comparative Analysis of Seismic Safety and User Autonomy for R+09 Buildings.

Feature	Individual Balcony Placement	Hybrid Ground Floor Placement
Seismic Safety	**High Risk:** Increases overturning moment and torsion.	**High Safety:** Mass is at the base; zero impact on building sway.
Social Trust	**High:** The resident controls their own water supply.	**High:** The resident still owns their private tank and pump.
Maintenance	**Difficult:** Requires access to private apartments; risk of leaks.	**Easy:** All equipment is in one accessible, waterproofed zone.
Cost	Resident pays for tank, pump, and balcony reinforcement.	Resident pays for tank, pump, and slightly longer piping.

5. Conclusions

The findings of this research emphasize that the current crisis of unauthorized water storage in high-rise collective housing is a multifaceted socio-technical challenge rather than a purely structural one. By shifting from the hazardous practice of balcony-mounted tanks to the **Ground-Level Decentralized Storage (GLDS)** model, this study provides a dual-purpose resolution.
From a **socio-technical perspective**, the GLDS system bridges the 'trust gap' between residents and urban infrastructure by preserving individual autonomy and pumping control, effectively halting the cycle of 'urban entropy' and façade degradation. Simultaneously, the **technical evidence** confirms a radical restoration of the building's seismic integrity. By lowering the center of gravity and eliminating the mass eccentricity that previously induced parasitic torsional moments, the structure is brought into full alignment with the rigorous safety mandates of **RPA 2024**. This transition ensures that R+09 shear-wall buildings achieve their intended dynamic performance, transforming a decentralized survival strategy into a standardized, resilient engineering asset.

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Conflicts of Interest
The authors report no conflicts of interest. The institutional affiliation with the **Department of Architecture** and the **Faculty of Science** at the **University of Algiers 1** did not influence the objectivity of this study.

Data Availability Statement
The data supporting the findings of this study are available upon request from the corresponding author. All primary research materials were compiled within the **Department of Architecture** and the **Faculty of Science** at the **University of Algiers 1**.

Institutional Review Board Statement
Not applicable. This study did not involve humans or animals.

CRediT Author Statement
Dr HAOUCHE Amina is the only Author ,affiliated with the **Department of Architecture** and the **Faculty of Science** at the **University of Algiers 1**.

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