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OVERVIEW OF SCHOOL BUILDING CONDITIONS IN RURAL AREAS – LAZAREVAC MUNICIPALITY

Summary: Rural primary schools within the Municipality of Lazarevac represent a significant portion of the public building stock. Most of the buildings are single-storey with load-bearing masonry systems, built in the second half of the 20th century according to the technical regulations of that period, which did not seismic resistance, durability, and energy efficiency. This paper reviews their key structural features, focusing on typical assemblies, materials, and operational deficiencies. The effects of the age, maintenance practices, and utilization level on structural performance are analyzed based on field surveys and condition assessment. The paper aims to identify predominant structural features and vulnerabilities of rural primary schools' masonry buildings, as well as to emphasize the need for a systematic approach to maintenance and rehabilitation within public infrastructure asset management.

Keywords: masonry structures, structural condition assessment, public infrastructure asset management, rural school buildings

PREGLED STANJA ŠKOLSKIH OBJEKATA U RURALNIM SREDINAMA – OPŠTINA LAZAREVAC

Rezime: Seoske područne osnovne škole na teritoriji Gradske opštine Lazarevac predstavljaju značajan deo javnog građevinskog fonda. Većina su izgrađene kao prizemni objekti sa zidanim nosećim sistemom potiču pretežno iz druge polovine XX veka i projektovani su prema tada važećim tehničkim propisima, bez savremenih zahteva u pogledu seizmičke otpornosti, trajnosti i energetske efikasnosti. U radu je dat pregled osnovnih karakteristika zidanih konstrukcija razmatranih objekata, sa posebnim osvrtom na tipične konstruktivne sklopove, materijale i uočene probleme u eksploataciji. Na osnovu podataka sa terena i postojećeg stanja objekata analiziran je uticaj starosti objekata, načina održavanja i stepena korišćenja na stanje konstrukcije. Cilj rada je da ukaže na dominantne konstruktivne karakteristike i slabosti zidanih školskih objekata u ruralnim sredinama, kao i da se naglasi potreba za sistemskim pristupom njihovom održavanju i sanaciji u okviru upravljanja javnom infrastrukturom.

Ključne reči: zidane konstrukcije, ocena stanja konstrukcije, upravljanje javnom infrastrukturom, seoski školski objekti

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1. INTRODUCTION

The education system of the Republic of Serbia has a two-century long tradition. The development of the school network has followed changes in social, economic and demographic conditions throughout history. The first schools were founded in 19th century during the period of reforms, and modernization of society when education became a priority in the period of the creation of an independent nation-state [1]. During the 20th century, investments in educational infrastructure were intensive, and their goal was to provide primary and secondary education for all citizens, regardless of income group and region.

In this context, primary schools in rural areas are of particular importance, representing a key link between rural communities and wide social development. Across the country, especially in rural areas with underdeveloped infrastructure, rural schools have not only been educational institutions, but also centers of social life, gathering places and dissemination of cultural and practical knowledge. They have a multiple role: from providing literacy and basic skills as a prerequisite for further education, to maintaining local communities and suppressing migrations [2].

The specificities of rural schools arise from various factors such as their function and location [3]. Unlike urban schools, which are often designed as multi-storey buildings, bigger, and more complex, rural schools are predominantly single-storey buildings, of smaller dimensions, adopted to smaller number of students in a territorially dispersed settlements [4]. In addition to functional requirements for teaching, school buildings must respond to local climatic conditions, building materials, and limited budgets.

Throughout history, school buildings in Serbia have been built from various building materials, which have changed in accordance with technical and technological achievements and economic possibilities, with one being dominant:

- Wooden structures – in the earliest periods of construction, especially in rugged and mountainous areas,
- Stone structures – in areas where stone is an available material,
- Masonry structures – the dominant type of construction after the industrial revolution and during the 20th century,
- Concrete and reinforced concrete (RC) structures – in the second half of the 20th century, especially for larger and more modern school buildings,
- Combined from various building materials – confined masonry walls (masonry walls with reinforced concrete framed by vertical and horizontal structural elements, e.g. braces).

In rural areas, due to the simplicity of construction, availability of local materials and lower construction costs, single-storey masonry buildings were most common, rather than the confined masonry ones, with roof structures and types of coverings adopted to local conditions.

The aim of this paper is to conduct a detailed survey of the school infrastructure, rural schools in the municipality of Lazarevac. A special focus is on degerming the current condition of the buildings, directly determined by their construction materials and age, which indicates structural integrity, energy efficiency, and the rate of degradation. We propose a systematic monitoring of the condition of buildings and need for interventions in order to ensure to maintain structural integrity, occupant safety, and long-term functional value while avoiding premature degradation.

2. STRUCTURAL CHARACTERISTICS OF MASONRY BUILDINGS

Masonry structures represent one of the oldest and most widespread building methods, based on the mutual connection of masonry elements (clay bricks, blocks or stones) using mortar infill as a critical binding agent. [5]. In the context of single-storey buildings, such as rural schools, masonry load-bearing walls are usually arranged in two mutually orthogonal directions, which constitute the primary structural elements and take on vertical loads from the weight of the structure itself and transfer them to the foundations, and they have low lateral stiffness to horizontal loads such as seismic forces.

As a composite material, the mechanical properties of masonry under different loading have a different mechanical property and its behavior in different directions. Masonry (ceramics, concrete blocks, mortar) forms a heterogeneous, anisotropic material with mechanical properties, such as strength and stiffness, that depend heavily on load direction (e.g., parallel vs. perpendicular to bed joints) and loading conditions. Experimental results of masonry are strong in compression but weak in tension and shear, exhibiting different behaviors because the bond between masonry and mortar is weaker than in homogeneous materials [6, 7].

Single-storey masonry buildings, such as school buildings in rural areas, utilize load bearing walls from standardized slid or hollow bricks, bonded with mortar forming monolithic brick system. Load bearing masonry walls are constructed to transfer vertical loads sometimes with minimal reinforcement. Basic masonry is significantly limited in controlling deformations and resisting high lateral loads (wind/earthquake) compared to modern buildings. Unlike confined masonry buildings, with horizontal (tie-beams) and vertical (tie-columns) reinforced concrete (RCC), historical ground-floor buildings primarily utilized thick, load-bearing masonry walls stability directly dependent on material quality and wall thickness [8]. These structures are often chosen for their low cost, durability, and fire resistance, requiring simple, robust designs that are typically limited to one or two stories.

19th and 20th century masonry load bearing masonry walls functioned as primary structural system. Buildings commonly constructed from brick, stone, or concrete blocks bound with lime or cement mortar [9]. Load-bearing masonry walls historically range from 25 to 38 cm in thickness, or more, depending on construction period, material availability, and design regulations [10]. Load bearing walls, which are vertical structural elements designed to support gravity loads, including their own weight, as well as ground floor and roof loads, transferring them to the foundation. They are highly resistant to compressive forces but have limited resistance to tension and shear. Research shows that the mechanical properties of walls depend not only on the strength of the bricks, but also on the quality of the mortar and the mutual connection of the wall elements, which is especially important in older buildings where weaker mortars were used [7,11,12].

A masonry shallow arch, often called a segmental or jack arches supported by iron beams were commonly used for basement ceilings. Masonry walls were paired with wooden beam ceilings and floors. In the twenties of the 20th century, a semi-prefabricated, one-way ribbed concrete slab known as Herbst appeared [10]. Traditional wooden, sloped roofs often rest directly on masonry walls without strong horizontal tying, or concrete ring beams in modern constructions. Terracotta tile roof coverings, historically fashioned, were commonly designed as flat, or grooved. Tile roofing is simple, dense, and double-layered (lap) roofing systems, and ridged Roman roof tiles. The absence of rigid horizontal diaphragms in buildings, particularly in unreinforced masonry or vernacular structures, leads to poor lateral forces performance because individual walls act independently rather than as a cohesive system. Without this rigidity, lateral forces are not properly redistributed among masonry walls [13]. In many articles weak connection between ceiling and masonry walls (poor anchoring) are critical seismic vulnerability [14,15,16].

Strip foundation, a type of shallow foundation, are conventionally used for single-storey buildings with load-bearing walls according to the technical regulations of that period, without detailed geotechnical calculations. Building foundations were commonly constructed using, brick masonry, natural stone, or rubble, or with unreinforced or only weakly reinforced concrete. Clinker bricks, known for being exceptionally hard, dense, and water-resistant due to high-temperature firing, were traditionally used in the foundations of smaller buildings [10]. Foundation depth is primarily dictated by local soil bearing capacity and the need to extend below the frost line to prevent frost heave. Strip foundation width was determined by the load of the building and the width of the load-bearing wall. Older buildings frequently develop wall cracks due to insufficient foundation width, or differential settlement. Modern research highlights that soil-structure interaction (SSI) significantly impacts the long-term stability of masonry buildings [15,17].

Masonry single-storey buildings, particularly rural schools, behave as brittle systems with low tensile strength, often failing via out-of-plane wall bending or diagonal shear cracking under seismic loads. Masonry buildings from the 19^{th} and early 20^{th} century often lack adequate seismic and structural reinforcement due to outdated construction practices, making them vulnerable to earthquakes. Without confining elements, RC ring beams, lintel bands masonry walls are not connected in stable construction system due to which the resistance to lateral loads is significantly reduced [9, 10]. Scientific research confirms that unreinforced masonry (URM) structures exhibit high seismic vulnerability, characterized by brittle failure mechanisms [13, 14, 16, 18]. Masonry building degradation due to aging and lack of maintenance requires structural assessment and strengthening.

3. OVERVIEW AND ANALYSIS OF THE CONDITION OF RURAL SCHOOL BUILDINGS OF A MUNICIPALITY OF LAZAREVAC

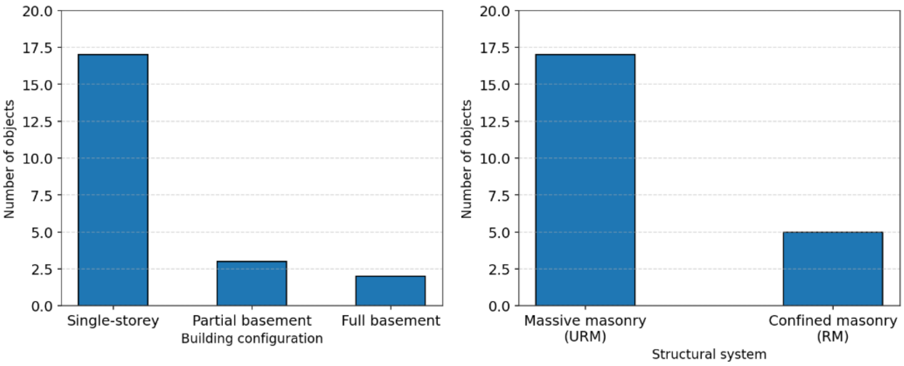
Most rural school buildings in Republic of Serbia were built mostly between 1950 and 1980, when the focus was primary on rapid expansion of school network to ensure access to primary education in rural areas. Masonry buildings relied on empirical rules, experience, and geometric proportioning rather than detailed calculations often focused on vertical load capacity, making them vulnerable to lateral forces, causing high vulnerability to horizontal loads [5, 9]. Today, this approach represents a major safety limitation for masonry buildings.

a) *b)*

Figure 1: a) School buildings in a village Arapovac build in 1930, and b) village Vrbovo build in 1960

Analyzed buildings of a Municipality of Lazarevac (Figure 1.) were built in the period from the end of the 19th to the end of the 20th century, more precisely, they were built in the period between 1873 and 2000. The most of them were post WWII school buildings, built between 1950 and 1970, which was a period of rapid expansion of school network. To obtain building condition, functionality, and maintenance it was analyzed 10 rural primary schools, and 22 separate classes [19]. The primary focus of this study is on the structural condition of buildings. Many examined school buildings are single-storey, load-bearing masonry structures built with similar techniques and similar timeframe [19]. Based on available documentation analyzed rural schools are representing a school network of a Municipality of Lazarevac. Rural school buildings are mostly of small capacity, adopted to reduced number of students, with simpler architectural and structural design.

Based on survey, out of 22 total buildings, 16 are in active use, and 6 abandoned, which indicates most of them is in active use. The inactive buildings are predominantly older. Rural school buildings typically have a total floor area of 150–460m^2, with the most frequent configuration consisting of one or two classrooms totaling 250-350 m^2. Most dominant are single-storey buildings, 17 of them, 3 buildings with partial basement, and 2 buildings with full basement (Figure 2.a). Rural school buildings are usually simple, one-story, functional, and often rectangular.



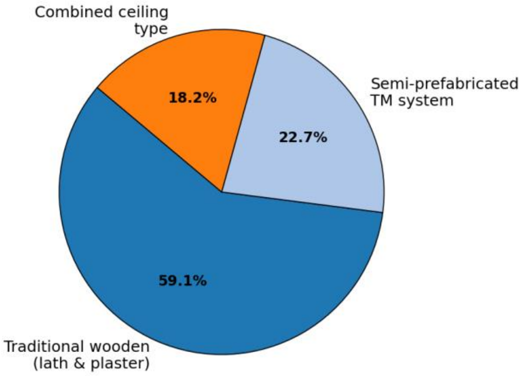
a) *b)*

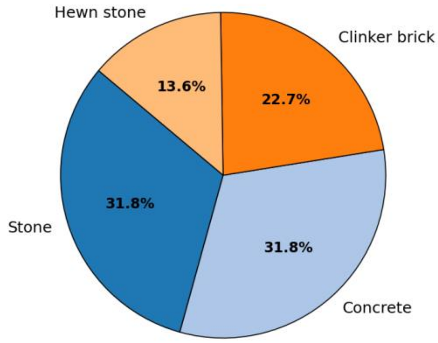
Figure 2: Relationship between a) the building configuration regarding the number of storeys and b) the structural system type of rural school buildings

The 17 buildings primarily constructed using solid brick in a massive masonry system, and the 5 confined masonry buildings use concrete elements (tie-columns and beams) cast around the masonry after wall construction (Figure 2.b). In post-1960s structures are introduced confined masonry which indicates the implementation of reinforced concrete confining elements, which is a consequence of implementation of modern codes and regulations. Burnt clay bricks (BCB) are dominant material for load-bearing walls in 17 buildings, and hollow clay bricks (HCB) in newer buildings. Load-bearing wall thickness typically ranges from 25–60 cm, varying heavily by material, building age, and structural load. Older masonry buildings often feature thicker walls (50–60 cm), while modern brick structures typically range from 25–40 cm. Surveys of 17 older buildings above the ground floor revealed traditional lath and plaster ceilings. Structure above the basement floor in two cases was a ceiling with crossbeams, and in one building the ceiling was made as a brick vault (Figure 3.). In modern constructions, a rigid fine-ribbed semi-prefabricated TM ceiling system was applied (Figure 4.a). The buildings are based on strip foundations, which are made of stone in seven buildings, hewn stone in three buildings, clinker brick in five buildings, while foundations are made of concrete in seven buildings (Figure 4.b).

a) *b)*

Figure 3: a) low brick vault School buildings in a village Krusevici, and b) piched-brick vault in a village Mali Crljeni

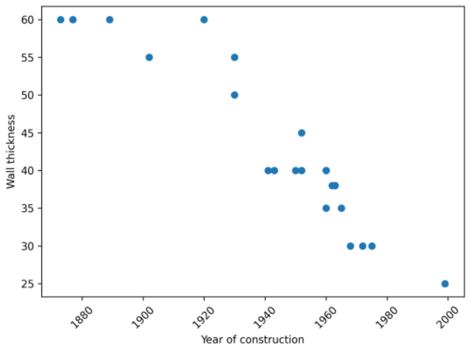


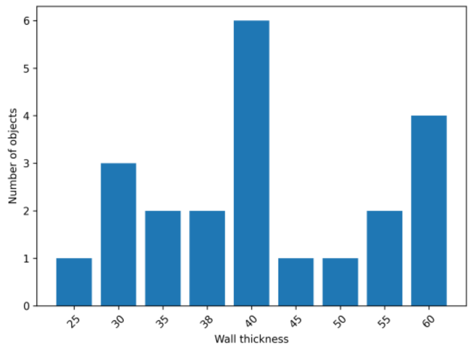


a) *b)*

Figure 4: Proportional share of rural school buildings according to a) the ceiling system type and b) the strip foundation material

Based on analysis of buildings the transition from massive, load-bearing walls in the late 19^{th}/early 20^{th} century to rational, structural solutions with thinner walls with reinforced concrete (Figure 5.) such as reinforced inter-floor construction, and RCC lintels bridge openings (doors/windows). Pre-1920 construction was characterized by massive, durable materials, featuring thick solid brick walls (55–60 cm), and wooden ceilings, stone foundations, less often hewn stone, while the lintels bridge openings were made of brick vaults. The 1920–1950 period featured improved, thinner masonry techniques, typically utilizing 35–40 cm thick brick walls, ceilings are still made by wood. While baked clay brick and stone remained common for foundations. Reinforced concrete (RC) elements like bands, lintels, and sills became common in 1950–1970 masonry construction, and walls are constructed with solid bricks or hollow clay brick walls (35-40 cm thick). Buildings constructed after 1970 often utilized 25 cm thick hollow clay blocks with RC bands, rigid RC slabs, and with RC foundations, reflecting a shift towards industrialized, faster construction methods like mass-produced concrete units and prefabricated elements.





a) *b)*

Figure 5: Relationship between a) the year of a buildings is constructed and the wall thickness, and b) wall thickness and rural school buildings

Analyzed school buildings utilize structural systems which characterized construction systems typical for that historical period. The load-bearing structure is based on massive walls made of solid bricks or hollow clay blocks, while the ceilings are mostly made of wood. Horizontal structural elements, such as RC bands were not systematically applied, or they are only in present in buildings of recent date.

Aging buildings typically exhibit deterioration caused by natural aging, intense usage, neglect, or improper, deferred maintenance, and environmental exposure. Common building failures involve water infiltration, structural foundation cracking, ground-level moisture, facade degradation, and mechanical system failures (Figure 6.). Based on the findings, the structural integrity and longevity of a buildings are primarily driven by the intensity of its usage and the regularity of maintenance activities. Active school buildings with regular renovations maintain better structural integrity, comfort, and safety compared to underutilized or poorly maintained. A lack of systematic maintenance accelerates structural degradation, leading to premature failure and increased lifecycle costs.

a) *b)*

Figure 6: General appearance and damages of a school building a) in village of Arapovac, and b) in village of Mirosaljci

Field inspections of rural school buildings indicate that deteriorating roof structures and worn-out coverings are critical risks, often causing structural damage to the building as a whole. Based on observation nine buildings, leakage was primarily caused by deteriorated roofing materials, including rotten structures, broken tiles, and blocked gutter systems. Urgent roof reconstruction is required for four school buildings due to safety hazards, such as structural decay, that put students at risk. In one building asbestos-containing wave sheet roofing (ACR) poses a significant health hazard, as it releases toxic, airborne fibers, which further increases the risk and requires planned removal in accordance with environmental safety regulations. Most of the school buildings miss waterproofing which occurs capillary moisture (rising damp). Thermal insulation, in most school buildings in the rural areas of municipality of Lazarevac are without it, and the facades are mostly made of plaster with visible damage and moisture in the plinth areas. On some buildings plaster falling off, particularly on north-facing or wet sides, primarily caused by moisture ingress, dampness, and poor adhesion. Fenestration is combined, around 40% is PVC and more than 60% is old wood more than 30 years old. Poorly sealed and deformed windows and doors cause significant heat loss and interior moisture (condensation).

Ageing and degradation of building components like roofs, façades, and installations significantly lowering technical performance and accelerating functional failure. Buildings from the late 19th/early 20th century (constructed in 1873, 1877, and 1902) often feature robust, preserved brick and/or stone structures but suffer from poor energy performance due to lack of insulation and outdated systems. Buildings constructed in the 1990s often feature improved structural technology compared to earlier eras but frequently fall short of modern energy efficiency standards due to inadequate insulation. Systematic renovation of the worst-performing buildings, guided by Minimum Energy Efficiency Standards (MEES) or Minimum Energy Performance Standards (MEPS), is a core trend.

Rural schools in the Municipality of Lazarevac face significant structural challenges, often requiring revitalization due to poor condition. These buildings typically share common construction characteristics, creating similar maintenance and structural problems, requiring a systematic approach for improvements, such as the comprehensive rehabilitation efforts.

Dominant non-reinforced masonry (URM) buildings need a rehabilitation techniques for reconstruction, and they are key factors that affect the current state of these buildings. These measures, which often involve addressing poor quality mortar and adding structural ties, are crucial for adapting these structures to modern safety standards. A systematic approach to school infrastructure management is essential, ensuring safety by addressing structural integrity, functionality, and emergency readiness to protect students and staff.

4. CONCLUSION

The study analyzes rural school buildings in the Municipality of Lazarevac, identifying single-storey masonry structures as the dominant type of school stock. Mid-20th-century buildings often suffer from high seismic vulnerability because they were designed to handle only vertical gravity loads, lacking proper reinforcement for horizontal seismic forces. These structures were built under outdated regulations that predated modern seismic codes, requiring significant structural retrofitting for safety.

The described, unreinforced masonry (URM) buildings with traditional timber roofs and strip foundations are highly vulnerable to earthquakes due to poor interlocking. Outdated construction solutions, while initially functional, often create significant limitations regarding long-term safety, structural durability, and modern seismic resistance standards.

Building condition identify moisture, structural cracks, and material degradation as primary defects, often linked directly with usage rates, maintenance, or environmental factors. Actively used and maintained school facilities exhibit significantly better conditions, than neglected or occasionally used buildings. Continuous maintenance and proactive, planned preventative care are essential for school infrastructure to prevent rapid degradation of public building stock.

Based on the conducted analysis, rural school buildings on observed location frequently require a systematic, modernized approach to structural safety assessment and planning of remedial strengthening. Research results providing a basis for further research, providing an expert basis for managing and revitalizing of public building stock as part of the rural building schools.

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