Research Journal of Agricultural Science, 58 (3), 2026; ISSN: 2668-926X;

http://doi.org/10.59463/RJAS.2026.3.32

STRUCTURAL DESIGN OF AN S+P+M BUILDING IN PETROȘANI, RUSU AREA, HUNEDOARA COUNTY

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Abstract. *This paper presents the structural design of the SPM building located in the Rusu area of Petroșani, Hunedoara County, Romania, in a mountainous region characterized by significant snow and wind loads and specific foundation soil conditions. The study aims to establish a safe and efficient structural solution for a building comprising a basement, ground floor and attic, intended for use as a private holiday cabin. The first stage involved analysing the site conditions, the seismicity of the area and the geotechnical characteristics obtained from field investigations. Based on these data, the foundation soil was classified as suitable for foundation works. Subsequently, the permanent, climatic and imposed loads acting on the building were assessed, and the main structural elements were designed, including the staircase, timber roof structure, roof boarding, rafters, purlins, posts and reinforced-concrete floor slab. The study also includes the preliminary design and analysis of the foundation, the design of the longitudinal reinforcement in the foundation beam and the verification of the maximum effective pressure transmitted to the soil. The results indicate that the adopted structural solution satisfies the requirements for strength, stability and serviceability under safe operating conditions, in accordance with the applicable design standards. The paper highlights the importance of correlating site conditions, structural analysis and the selection of an appropriate structural system when designing civil engineering structures in mountainous areas.*

Keywords: *structural design; foundation soil; timber roof structure; foundation beam; climatic loads; civil engineering structures; Petroșani.*

INTRODUCTION

The design of a building's load-bearing structure must ensure its safety, stability, durability, and economic efficiency throughout its service life. In the case of small residential buildings, the structural solution must meet both functional requirements and local conditions of climate, seismicity, and foundation. In mountainous areas, such as the Municipality of Petroșani, snow loads, low temperatures, and the particularities of the terrain can significantly influence the sizing of the roof, floor slabs, and foundations.

The objective of this paper is to design the load-bearing structure of an SPM building proposed in the Rusu area, Petroșani, Hunedoara County. The building is intended to serve as a cabin, with a basement, ground floor, and attic. The structural system consists of load-bearing masonry, reinforced concrete floor slabs, reinforced concrete beams, and a roof made of timber elements, covered with tiles.

Table 1

	Value/ Materials
Building destination	Cabin, private property
Location	Rusu area, Municipality of Petroșani, Hunedoara County
Number of storeys	Basement, ground floor, attic
Superstructure	Load-bearing masonry
Floor slabs	Reinforced concrete slabs and beams
Roof	Timber structure, tile covering
Foundation	Continuous reinforced concrete foundation
Main actions	Self-weight, live load, snow, wind

The objective of this paper is to design the load-bearing structure of an SPM building proposed in the Rusu area, Petroșani, Hunedoara County. The building is intended to serve as a cabin, with a basement, ground floor, and attic. The structural system consists of load-bearing masonry, reinforced concrete floor slabs, reinforced concrete beams, and a roof made of timber elements, covered with tiles.



Figure 1. 3D Structural Model of the Proposed Cabin

This study analyzes the main factors influencing the structural behavior of the building: site conditions, the geotechnical characteristics of the soil, the seismicity of the area, as well as snow and wind actions. The roof structure is verified through the calculation of the

purlins, rafters, panels, and posts. The reinforced concrete floor slabs and the corresponding beams are analyzed for bending and shear, and the required reinforcement is determined. The continuous foundation is verified in terms of effective soil pressure and is reinforced according to the bending moments and shear forces resulting from the calculation.

A complete calculation sequence is presented for a small building located in a mountainous area. The assessment of permanent, useful, and climatic actions is combined with the verification of both superstructure and infrastructure elements. The originality of this work lies in the application of a practical and integrated methodology to a real building configuration, using the available data on the site and the foundation soil. The practical relevance of the research is given by the possibility of using the results and the calculation method for the design of similar buildings in the Petroșani area.

MATERIAL AND METHODS

The sizing of the timber elements of the roof was carried out by modeling the purlins, rafters, and panels as simply supported beams, and the posts as axially compressed elements, verified against buckling. For each element, the permanent loads, snow load, wind load, and the concentrated maintenance live load of 1,000 N were considered.

Table 2

Calculation data and materials used

Parameter	**Value/materials**
Number of storeys	Basement + ground floor + attic
Floor slabs	Reinforced concrete
Foundation	Continuous, reinforced concrete
Concrete for floor slabs and beams	C16/20
Steel for floor slabs and beams	OB37 / PC52
Foundation concrete	Bc15
Foundation steel	OB37
Foundation soil	Sandy silty clay / sandy silt
Geotechnical category	1
Foundation depth	1.50 m
Conventional soil pressure	300 kPa
Subgrade reaction coefficient	10 daN/cm³
Basement–ground floor slab thickness	12 cm

http://doi.org/10.59463/RJAS.2026.3.32

Ground floor–attic slab thickness	10 cm
Beam G1 cross-section	25 × 45 cm
Column loads	$N_1 = 2.000_{\text{kN}}; N_2 = 1.000_{\text{kN}}; N_3 = 1.500$ kN

The maximum bending moment for simply supported elements subjected to a uniformly distributed load was determined using the following relation:

$M_{\max} = \frac{ql^2}{8}$, where **q** represents the design uniformly distributed load and **l** is the design span of the element. The strength verification of the timber elements was carried out using the following condition:

$\sigma = \frac{M}{W} \leq k_m k_d \frac{R}{\gamma_m}$, where M is the design bending moment, W is the section modulus, R is the characteristic strength of the timber, and k_m, k_{ds}, γ_m are the working, duration, and partial safety coefficients. The stiffness was verified by comparing the calculated deflection with the allowable deflection.

The reinforced slab between the basement and the ground floor, with a thickness of 12 cm, was analyzed as a two-way reinforced slab, since the ratio between its sides allows the loads to be transferred in both directions. The slab between the ground floor and the attic, with a thickness of 10 cm, was analyzed as a one-way reinforced slab. The required reinforcement was determined based on the design bending moment and the effective depth of the section.

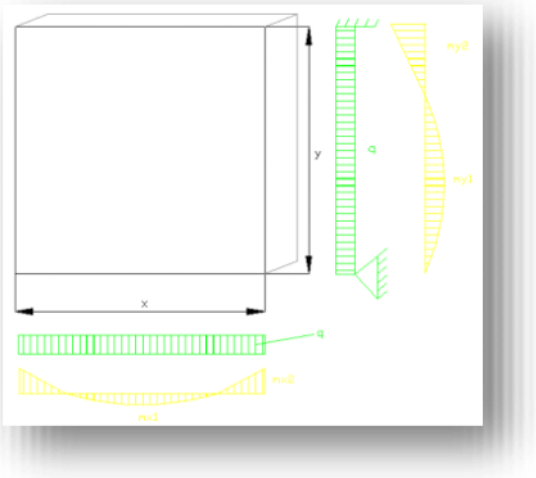


Figure 2. Calculation scheme of the two-way reinforced slab

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The reinforced concrete beam G1, with a cross-section of 25 × 45 cm, was considered simply supported. The maximum bending moment was determined using the following relation:

and the maximum shear force using the following relation:

$$Q_{\max} = \frac{ql}{2}$$

Table 3

Design loads on floor slabs

Element	Permanent load [daN/m²]	Live load [daN/m²]	Total design load [daN/m²]
Basement–ground floor slab	451	280	731
Ground floor–attic slab	431	105	536
Roof	94	–	276, including snow

The required longitudinal reinforcement was calculated using the following relation: $A_a = \frac{M}{0{,}875 h_0 R_a}$, where h_0 is the effective depth of the section and R_a is the design strength of the steel.

The continuous foundation was analyzed using the Winkler model, in which the foundation soil is assimilated to elastic springs. The soil pressure is proportional to the settlement:

$p = K_s y$, where K_s is the subgrade reaction coefficient of the soil, adopted as 10 daN/cm³, and y is the settlement. The elastic length of the foundation beam was determined using the following relation:

$L_e = 4\sqrt{\frac{4EI}{K_s B}}$, where **E** is the modulus of elasticity of concrete, **I** is the moment of inertia of the section, and **B** is the width of the foundation footing.

The verification of the foundation was carried out by comparing the maximum effective soil pressure with the allowable conventional pressure: $p_{\max} \leq p_{conv}$

The effective pressure includes both the pressure resulting from the loads on the structure and the pressure due to the self-weight of the foundation and the earth backfill.

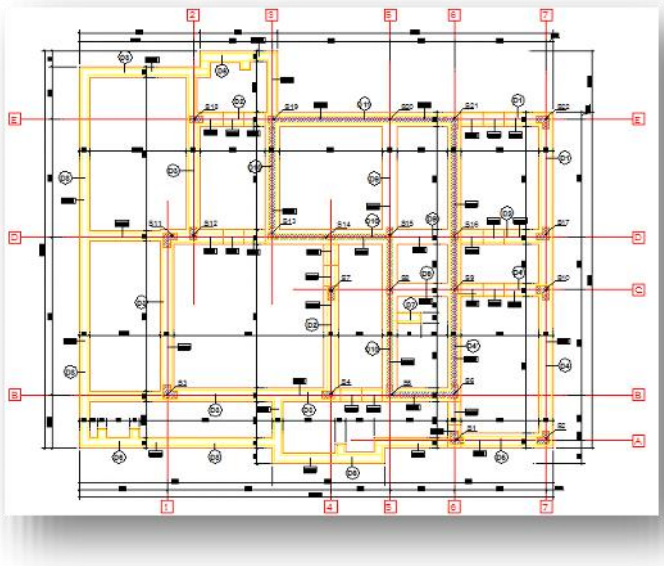


Figure 3. Calculation scheme of the foundation beam and column loads

RESULTS AND DISCUSSIONS

For the slab between the basement and the ground floor, with a thickness of 12 cm, the design bending moments in the span and at the supports were determined. The total design load was 731 daN/m². Following the calculation, the required reinforcement in the span was 1.72 cm², and 8Ø15 bars were adopted, with an effective area of 3.35 cm². At the supports, the required reinforcement was 4.54 cm², and 10Ø15 bars were adopted, with an effective area of 5.24 cm².

The results show that the adopted reinforcement covers the required reinforcement with a margin, both in the span and at the supports. The difference between the required area and the effective area provides a safety reserve and allows simple execution, with bars of the same diameter, uniformly distributed.

For the slab between the ground floor and the attic, with a thickness of 10 cm, the total design load was 536 daN/m². The maximum bending moment at the supports was 486 daN·m/m, while the maximum bending moment in the span was 380 daN·m/m. Based on these internal forces, the required reinforcement at the supports was 2.02 cm², and in the span it was 1.58 cm². Reinforcement with 8Ø15 bars was adopted, having an effective area of 3.35 cm², both at the supports and in the span.

The choice of the same reinforcement for both zones simplifies the execution of the slab and ensures coverage of the design loads. Although the effective reinforcement is greater than the required reinforcement, the solution is justified by the detailing requirements regarding the spacing between bars and by the need for uniform reinforcement over the entire surface of the slab.

Beam G1, with a cross-section of 25 × 45 cm, was analyzed as a simply supported beam. The total design load was 1,717 daN/m, and the design span was 5.75 m. Following the

http://doi.org/10.59463/RJAS.2026.3.32

calculation, the maximum bending moment was 7,096 daN·m, and the maximum shear force was 4,936 daN.

The required longitudinal reinforcement was 6.06 cm². Reinforcement with 3Ø18 bars was adopted, having an effective area of 7.62 cm². The shear force verification was satisfied, and the stirrups were arranged according to detailing requirements. Thus, the adopted section ensures both bending resistance and shear behavior.

The continuous foundation was analyzed using the Winkler method, with a subgrade reaction coefficient of the soil of 10 daN/cm³. The design axial loads of the columns were $N_1 = 2.000$kN, $N_2 = 1.000$kN, and $N_3 = 1.500$kN. In section 2, located at the first column, a maximum bending moment of 715.46 kN·m and a maximum shear force of approximately 935 kN were obtained.

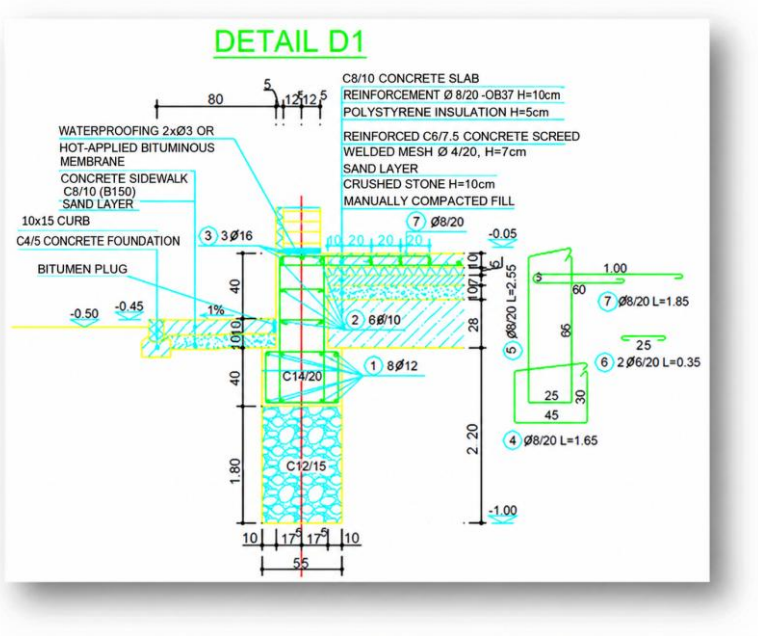


Figure 4. Foundation Detail D1

The longitudinal reinforcement of the foundation was determined in two calculation zones. For the left portion, between sections a and 8, the required reinforcement was 15.78 cm²/m. Ø16 bars were adopted, spaced at 12.5 cm, with an effective area of 16.08 cm²/m. For the right portion, between sections b and 8, the required reinforcement was 11.64 cm²/m. Ø16 bars were adopted, spaced at 16.5 cm, with an effective area of 12.06 cm²/m.

The maximum effective soil pressure was determined by adding the pressure resulting from the loads on the structure, of 268.9 kPa, to the pressure due to the self-weight of the foundation and the backfill, of 33.6 kPa: $p_{\max} = 268{,}9 + 33{,}6 = 302{,}5$ kPa

Compared with the allowable conventional soil pressure of 300 kPa, the maximum effective pressure is higher by 2.5 kPa, representing approximately 0.8%. Although the difference is small, the condition $p_{\max} \leq p_{conv}$ is not strictly satisfied.

To ensure a clear safety margin, it is recommended to slightly increase the width of the foundation footing or to review the design loads. A modest increase in the width of the footing would reduce the soil pressure below the allowable value, without significant changes in the execution cost.

Table 4

Main results of the sizing

Element	Internal force / result	Adopted solution
Basement–ground floor slab, span	$A_a = 1{,}72_{\text{cm}^2}$	8Ø15, $A_a = 3{,}35_{\text{cm}^2}$
Basement–ground floor slab, supports	$A_a = 4{,}54_{\text{cm}^2}$	10Ø15, $A_a = 5{,}24_{\text{cm}^2}$
Ground floor–attic slab, supports	M= 486 daN·m/m	8Ø15, $A_a = 3{,}35_{\text{cm}^2}$
Ground floor–attic slab, span	M=380 daN·m/m	8Ø15, $A_a = 3{,}35_{\text{cm}^2}$
Beam G1	M= 7,096 daN·m	3Ø18, $A_a = 7{,}62_{\text{cm}^2}$
Foundation, left portion	$A_a = 15{,}78_{\text{cm}^2/\text{m}}$	Ø16 at 12.5 cm, $A_a = 16{,}08_{\text{cm}^2/\text{m}}$
Foundation, right portion	$A_a = 11{,}64_{\text{cm}^2/\text{m}}$	Ø16 at 16.5 cm, $A_a = 12{,}06_{\text{cm}^2/\text{m}}$
Soil pressure	$p_{\max} = 302{,}5_{\text{kPa}}$	$p_{conv} = 300_{\text{kPa}}$

CONCLUSIONS

This study presented the sizing and verification of the main elements of the load-bearing structure of an SPM building intended as a cabin, located in the Rusu area, Municipality of Petroșani, Hunedoara County. The analysis focused on the reinforced concrete floor slabs, beam G1, and the continuous foundation, using the permanent, live, and climatic loads corresponding to the site.

For the slab between the basement and the ground floor, with a thickness of 12 cm, the required reinforcement in the span was 1.72 cm², and 8Ø15 bars were adopted, with an effective area of 3.35 cm². At the supports, the required reinforcement was 4.54 cm², and 10Ø15 bars were adopted, with an effective area of 5.24 cm². The results confirm that the adopted reinforcement covers the design loads.

For the slab between the ground floor and the attic, with a thickness of 10 cm, maximum bending moments of 486 daN·m/m at the supports and 380 daN·m/m in the span were obtained. The adopted reinforcement, 8Ø15, with an effective area of 3.35 cm², ensures coverage of the required reinforcement and simplifies the execution of the slab.

Beam G1, with a cross-section of 25 × 45 cm, was verified for a maximum bending moment of 7,096 daN·m and a maximum shear force of 4,936 daN. The adopted reinforcement, 3Ø18, with an effective area of 7.62 cm², covers the required reinforcement of 6.06 cm², and the shear force verification was satisfied.

The continuous foundation was analyzed using the Winkler method, considering the axial loads of the columns of 2,000 kN, 1,000 kN, and 1,500 kN. The maximum calculated bending moment was 715.46 kN·m. The adopted reinforcement, with Ø16 bars, ensures coverage of the required reinforcement in both portions of the foundation.

The maximum effective soil pressure was 302.5 kPa, compared with the allowable conventional pressure of 300 kPa. Although the difference is small, approximately 0.8%, it is recommended to slightly increase the width of the foundation footing or to review the design loads, in order to ensure a clear safety margin.

In conclusion, the analyzed structural solution can ensure the strength and stability conditions for the reinforced concrete elements, with a minor adjustment of the foundation footing dimensions. The results have practical relevance for the design of small buildings located in areas with similar geotechnical and climatic conditions.

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