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The Economic Demands on the Method of Founding a Passive Brick House on Foamed Glass Granulate

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Abstract: The cost of acquisition of a passive house is a little higher than that of a conventional house. Proper design of a passive house should include not only thermal protection and stability of the construction, but it must also take into account the price demands on each of the proposed structures and solution of details. The paper deals with the financial comparison of the traditional method of a foundation on the foundation strips of plain concrete and the modern method of founding a passive house as brick construction on the reinforced concrete slab base with a compact subsoil layer of thermal insulation in the form of granules of foamed glass.

Key words: Passive house, financial comparison, granules of foamed glass.

1. Introduction

Financial comparison is made on the family house with external dimensions of 10.5 × 8.75 m (including insulation) built in passive standard. This is a two-storey house with a pent roof slope of 5 °. Perimeter walls are constructed of ceramic blocks with a thickness of 250 mm; internal bearing masonry thickness is 240 mm. Perimeter walls are insulated with thermal insulation thickness of grey polystyrene thickness being 250 mm (heat transfer coefficient U for the external walls is 0.09 W/(m^2 К)). The roof cladding is insulated with thermal insulation of mineral wool with a thickness of 400 mm (roof heat transfer coefficient U is 0.10 W/(m^2 К)). Types of flooring P1 is shown in Fig. 2 (heat transfer coefficient U on the ground floor is 0.12 W/(m^2 К)). Window and balcony openings are plastic with triple glazing; the heat transfer coefficient of the window U_w is 0.80 W/(m^2 К). The entrance door is also plastic with the heat transfer coefficient of entrance door U_d is 0.90 W/(m^2 К) [1]. Building heating and primary hot water heating is provided by means of heat pumps of ground-water. Partial need of electrical power is provided by 12 pieces of polycrystalline panels with a total installed capacity of 3 kWp [2]. Photovoltaic power plant will mainly supply the photovoltaic heater for heating water using combined AC (alternating current) DC (direct current) power and also lighting and small appliances. The building is heated by a hot air regenerative unit.

Total energy reference floor area is 183.75 m^2, the total floor area 147.25 m^2. The total enclosed volume of the heated area is 662.42 m^3. Specific annual heat demand for heating a passive house is EA = 14 kWh/(m^2 a).

Leading (indicative) prices of construction work are used for financial evaluation of each method of the building foundation. Calculation of the financial evaluation is processed in software BUILDPower S from Brno company RTS, with the volume of construction work prices (data-base) from the first half of 2012 (RTS 12/1). Retail prices of construction materials are also used (items No. A25-27th and B6) from the price list of the largest building materials supplier in the Czech Republic [3]. All prices are in CZK ex VAT (value-added tax).

2. Method of Foundation of the Family House on Foundation Strips

For financial comparison, the structure of the house

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foundation was proposed on the foundation strips with the same heat transfer coefficient on the field as the founding of the family house on the foundation slab. To eliminate thermal bridges at the foot of the wall, the masonry is based on the foam glass plate with a height of 115 mm. Exterior footings are based in frost-free depth and with an extension of 150 mm on the inner side of the foundation, see Fig. 1. Internal strip foundation under the load-bearing walls is size 0.55 × 0.6 m. Due to the greater thickness of the floor the overall height of floors of the first above-ground floor was increased. The increased amounts of materials to the second variant are included in items No. A13 to A20.

Table 1 shows costs of building materials and labor including the amount when founding the family house on foundation strips.

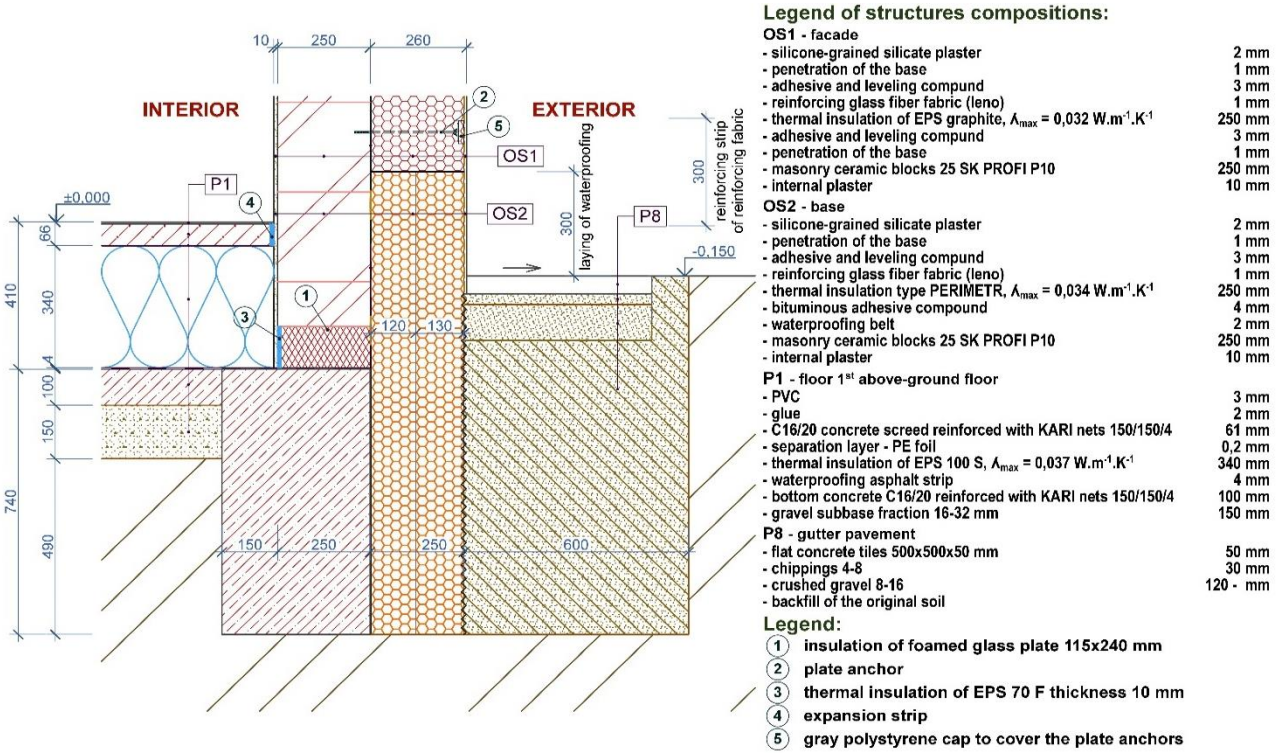


Fig. 1 Detail of the family house foundation on foundation strips.

Table 1 Costs of building materials and work when founding the family house on foundation strips.

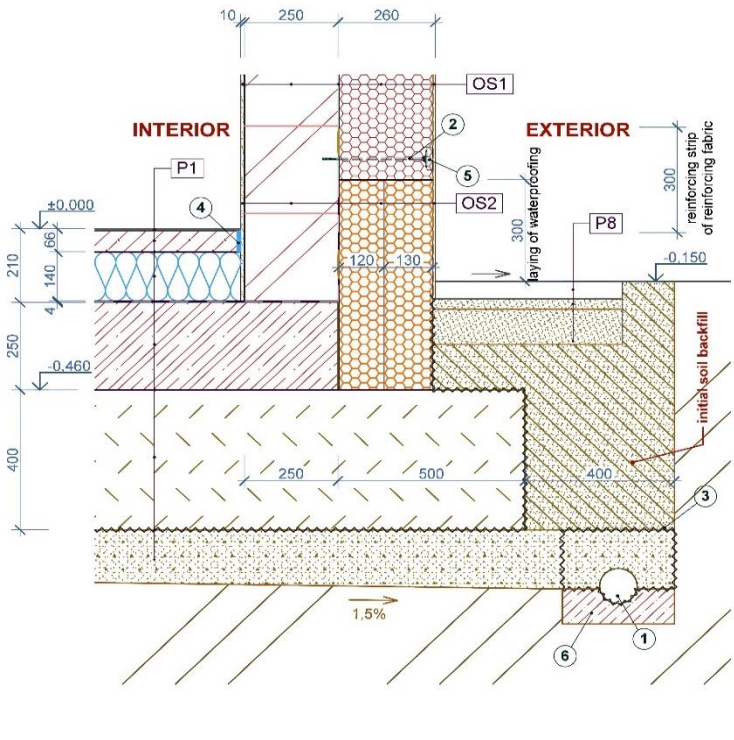
Serial no.	Description	UM	Amount	Cost/UM CZK	Cost CZK
A1	Removal of topsoil	m^3	59.287	46.00	2,727.23
A2	Excavation of foundation pits without sheeting	m^3	24.538	270.72	6,642.97
A3	Trenching to a width of 60 cm	m^3	2.984	657.37	1,961.59
A4	Trenching to a width of 200 cm	m^3	33.815	410.87	13,893.93
A5	Horizontal transfer of excavated material within 1,000 m	m^3	79.770	80.70	6,437.47
A6	Backfill of pits, trenches with compaction	m^3	30.729	61.20	1,880.65
A7	Gravel sand fraction 0-32 B	t	15.11	317.50	4,799.74
A8	Reinforced concrete of foundation slabs C 16/20	m^3	6.108	2,555.62	15,609.73
A9	Reinforcement of foundation slabs with welded mesh	t	0.123	24,981.71	3,083.24
A10	Plain concrete of foundation strips C 16/20	m^3	14.806	43,564.29	37,853.89
A11	Wall formwork of foundation strips: installation	m^2	45.550	376.57	17,152.76
A12	Wall formwork of foundation strips: removal	m^2	45.550	76.47	3,483.21
A13	Installation of geotextile	m^2	36.575	15.96	583.74
A14	Geotextile 150 g/m^2 width 200 cm 100% PP	m^2	39.501	15.40	608.32

Table 1 to be continued

A15	Ceramic blocks 17.5 Profi P10, width 175 mm	m^2	0.876	538.90	472.21
A16	Ceramic blocks 24 Profi P10, width 240 mm	m^2	0.892	672.11	599.86
A17	Ceramic blocks 25 SK Profi P10, width 250 mm	m^2	4.437	989.63	4,391.48
A18	Partitions 11.5 Profi, width 115 mm	m^2	0.738	409.36	302.11
A19	Plaster of interior walls, MVC	m^2	15.508	190.50	2,954.27
A20	Insulation system EPS graphite width 250 mm	m^2	1.540	1,278.48	1,968.86
A21	Thermal insulation of floors dry: installation	m^2	70.020	29.12	2,038.98
A22	EPS board 100 S width 200 mm: delivery	m^2	71.42	452.00	32,282.02
A23	Thermal insulation bonding: installation	m^2	39.660	86.29	3,422.30
A24	Board EPS PERIMETR 120 + 130 mm: delivery	m^2	27.489	679.90	17,354.79
A25	Plate glass insulating foam 450 ×115 ×240 mm: delivery	Pcs	87.000	451.24	39,273.54
A26	Plate glass insulating foam 450 ×115 ×175 mm: delivery	Pcs	17.000	388.41	6,602.97
A27	Plate glass insulating foam 450 ×115 ×115 mm: delivery	Pcs	15.000	296.47	4,475.05
A28	Material transfer	t	70.482	211.46	14,904.20
Total cost ex VAT		Rounded to crowns			249,659.00

3. Method of Founding a Family House on the Foundation Slab

In the process of establishing a building on the foundation slab with a sub-base of the foam glass granulate with a thickness of 400 mm it is necessary to make a drainage layer of sandy gravel fraction 0-32 mm with a slope to a drainage pipe below it. In case of a change of the direction of drainage, piping drainage well must be designed. According to the statistic calculation there is designed reinforced concrete slab of reinforced concrete C20/25 reinforcing grids 100/100/8 mm at the upper and lower surface. Reinforcement of reinforced concrete slabs comes to 100 kg/m^3 of concrete. Types of flooring including basic dimensions are shown in Fig. 2.



Legend of structures compositions:

OS1 - facade

- silicone-grained silicate plaster	2 mm
- penetration of the base	1 mm
- adhesive and leveling compund	3 mm
- reinforcing glass fiber fabric (leno)	1 mm
- thermal insulation of EPS graphite, λ_{max} = 0,032 W.m^{-1}.K^{-1}	250 mm
- adhesive and leveling compund	3 mm
- penetration of the base	1 mm
- masonry ceramic blocks 25 SK PROFI P10	250 mm
- internal plaster	10 mm

OS2 - base

- silicone-grained silicate plaster	2 mm
- penetration of the base	1 mm
- adhesive and leveling compund	3 mm
- reinforcing glass fiber fabric (leno)	1 mm
- thermal insulation type PERIMETR, λ_{max} = 0,034 W.m^{-1}.K^{-1}	250 mm
- bituminous adhesive compound	4 mm
- waterproofing belt	2 mm
- masonry ceramic blocks 25 SK PROFI P10	250 mm
- internal plaster	10 mm

P1 - floor 1st above-ground floor

- PVC	3 mm
- glue	2 mm
- C16/20 concrete screed reinforced with KARI nets 150/150/4	61 mm
- separation layer - PE foil	0,2 mm
- thermal insulation of EPS 100 S, λ_{max} = 0,037 W.m^{-1}.K^{-1}	140 mm
- waterproofing asphalt strip	4 mm
- C25/30 reinforced concrete slab	250 mm
- separation layer - PE foil (foil against the flow through)	0,2 mm
- foam glass gravel, λ_{max} = 0,08 W.m^{-1}.K^{-1}	400 mm
- separation layer - 150 g/m2 nonwoven geotextile	0,1 mm
- gravel subbase fraction 16-32 mm	100-170 mm

P8 - gutter pavement

- flat concrete tiles 500x500x50 mm	50 mm
- chippings 4-8	30 mm
- crushed gravel 8-16	120 - mm

Legend:

1. plastic molded flexible perforated PVC pipe JS 100
2. plate anchor
3. separation layer - 150 g/m^2 nonwoven geotextile
4. expansion strip
5. gray polystyrene cap to cover the plate anchors
6. base concrete C8/10

Fig. 2 Detail of the method of founding a family house on the foundation slab.

Table 2 Prices of building materials and labor when founding the family house on foundation slab.

Serial no.	Description	UM	Amount	Price/UM CZK	Price CZK
B1	Removal of topsoil	m^3	59.287	46.00	2,727.23
B2	Excavation of foundation pits without sheeting	m^3	68.440	260.50	17,828.75
B3	Horizontal transfer of excavated material within 1,000 m	m^3	96.312	80.70	7,772.39
B4	Backfill of pits, trenches with compaction	m^3	75.094	61.20	4,575.79
B5	Gravel sand fraction 0-32 B	t	33.264	317.50	10,561.48
B6	Granular foam glass insulation, particle size 30-60 mm	m^3	52.910	1,497.85	79,251.24
B7	Reinforced concrete foundation slabs C 20/25	m^3	23.125	2,640.00	61,050.00
B8	Wall formwork of foundation slabs: installation	m^2	11.550	517.00	5,971.35
B9	Wall formwork of foundation slabs: removal	m^2	11.550	78.10	902.06
B10	Reinforcement of foundation slabs	t	2.312	25,730.00	59,500.63
B11	Installation of geotextile	m^2	210.840	15.96	3,365.01
B12	Geotextile 150 g/m^2 width 200cm 100% PP	m^2	227.707	15.40	3,506.69
B13	Drainage bed of plain concrete	m^3	1.275	2,388.02	3,044.73
B14	Drainage from drainage pipes DN 10 cm without bed, PVC (polyvinyl chloride)	m	50.000	39.30	1,956.00
B15	Normal drainage shaft from PE	ks	4.000	2,406.93	9,627.72
B16	Fixing manholes	kg	8.000	47.46	379.68
B17	Cover to the shaft tube 315 mm/1.5 T PP	ks	4.000	381.00	1,524.00
B18	Laying the insulating film, including PE film delivery	m^2	91.875	27.42	2,519.21
B19	Transfer of materials	t	104.584	211.46	22,115.42
Total cost ex VAT		Rounded to crowns			298,208.00

Table 2 shows the prices of construction materials and labor, including the amount when establishing the family house on the foundation slab.

4. Conclusion

In the final financial evaluation of both variants the cheaper one is the variant of founding the building on foundation strips with the price of 249.659 CZK without VAT, while only the board from foam glass comes to approximately 50.000 CZK without VAT. Variant of founding the building on the foundation slab with a sub-base of the foam glass granulate comes to 298.208 CZK without VAT, which is 20% more than the first variant. From the perspective of the total price of the family house (3.0 million CZK without VAT) price increases by only 1.6% more than the first variant. However, the variant of founding the building in the passive standard shows the positives in the elimination of thermal bridges (the establishment of a continuous thermal insulating envelope of the building without thermal bridges), followed by the perspective of time (time savings when realizing substructures) and technology (effort). Another possible alternative is leaving out the layer of the floor polystyrene (thermal comfort will provide a layer of foamed glass granulate), which saves costs and increases the accumulation capacity of a house.

The aim of the authors of the paper is to investigate the course of the temperature field using temperature sensors in the soil under the floor of a passive brick house based on a reinforced concrete foundation and compared with theoretical calculations of the temperature field.

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