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Research Paper

Research Project - Type Panel House IDA I.

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ABSTRACT: *Ranking among alternative combined building-energy systems with a high potential for the use of RES are self-supporting panels used for the construction of buildings with built-in active thermal protection (ATO) with one or two thermal barriers as described, for example, in patent SK 284 751. This is a wall energy system ISOMAX originating in Luxembourg (author: Krecké Edmond D .; Beaufort; LU), which similarly to TABS systems uses thermally activated mass. During its operation, this system uses the heat obtained from solar radiation, which is stored in heat storages, to actively reduce heat loss through enveloping structures. During the heating season, water is supplied to the pipes from ground heat storage, the average temperature of the heating water is in the range of 15°C to 20. Cold water from the ground pipe register is used for cooling in the summer.*
KEYWORDS: *Panels with built-in active thermal protection, thermal barrier, solar roof, solar absorbers, large-capacity ground heat storage, air ground heat exchanger, solar energy, geothermic energy, recuperation ventilation, cooling circuit of the ground pipe register*

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I. INTRODUCTION

Based on the request of the limited liability company AQUA IDA Slovakia, s.r.o. (formerly a concrete panel manufacturer in Bratislava - Vrakuna), in accordance with the research project HZ 04-309-05, the Department of Building Services, Faculty of Civil Engineering, STU in Bratislava in 2005-2006 designed and implemented a type panel house IDA I., which currently serves as an administrative building for the company, (responsible researcher: Kalús, D.), [7]. Subsequently, on the basis of research projects HZ 04-310-05 and HZ 04-142-07, the Department of Building Services, Faculty of Civil Engineering, STU in Bratislava in the years 2006 to 2007 carried out measurements of heat-comfort state in this building (responsible researcher: Kalús, D.), [8], [9].

Since the production of panels in the form of lost formwork, Figure 1, in accordance with patent SK 284 751 did not work, was too complicated and lengthy, the investor decided that reinforced concrete perimeter panels will be produced without thermal insulation so that tubular coils of active thermal protection (ATO) are in the central structure of the panels on steel reinforcement, Figure 2, and thermal insulation from the outer and inner side of the perimeter walls will be applied additionally only after the completion of the initial structural construction stage (foundations, walls, roof).

With the ISOMAX system, the only heat source is solar and geothermic energy. Solar energy is absorbed through the solar roof. This source causes unstable and insufficient absorption of solar radiation, it is usable in the summer and partly in the transitional period with sufficient heating of the heat transfer medium, i.e. temperature higher than the temperature in the long-term heat storage in the ground (ground heat storage). Geothermic energy is captured in the ground storage to an extent negligible for heating needs. The ISOMAX system captures these energies only for direct use in the so-called thermal barrier without increasing energy efficiency e.g. by means of a heat pump or solar collectors. The amount of energy is difficult to determine exactly due to the large number of unstable physical parameters influencing the capture of solar radiation. The captured energy is only applied to charge the long-term storage. The source is difficult to regulate and cannot cover sudden requirements for increasing the energy supply and cannot cover the year-round need for energy for heating, hot water, or for ventilation. The design of resources e.g. with the ISOMAX system is done only empirically - by estimation.

Figure 1: ISOMAX system panels - lost formwork - concreting on site [2], [27], [28]

Figure 2: Manufactured reinforced concrete panels of the type panel house IDA I.
(photo archive: Kalús, D.) [7, 8, 9]

From the implementations so far of the ISOMAX system, it is clear that a stable peak source of heat/cold is necessary so that energy systems are not dependent on variable and difficult to predict solar and geothermic energy accumulated in large-capacity, in particular ground heat storage. For this reason, the investor's requirement was to design a heat source for the given type house IDA I., which will represent an optimal solution from the viewpoint of energy, economy, and environment considerations.

II. TECHNICAL SOLUTION OF TYPE PANEL HOUSE IDA I.

2.1 Construction solution of a type panel house IDA I

The construction of the type panel house IDA I. began in August 2005 after the completion of design work provided by a team of researchers from the Department of Building Services, Faculty of Civil Engineering, STU in Bratislava. The building is situated on the site of the former concrete panel manufacturer Paneláren Vrakuňa on 59 Ráztočná Street in Bratislava. It is a two-storey building with a ground floor and an attic. The building served as an administrative building and in the years 2005 - 2007 also as an experimental building for scientific research purposes of the company AQUA IDA in cooperation with the Department of Building Services, Faculty of Civil Engineering, STU in Bratislava. The thermal-technical properties of the designed building structures are with the following heat transfer coefficients: perimeter walls U = 0.120 W/(m^2.K), floor U = 0.180 W / (m^2.K), roof U = 0.085 W / (m^2.K), windows and doors U = 1.000 W / (m^2.K).

From the statics point of view, it is an assembled longitudinal load-bearing system with load-bearing peripheral and one middle wall, which is formed by reinforced concrete panels, Figure 3. The ceiling is made of filigree and monolithic reinforced concrete slab. The truss is wooden, gable roof, concrete roofing. The building is designed as a two-storey - ground floor and attic.

Figure 3: Photographs from the assembly of type panel house IDA I. (photo archive: Kalús, D.) [7, 8, 9]

2.2 Description of the technical solution of energy systems

The heat source for heating and ventilation is solar energy absorbed by the energy roof, Figure 4a and accumulated in a medium-temperature earth heat storage (GHS-ST), 30°C to 50°C, Figure 4b. As a peak heat source to cover heat losses, a fireplace with a hot water heat exchanger is proposed, which is connected to a heating water storage tank and a ground heat storage. Solar energy absorber **-** energy roof is designed from pipe circuits made of PP pipes 20x2 or 16x2, with lengths of 100 m to 120 m. The individual circuits are connected in the attic space by means of a distributor and a collector with a heating system in the type panel house IDA I. The ground heat storage (GHS) consists of three zones with different temperatures. Two temperature zones are located under the foundation slab, Figure 5, the third temperature zone is formed directly in the foundation slab of Figure 6.The zones are formed by PP pipes 20x2 with lengths from 120 m to 200 m, Figure 7.

a) energy roof **b)** ground heat storage

Figure 4: Solar energy roof and ground heat storage built into and under the foundation slab of a type panel house IDA I. (photo archive: Kalús, D.) [7, 8, 9]

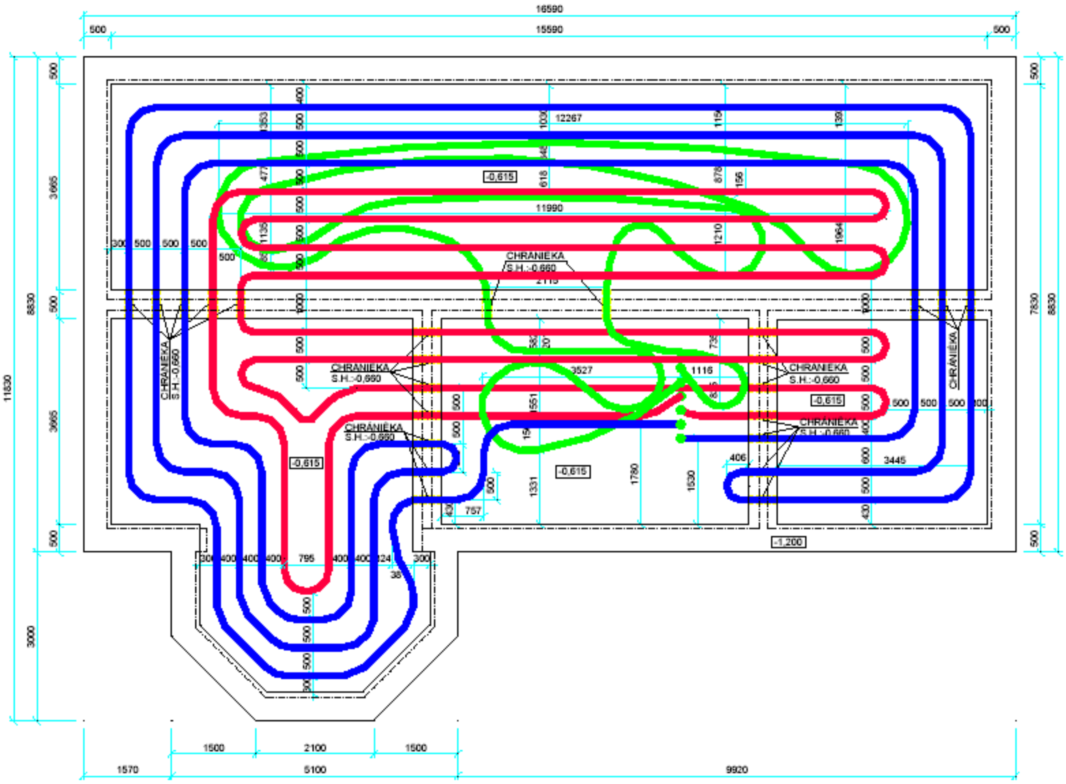

Figure 5: Circuits in the ground heat storage under the foundation slab (red - central zone of the ground heat storage, blue - edge zone of the ground heat storage, green - preheating of hot water) [7, 8, 9]

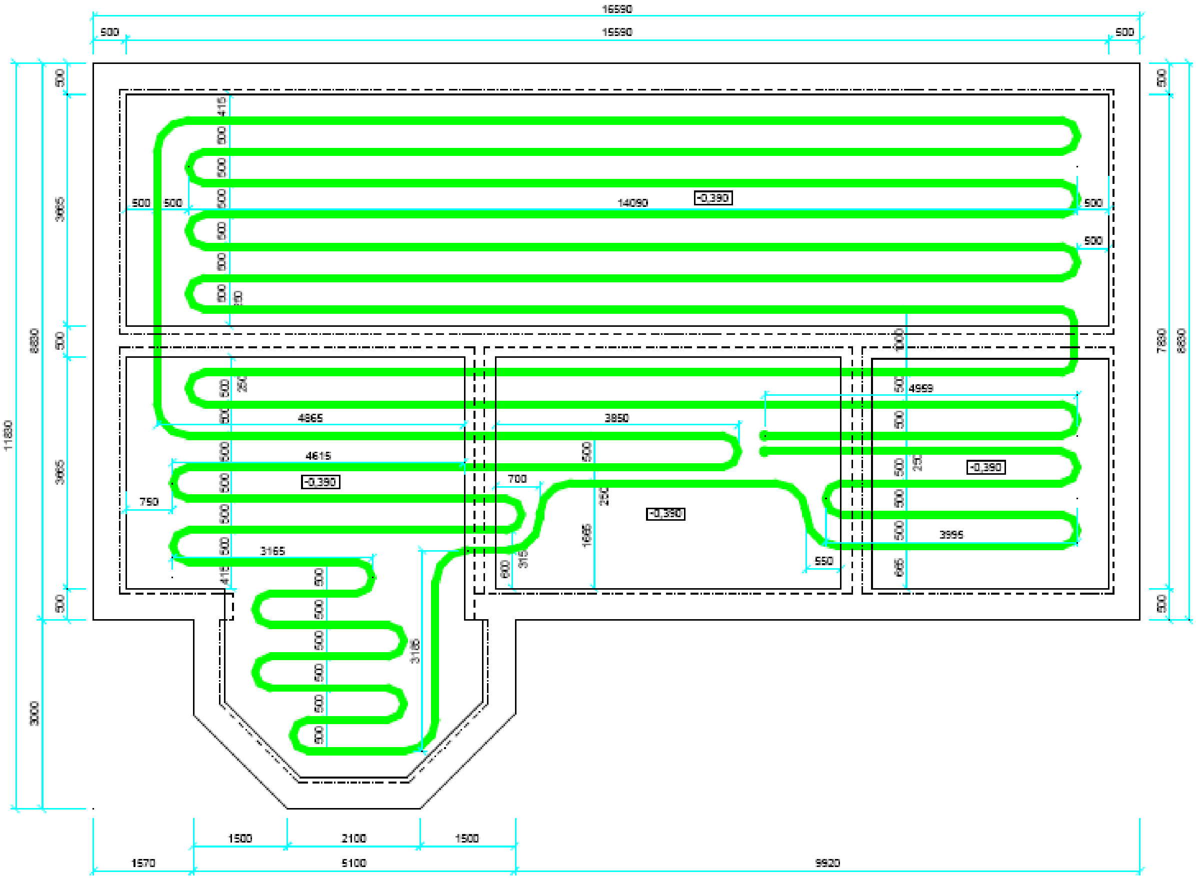

Figure 6: Circuit in GHS in the foundation slab [7, 8, 9]

a) GHS circuits under the foundation slab **b)** GHS circuits in the foundation slab

Figure 7: Circuit in GHS above the foundation slab and directly in the foundation slab (photo archive: Kalús, D.) [7, 8, 9]

The heating system consists of underfloor heating circuits. Circuits built into the walls serve as a thermal barrier. The individual circuits are connected by distributors and collectors to the energy roof, ground heat storage, and the peak heat source - fireplace with a hot water exchanger, as well as a heating water storage tank, so the supply of energy needed for heating and controlled heat transfer ATP built into the walls is possible at any time from whichever of the heat sources, Figure 8.

Figure 8: Photos from implementation of underfloor heating, a view of the storage tank of heating water, the engine room of energy systems and the cabinet of the distributor and the collector with the connection of ATP circuits in the circuit panels (photo archive: Kalús, D.) [7, 8, 9]

Figure 9: Photos of excavations and installation of a recuperative ground heat exchanger used for recuperation ventilation of the type panel house IDA I. (photo archive: Kalús, D.) [7, 8, 9]

A counter-current recuperative heat exchanger pipe in pipe is designed for ventilation of the building and heat recovery in accordance with the patent solution SK 284 751 - ISOMAX. It consists of a special stainless steel pipe with an antimicrobial surface, dimension DN 180 for the inner pipe and an outer pipe DN 250, Figure 9. The pipe is located partly outside the building at a depth of 2 m below the ground level, length 40 m and partly directly under the building in a ground heat storage at a depth of 1.0 m below the floor with a length of 40 m. With regard to its construction and location, the countercurrent air recuperation heat exchanger uses not only the exhaust air from the interior but also geothermic energy for heat treatment of the air, in the winter to heat the supplied air, in the summer for cooling, Figure 10.

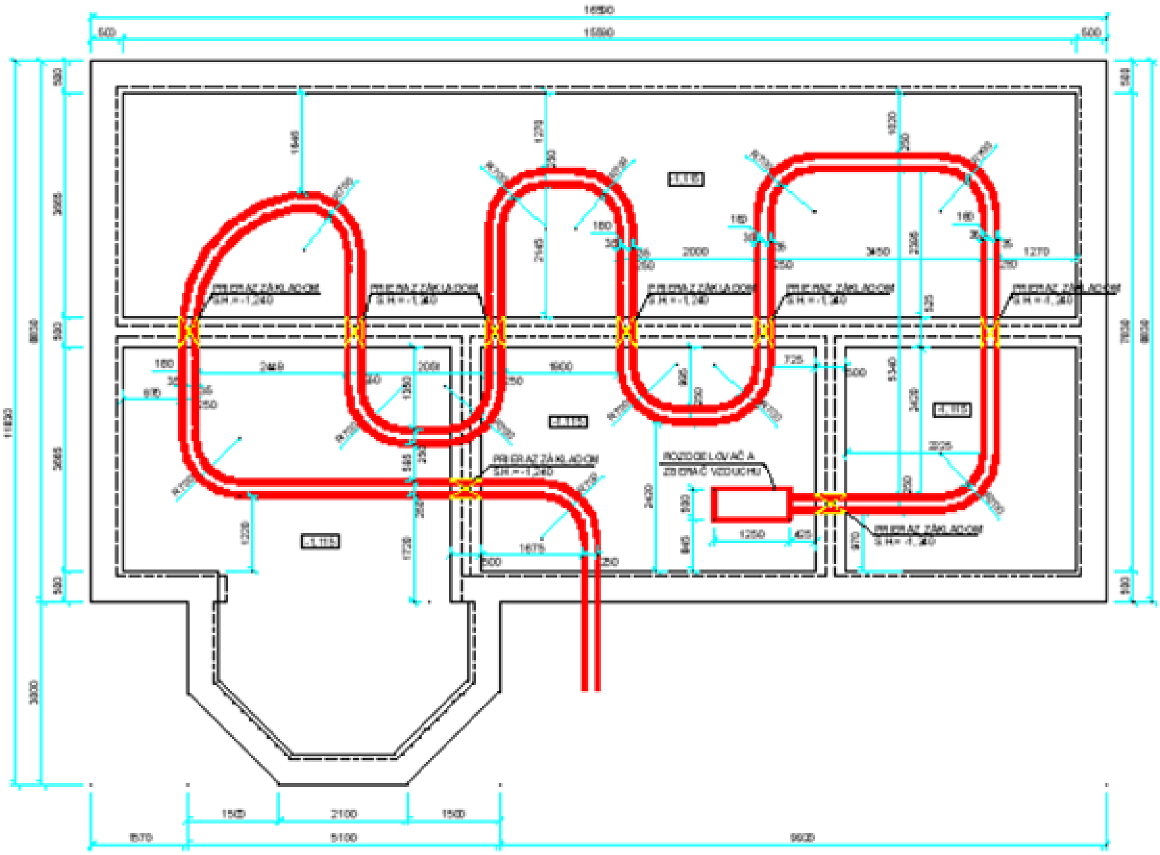

Figure 10: Location of the recuperative pipe in pipe - air-air - heat exchanger in the ground heat storage under the foundation slab of the type panel house IDA I. [7, 8, 9]

Figure 11: Distribution of ventilation ducts of the recuperation ventilation system under the foundation slab of the type panel house IDA I. (photo archive: Kalús, D.) [7, 8, 9]

Figure 12: Installation and insulation of ventilation ducts in the interiors of the type panel house IDA I. (photo archive: Kalús, D.) [7, 8, 9]

Interior ventilation ducts were installed in the thermal insulation in the floors, Figure 12, which are connected to the counter-current recuperative pipe in pipe heat exchanger in accordance with the patent solution SK 284 751 - ISOMAX, Figure 10 and Figure 11.

A ground cooling circuit is also designed for cooling the building, i.e. a pipe system made of PP pipes 20x2 placed at a depth of 2 m outside the building. This cooling system is connected via a distributor and a collector with circuits in the walls, which serve not only as wall heating but also wall cooling and thermal barrier - balancing the effects of radiated or cooled walls.

Preparation of hot water is done in two phases. In the first phase, the water in the ground tank is preheated from a temperature of approximately 10°C to approximately 35°C, Figure 13. In the second phase, the hot water is reheated to the required temperature of 55°C in a trivalent storage heater by means of solar energy, electricity, or heating water heated in the fireplace.

Figure 13: Installation of pipes for preheating hot water in the ground heat storage built-in under and in the foundation slab of the type panel house IDA I. (photo archive: Kalús, D.) [7, 8, 9]

2.3 Principle diagram of connection of energy systems

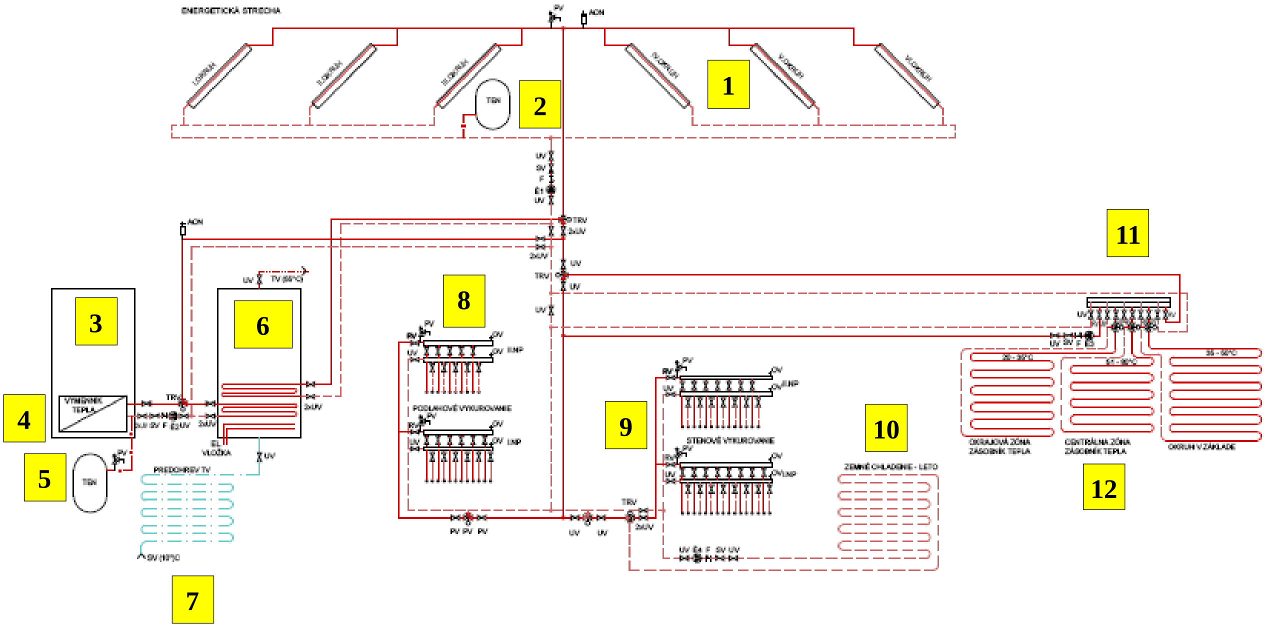

Figure 14: Simplified connection diagram for the technical solution of energy systems in type panel house IDA I. [7, 8, 9]

1 - solar energy roof circuits, 2 - expansion vessel for the solar roof, 3 - fireplace, 4 - fireplace hot water heat exchanger, 5 - expansion vessel for the heating system, 6 - hot water tank, 7 - register of pipes in the ground heat tank for preheating hot water, 8 - distributors and collectors for underfloor heating, 9 - distributors and collectors for the thermal barrier in the walls, 10 - register of pipes in the ground used for cooling, 11 - distributor and collector of the ground heat storage, 12 - circuits of the ground heat storage

A simplified diagram of the technical solution of energy systems of the type panel house IDA I. is shown in Figure 14. The arrangement of individual energy systems in the ground heat storage of the type panel house IDA I. is apparent from Figure 15.

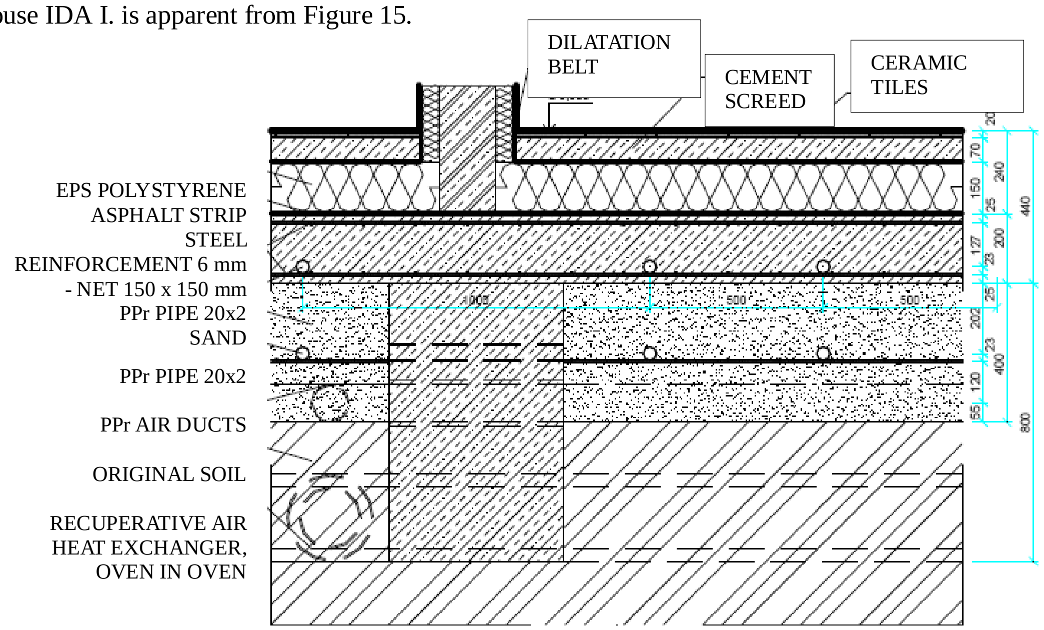

Figure 15: Detail of the layout of individual energy systems in the ground heat storage in the type panel house IDA I. [7, 8, 9]

III. RESULTS OF THE RESEARCH

Apart from the foundations, the ground heat storage, the ground heat exchanger, the roof structure with a solar energy roof, the structural and energy components of the type panel house IDA I were industrially manufactured in the panel shop as common parts for panel production.

Advantages of the type panel house IDA I .:

* unification of panels, fast mass production, fast assembly of a building without significant technological intermissions,
* high potential for the use of RES or waste heat,
* storage capacity of envelope structures to accumulate heat/cold – thermal barrier - active control of heat transfer through building structures,
* use of the self-regulatory effect of large-area radiant systems and TABS systems,
* application of a peak heat source and a small-capacity heating water storage tank eliminates instability and dependence of energy systems on variable and difficult to predict solar and geothermic energy accumulated in a large-capacity, especially in ground heat storage.

Disadvantages of the type panel house IDA I .:

* production of combined building-energy components with ATO is more time-consuming compared to conventional components of prefabricated production due to the fastening of pipe coils to reinforcement and compaction of concrete around the pipes,
* the need for technological breaks due to the hardening time of concrete (28 days),
* in the event of a leak from pipes in the panels, the repair is very demanding and the panel loses its energy function,
* the contact thermal insulation system can be realized only by gluing, anchoring could damage the pipe system in the panels,
* application of the IDA I. type panel solution in the sense of the patent solution SK 284 751 - ISOMAX, thermal insulation of the interior and exterior side of the perimeter walls limits the function of the combined building-energy system with ATO only to the function of a thermal barrier,
* The implementation of recuperation ventilation by a ground heat exchanger (pipe in pipe), as well as its subsequent maintenance or disinfection, also appears to be complicated and cost intensiv .

IV. CONCLUSION

The type panel house IDA I. is a building which, thanks to the application of combined construction and energy systems, has a high potential to use RES to a large extent and in accordance with Directive 2018/844 / EU to meet the requirements for *nearly Zero Energy Buildings*.

Based on the conducted research, it is possible to recommend the production of panels with integrated active thermal protection and thermal insulation exclusively from the exterior in a unified way directly in the production. With such a modification, we obtain a multifunctional combined building-energy system, namely: large-area radiant low-temperature heating/high-temperature cooling, a thermal barrier and the accumulation of heat and cold in the mass making up the static part of the panels. We also avoid complications and time loss for subsequent thermal insulation of the building.

In the area of combined construction and energy systems, research and optimization of suitable solutions continues, which have been transformed into one European patent and three utility models [3, 4, 5, 6].

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