The aim of this project is experimental and numerical analysis of heat and fluid flow processes in layers of granular materials. The granular and porous materials find application in many branches of industry (building construction, chemistry, energy, food production, transport, furniture, etc.). They can be natural or artificially created and can be composed of one type of material (e.g. carbon in a filtration columns, glass balls in absorption columns, polyurethane in technical foams, polystyrene in building insulation) or they may consist of their various combinations (e.g. sand-gravel-coal in filter beds, foam glass in insulation, gravel-stones in insulation and road underlay). The layers made of granular materials can be characterized by an ordered internal structure, or can have irregular nature in which the distribution of intergranular spaces and fragments of solid materials is random. In addition to the strength parameters of this type of layers, one of the main factors determining their practical applicability are their permeability and thermal characteristics. Due to common use of the granular materials, they are currently in a focus of extensive interest and they constitute one of the most important directions of research, both in industrial centers and research institutions. To a large extent, this is dictated by an increasing emphasis on reducing of energy consumption and related activities aiming at ensuring higher energy efficiency of new and existing buildings and technological processes. The granular materials play a significant role in the construction sector, which is responsible for 40% of final energy consumption in the European Union. For this reason the investments in research in this sector are particularly large. One of the actions that are taken to improve thermal efficiency in existing buildings is the insulation of external walls. For this purpose, additional layers of insulating material are added to the existing exterior wall. They are usually made of the polystyrene or mineral wool and more and more often insulation is made of the granular materials whose strength is greater than that of typical insulating layers.

The elements (layers, partitions, etc.) made of granular materials are characterized by a very complex internal structure with a large number of solid objects, called grains or granules, and intergranular spaces. Their individual fragments may vary, e.g. due to the size and shapes and physical properties. These types of materials behave differently than the well-known material phases (solids, liquids or gases). From the physical point of view this difference causes that the granular materials could be regarded as an additional state of matter characterized by definitely different properties than the solid material of which they are built. Unfortunately, in practice, the parameters of granular materials are usually determined on a macro scale, treating them as a homogeneous structure. For example, the thermal conductivity of the layer is determined on the basis of the thermal conductivity of the material (granulate), while the inter-grain spaces that have a significant influence on the heat flow are neglected. Considering the layer filled with the granular material, it is observed that only some part of the volume is occupied by the solid phase, i.e., the granulate. The rest is an empty space that can be filled with single phases, liquid or gaseous, or a mixture thereof. In the latter case, each phase occupies a fragment of empty space but analytical determination of their exact location is hardly possible. The intensity of the flow between the grains, or lack of it, has very significant impact on the rate of heat exchange between the liquid phase and granulate, and thus on the thermal efficiency of the analysed materials.

The tasks of the project will include detailed research on gas / liquid flow through the granular layers and heat transfer phenomena between the gas and solid phases within the grains. We will also consider the situations when the layers are combined with homogeneous materials. The conducted research will use both sophisticated measurement methods and advanced mathematical modelling techniques (CFD - Computational Fluid Dynamics). The experimental research will allow determining the basic characteristic parameters of the analysed processes (e.g. temperature distributions varying in time and space), which will be then used to verify the numerical model. The research will include the layers (insulating barriers) composed from a single granular material as well as in combination with other materials with solid homogeneous structure. The materials with known physical and geometric properties as well as new materials will be considered. One of the most important tasks of the project will be to investigate the effect of internal structure of the layers on the temperature distribution. We will compare the results obtained for the cases with varying widths and different layering order, as well as with a random or with *a priori* determined distribution of grains. In numerical simulations, in contrast to experimental research, many issues are simplified. For instance, a quite complex problem of simultaneous measurement of temperature and fluid velocity does not pose any difficulties in simulations. This does not mean, however, that performing the precise numerical computations is easy or trivial. The existing "numerical tools" are mostly based on simplified physical models, which often provide the results significantly different from the results of measurements. One of the aims of the project is to improve the modelling approach, which will allow us for a thorough analysis of the heat and flow processes occurring both within the granules and in between them.