The main application area for the porous beds, made of particles, monolithic structures, knitted wires or more recently solid open-cell foams, is undoubtedly that of chemical, petrochemical and automotive industries, where perhaps the most widespread application is for gas-solid catalytic reactions. More strict and demanding environmental legislation, along with economic issues, and the need for better management of feedstock, open up new goals and challenges for modern chemical engineering. Instead of "*one-fits-all*" designs, time has come to develop a dedicated "*tailor-made*" design philosophy. Artificial cellular and foam materials were first developed after World War II. However, mass production began in the late 1950s with polymeric foams. Long before that, in prehistoric eras, humans had already mastered the attractive attributes of natural cellular materials, such as wood and bone, for construction and hunting, and also for making various tools, taking advantage of their favorable specific strength (strength/density) or their thermal insulation properties. In terms of (bio-)processes, an excellent and almost infallible example of a system using irregular solid foam created by nature is hematopoiesis, that in case of birds and mammals takes place primarily in the bone marrow, a semi-solid tissue located in the spongy portions of bones.

Structured packings are still an emerging innovation and a topic requiring intensive research, due to the vast array of possible improvements in process design that such arrangements could be able to allow, especially thanks to the development of 3D printing techniques. There are in fact virtually unlimited options for designing a bed structure. This, combined with a wide diversity of materials, makes it extremely difficult to find the optimal solution for a specific chemical or even physical process such as e.g. adsorption. For undertaking design work aiming at the development of future specific apparatus solutions, it is thus essential to thoroughly analyze and understand the basic phenomena of energy, mass and momentum transport in various types of "*tailor-made*" packings. This, in turn, requires synergistic investigations combining experimental and modeling studies.

The objective of the present project is to improve via extensive experimental studies, the fundamental knowledge about the mechanisms of energy, mass and momentum transport in a variety of different packings characterized by a defined structure, both of regular and irregular nature, which can be used to carry out physical and chemical gas-solid processes, and to develop a modelling approach and computational methodology that would enable efficient simulation of transport properties for different structures and their prospective design.

The methodology used in the project will combine experimental studies performed on a laboratory scale with in-depth analysis of the results, which will be further combined with comprehensive mathematical modeling made with the aid of different approaches. The possible applications of the knowledge acquired within the project, and of the methodology developed, will not be limited to catalytic or adsorptive chemical reactors and their more efficient and optimal design. In fact, "*tailor-made*" fixed beds, including hybrid beds made of material characterized by different properties, can find application in many other fields, including among the others novel heat storage and cooling technologies. In addition, given that multiphase systems incorporating more or less irregular porous solid structures are ubiquitous in nature, some of the results and tools can be transferred in future to other fields far beyond chemical engineering, e.g. biomedical engineering.