In this investigation, the constitutive model of the tritium breeder and neutron multiplier pebble beds, based on the modified Drucker-Prager-Cap model, has been adopted for the prediction of thermo-mechanical behaviour of Helium Cooled Pebble Bed (HCPB) blanket, in fusion reactor relevant conditions. In the present material model, the time-dependent behaviour and thermo-plasticity have been included. The verification of the material model has been made for different temperature levels. The bulk thermal conductivity of pebble beds depends on the both local temperature and inelastic volumetric strain. In the interface regions of steel containment walls, the heat transfer is dominated by a pressure-dependent thermal contact conductance.

As benchmark exercises, HELICA and HEXCALIBER mock-ups have been tested at the HE-FUS 3 facility of ENEA Brasimone for investigating the thermo-mechanical behaviour of pebble beds. The present material model has been implemented in the commercial finite element package, ABAQUS. The finite element analysis shows the temperature distribution of the mock-up experiments, as well as the stress-strain fields. The overall behaviour of the lithium orthosilicate cassette (HELICA) and the interactions of ceramic breeder pebble beds and beryllium pebble beds (HEXCALIBER) are studied numerically. The predictions of HELICA mock-up are compared to the experiments. The results include the temperature measured by thermo-couples located inside the pebble beds and the lateral deformation of the cell. The simulation shows that the thermo-mechanically coupled analysis will be an efficient and important tool for the design of HCPB blanket.