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# Important Aspects in the Formulation of Solid-Fluid Debris Flow Models

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Most debris flows that are triggered by typhoons are either dense flows with a dynamically active interstitial fluid or a particle laden flow with suspended particles in a bearer fluid. The literature on such systems is split into essentially two classes, so-called **mixture theories** as treated in rational mechanics and continuum mechanics and **multi-phase systems**, which emerged as speciality of fluid mechanics. Specialists of the two classes tend to emphasise their differences, however, these are superfluous, if thermodynamics is used as an underlying governing concept.

It is shown that thermodynamics is the approach that will unify the two classes and identify differences as differences in the constitutive postulates. We show results obtained from a thermodynamic analysis of a mixture of a number of solid and fluid constituents of elasto-visco-plastic behaviour. Important aspects are the notions of **compressibility-incompressibility** of the constituents and the **saturation** of the mixture. Of significance is equally the recognition that mass changes of the constituents within the mixture are due to mass changes of the constituents within the mixture as well as their volume fraction changes. This implies that three different types of pressures may exist in fluid-solid mixtures, (1) the thermo-dynamic pressures due to the true mass changes of the constituents corresponding to the thermal equation of state in fluids, (2) the configuration pressure due to volume fraction changes and (3) the saturation pressure, which is the constraint variable guaranteeing the maintenance of

the saturation condition.

A mixture concept that accounts for the frictional affects of the granules (heap formation) must include plastic behaviour. We shall incorporate this into the model by an internal symmetric tensor variable of second order which, upon appropriate selection of the production density, is shown to be capable to describe material behaviour of the class of hypo-plasticity.

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One very important aspect of the thermodynamic formulation is that all constitutive variables, such as the constituent stress tensors, interaction forces are additively decomposable into equilibrium quantities and non equilibrium quantities. The former are uniquely determined via the exploitation of the entropy principle, the latter are constrained by it via the requirement that the entropy production is positive. These results are important as they demonstrate that the often employed, but physically unjustified pressure equilibrium leads, in general, to conflicting conclusions. A thermodynamic alternative leads, however, to non-conflicting inferences and well behaving elasto-visco-plastic formulations.