Laboratory Sands and Natural Siliciclastic Sandstones; Implications for the Behaviour of Reservoirs

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ABSTRACT

A lack of understanding in behavioural differences between sands and sandstones has led to confusion on how to approach and predict the behaviour of sandstone reservoirs, particularly those that are unconsolidated or located at shallow depths. While the geotechnical community has long dealt with the problems of sands, primarily focused on laboratory testing, the petroleum industry has a wealth of geological data from around the world. By plotting this data, the properties of laboratory sands are compared and used as a framework to assess the in situ state and behaviour of natural siliciclastic sandstones. As granular materials are one dimensionally compressed in the laboratory they show a relationship between the vertical effective stress and porosity (converted to voids ratio) called the intrinsic normal compression line. In laboratory tests at low effective stresses, typically less than 10 MPa for siliciclastic sands, the position of the intrinsic compression line in stress vs void ratio space is dependent upon the initial porosity of the sand. As the vertical effective stress increases these unique curves exhibit a significant change in slope and converge to a single curve called the limiting compression curve (LCC). This slope change reflects the onset of grain crushing. Compression follows this curve, until at very large stresses the grain packing limit is reached and porosity loss becomes minimal. In contrast to these laboratory results, compaction curves derived from subsiding first cycle sedimentary basins show a greater porosity loss for the same effective stress compared to the laboratory data. The geological field data and the lab derived normal compression line diverge at the development of post sedimentation structures in the form of significant quartz cementation and chemical compaction at around 25 MPa effective vertical stress. The divergence of the field data and the lab derived normal compression line appears to coincide with a shift in the applicability of critical state failure in soil mechanics to frictional failure (Byerlee's Law). The position of sandstone reservoirs on the intrinsic compression curve plot has implications for both the study and understanding of these reservoirs and practical field development. Knowing how the reservoir will behave will not only allow for production optimisation of existing fields but could also potentially unlock previously unproducible or uneconomic reservoirs.