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Discussion of "Advancement in estimation of undrained shear strength through fall cone tests" by Abhishek Ghosh Dastider, Santiram Chatterjee, and Prasenjit Basu

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The original paper (Dastider et al. 2021) presents a valuable and welcome contribution towards gaining a fuller understanding of the determination of the cone factor K used in calculations of the laboratory fall-cone (FC) undrained shear strength s_u, with consideration of various cone apex angles β, smooth and rough cone–soil interface conditions, and for fine-grained soils having different strain-rate- dependent strength enhancement parameter μ.

In terms of the experimental determination of the FC s_u for fine-grained soil at lower liquidity index, the final depth of cone penetration h_f (measured from an initial position of point contact with the surface of the soil test-specimen) is smaller, and often so small it is difficult to measure correctly for water contents at or near Atterberg's plastic limit (PL). As stated by the authors, "Potential alternatives to overcome the issue with small penetration depth might be (1) to use a fall cone with enhanced mass (Wood and Wroth 1978), (2) to increase the drop height such that the cone hits the soil surface with an impact velocity …, or (3) a combination of both. (p. 1 and 2)". While the authors cite the option (1) appropriately, it should be pointed out that both options (2) and (3) were originally proposed in the context of FC s_u determination at low liquidity index, along with a description of the test apparatus development, and presentation of experimental validation for 10 very different fine-grained soils, in the research paper by Sivakumar et al. (2015).

With the FC liquid limit (i.e., LL_{FC}) established using a smooth 80g–30° cone for h_f = 20 mm (according to British Standard BS1377-2 (BSI 1990)), and employing the same cone setup, the PL_{100} parameter (Harison 1988; Stone and Phan 1995; Stone and Kyambadde 2007; Haigh et al. 2013; Sivakumar et al. 2016a; O'Kelly 2021), defined as the lower water content for a FC s_u magnitude of one-hundred times greater than that mobilized at the LL_{FC}, would corresponding to h_f = 2 mm, as predicted by Hansbo's equation (Hansbo 1957). Note, as elaborated below, the PL_{100} is fundamentally different from Atterberg's PL. As well as investigating a smooth 8kg–30° cone, whose tip initially just contacted the soil surface, and with experimental PL_{100} set as determined for h_f = 20 mm, Sivakumar et al. (2015) experimented with using 30° FCs having enhanced mass m, and also incorporating an initial drop height h_d, such that the cone tip contacts the surface of the soil test specimen with an impact velocity. Using an energy-based approach and with consideration of significantly higher strain rates mobilized compared to the 8kg–30° contacting cone, Sivakumar et al. (2015) settled on a modified FC test setup that employed a 0.727kg–30° cone, and incorporated a free-fall height of h_d = 200 mm (i.e., at the start of cone penetration, initial (impact) velocity $v_i = \sqrt{2gh_d}$ ≈ 2.0 m/s; where g is the gravitational constant) for determination of the PL_{100} water content corresponding to h_f = 20 mm. Of course, the PL_{100} of fine-grained soil can be determined using the modified FC test setup employing any suitable combination of cone characteristics (m, β), h_f and h_d. The simple calculation for the modified cone factor K_d from the conventional cone factor K (for h_d = 0) (i.e., $K_d = K(1 + h_d/h_f)$), as given in Eq. (6) of Dastider et al. (2021), allows FC s_u determination using the modified FC test for fine-grained soils in the plastic range. In the Sivakumar et al. (2016b) discussion paper of the Sivakumar et al. (2015) investigation, S. K. Haigh and P. J. Vardanega proposed dynamic analysis of the modified FC test, equating the potential energy lost by the cone of weight Q when dropped from height h_d with the work done by the force Q ($= s_u h_f^2/K$ from rearrangement of Hansbo's equation) in bringing the cone back to rest at a penetration h_f. Hence, for the contacting FC test setup, $mgh_f = Qh_f = s_u h_f^3/K$, whereas for the modified FC test setup, one gets $mg(h_f + h_d) = s_u h_f^3/K$. After some rearranging, and then comparing the two cases with the standard form of Hansbo's equation $s_u = f_n(Q/h_f^2)$, one also obtains that for the modified FC test $K_d = K(1 + h_d/h_f)$.

Finally, as a minor but important clarification point, Dastider et al. (2021) state that "the depth h_f of cone penetration at or near the PL is very small (≈0.1 times of h_f measured at LL) (p. 1)", where LL is the liquid limit. Here, one must distinguish between the strength-based PL_{100} and the Atterberg PL, with the latter defining the water content at the plastic–brittle transition, having its standard determination by the 'rolling of threads' method. It is well established experimentally that the ratio of saturated remolded undrained shear strengths at the Atterberg PL to LL water contents can vary over a wide range when considering a variety of different fine-grained soils (Nagaraj et al. 2012; Haigh et al. 2013; O'Kelly 2013; O'Kelly et al. 2018). As such, the mentioned statement by the authors that the depth h_f of cone penetration at (or near) the 'PL' is ≈0.1 times of h_f measured at LL relates to PL_{100} determination, but generally not to Atterberg's PL.

Data Availability Statement

All data, models, and code generated or used during the study appear in the submitted article.

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