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Appraisal of novel power-based extrusion methodology for consistency limits determinations of fine-grained soils

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Presentation Overview

- Consistency limits

  Their conventional determination

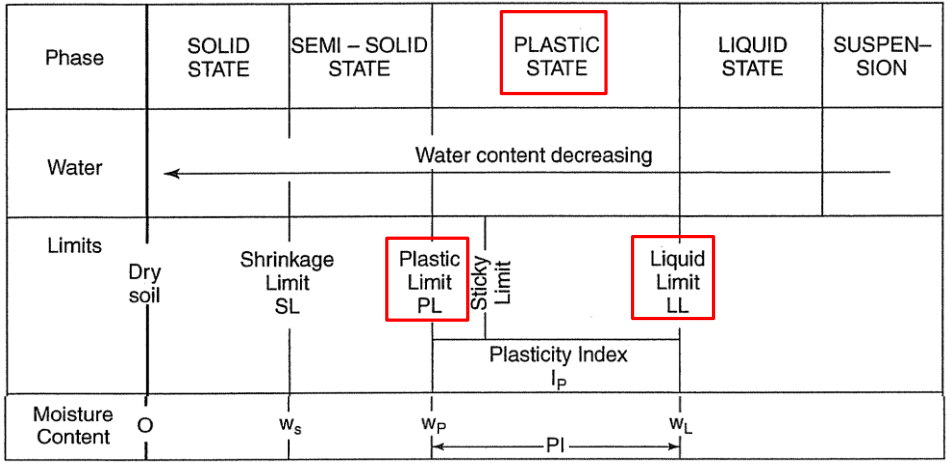
  Undrained strength at the consistency limits

- Previous extrusion approaches for fine-grained soil testing
- The extrusion pressure – water content relationship
- Extrusion pressure and the consistency limits?
- Consider the power needed to deform soil at its consistency limits

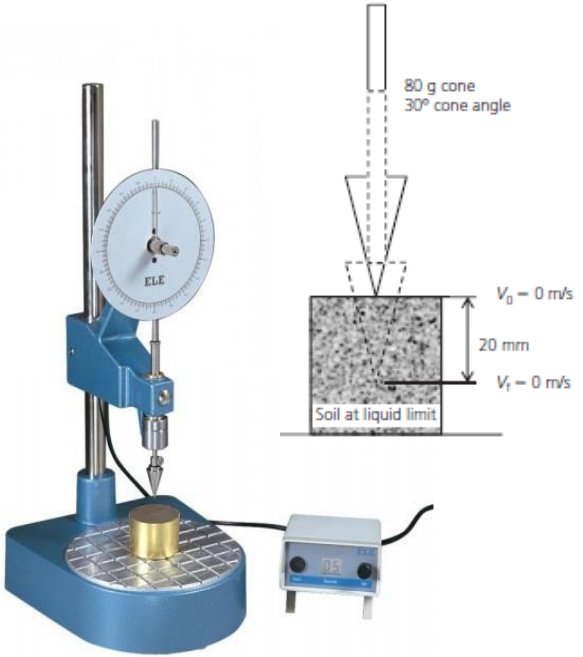
  Basis of new experimental testing approach?

- Conclusions

Consistency limits and their conventional determination



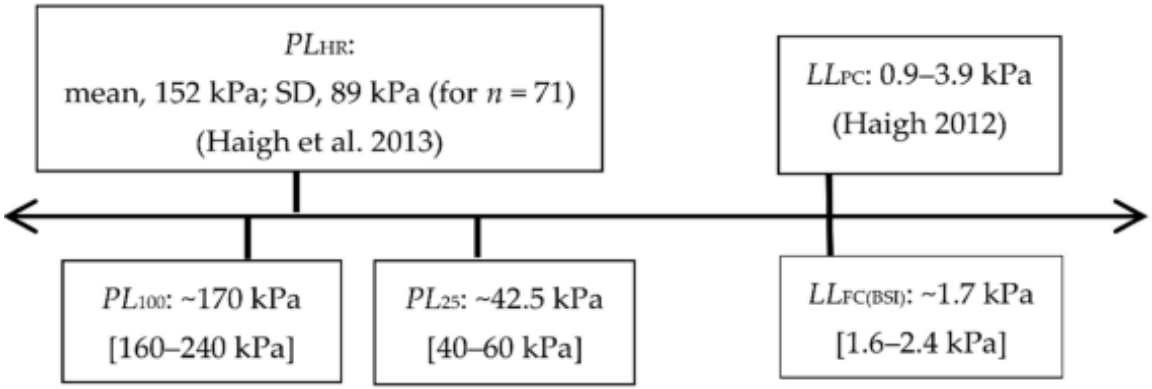
Thread-rolling method (Atterberg)



Fall-cone method

(or Casagrande percussion-cup method)

Undrained shear strength (s_u) and consistency limits



Increasing water content

(after O'Kelly *et al.*, 2018)

LL_{PC} = Casagrande LL

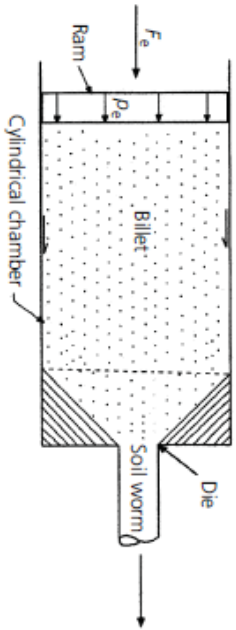
LL_{FC} = fall-cone LL

PL_{HR} = Atterberg PL (i.e., the brittle/ductile state transition)

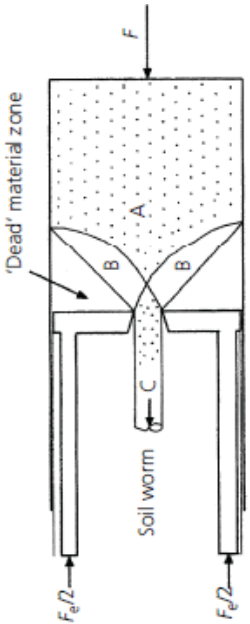
PL_{100} = plastic strength limit [$s_u@PL_{100} = 100 \times s_u@LL_{FC}$]

For PL_{25}, $s_u@PL_{25} = 25 \times s_u@LL_{FC}$

Previous extrusion approaches for fine-grained soil testing

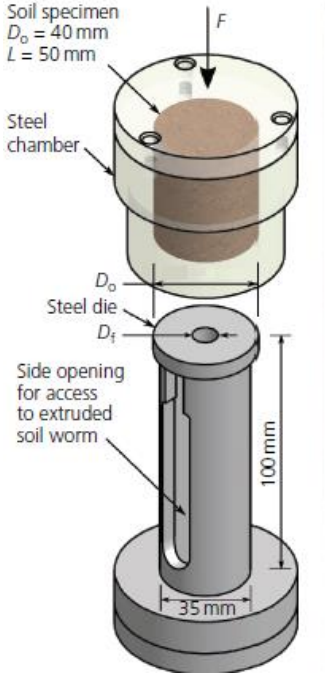


Direct extrusion



Reverse extrusion

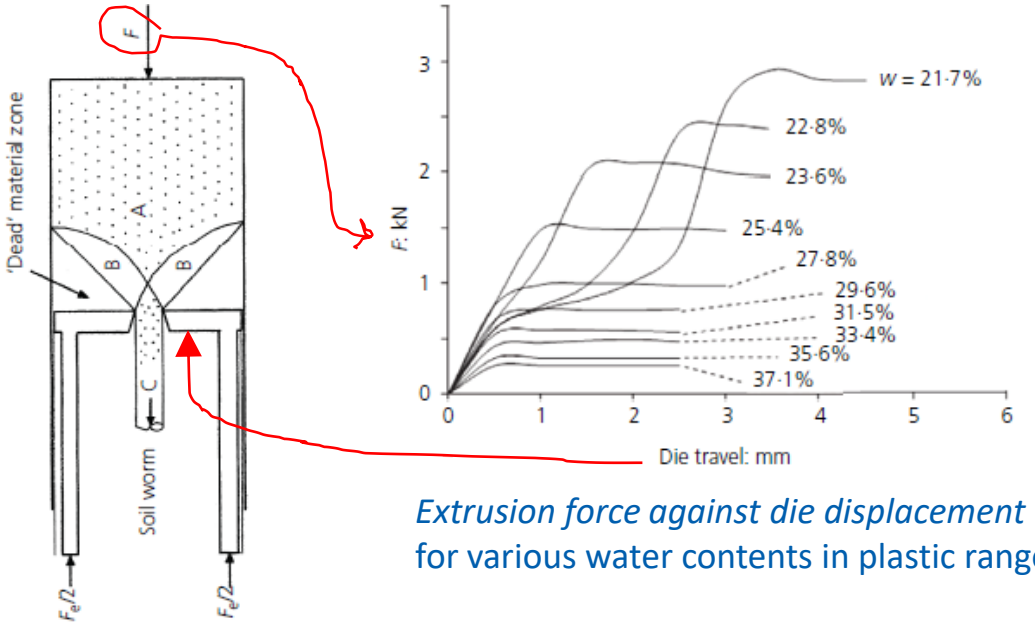
Reverse extrusion in axial loading machine



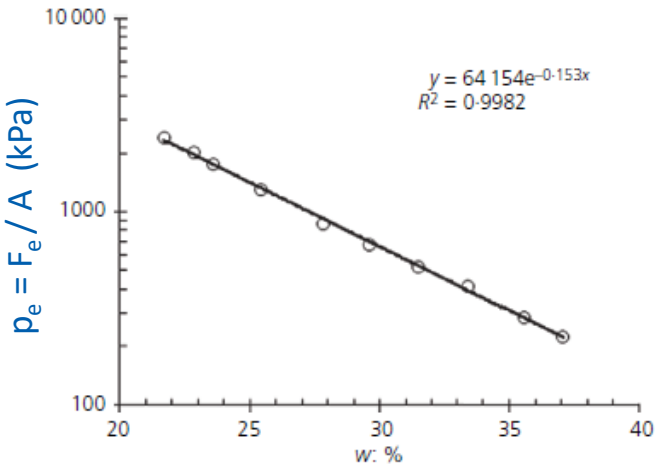
(Verástegui-Flores and Di Emidio, 2014)

(Kayabali and Ozdemir, 2013)

The extrusion pressure – water content relationship



Extrusion force against die displacement for various water contents in plastic range



Extrusion pressure (p_e) against water content

(A = bore area of cylinder chamber)

Reverse extrusion of high plasticity soil (LL_{FC} = 61%; PL = 24%) for R = 40·1 and v = 1 mm/min (after Kayabali *et al.*, 2015)

Extrusion pressure and consistency limits?

- Extrusion pressure related to the soil 'flow' stress
- 'Flow' stress taken as (or a proxy for) the soil undrained shear strength
  - ⇒ Extrusion approach should work for LL determination
  - ⇒ Extrusion will ***not*** work for Atterberg PL (latter not strength based)

Hypothesis: Consider the work done in deforming the soil by extrusion occurring over specified time period; i.e., [Applied force × die displacement/extrusion time] (Manafighorabaei, 2017)

Work done/time = Power

For given extrusion apparatus, can consistency limits of all fine-grained soils be defined in terms of unique power values? If yes, then could possibly determine the consistency limits for calibrated power values

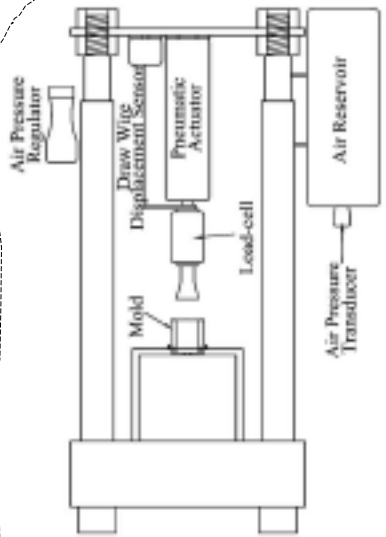
Hypothesis investigated using two experimental apparatus

Both direct extrusion

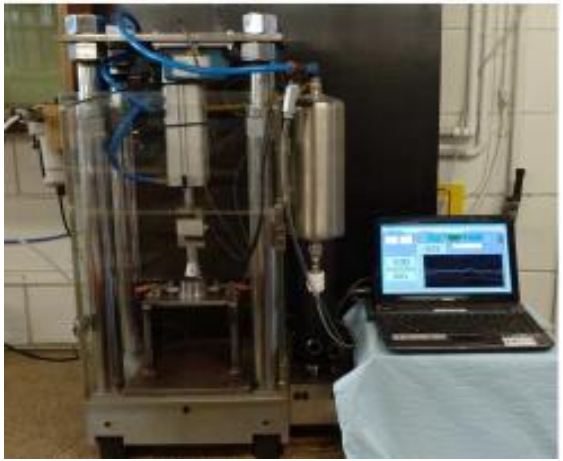
Manafighorabaei (2017)

O'Kelly (2022)

Trinity College Dublin extrusion apparatus (2015–2017)



Manafi *et al*. (2022)



University of Adelaide extrusion apparatus (2018–2022)

Basis of new consistency limits determination approach?

- According to Manafi *et al.*, *Yes, for both LL and PL*
- B O'Kelly's viewpoint — *Yes for LL, but No for PL*
  - Power-based approach can also be considered as essential a strength test, and the LL is strength-based (but not the PL)
  - An important consideration is the ***remoulding toughness*** at the PL can vary over a wide range for different fine-grained soils
  - So, for example, when performing the thread-rolling PL test, the hand pressure (force) applied to the rolling soil thread, and also the number of back-and-forth rolling actions necessary to reach/cause crumbling condition, can both vary significantly between different soil plasticity classes

Qualitative measure
of work done and time to remould soil

Conclusions

- Extrusion method has potential for soil strength measurement

  And also for LL determination

- Extrusion approach is ***not*** appropriate for Atterberg PL determination

- Hypothesised power-based extrusion approach ***not*** appropriate for Atterberg PL determination (BO'Kelly's viewpoint)

  As this hypothesis overlooks the fact that the remoulding toughness can varying significantly between different soil plasticity classes

- Atterberg PL uniquely determined by the standard thread-rolling test

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Thank You

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