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

<table>
<thead>
<tr>
<th>Phase</th>
<th>SOLID STATE</th>
<th>SEMI – SOLID STATE</th>
<th>PLASTIC STATE</th>
<th>LIQUID STATE</th>
<th>SUSPENSION</th>
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</thead>
<tbody>
<tr>
<td>Water</td>
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<td>Water content decreasing</td>
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<td>Limits</td>
<td>Dry soil</td>
<td>Shrinkage Limit SL</td>
<td>Plastic Limit PL</td>
<td>Sticky Limit</td>
<td>Liquid Limit LL</td>
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<td>Moisture Content</td>
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<td>w_s</td>
<td>w_p</td>
<td>PL</td>
<td>w_L</td>
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</tbody>
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Thread-rolling method (Atterberg) (or Casagrande percussion-cup method)

Fall-cone 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

Reverse extrusion of high plasticity soil ($LL_{FC} = 61\%$; $PL = 24\%$) for $R = 40\cdot1$ 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., \([\text{Applied force} \times \text{die displacement/extrusion time}]\) (Manafighorabaei, 2017)

\[
\text{Work done/time} = \text{Power}
\]

*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

Trinity College Dublin extrusion apparatus (2015–2017)

University of Adelaide extrusion apparatus (2018–2022)

Manafighorabaei (2017)

O’Kelly (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
Thank You
References


- O’Kelly BC (2022) — i.e., the presented paper published in the CERI2022 Conference Proceedings