# Reconciling particle size distributions obtained by laser diffraction and sedimentation

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## INTRODUCTION

- Particle size influences important soil properties like pore distribution, water retention, thermal conductivity and sorption.
- Particle Size Distribution (PSD) is widely measured using Pipette (sedimentation) (ISO 11277, 1990) and Laser Diffraction (LD) methods. However, the PSD curves obtained from both methods oftentimes do not match (below at left).

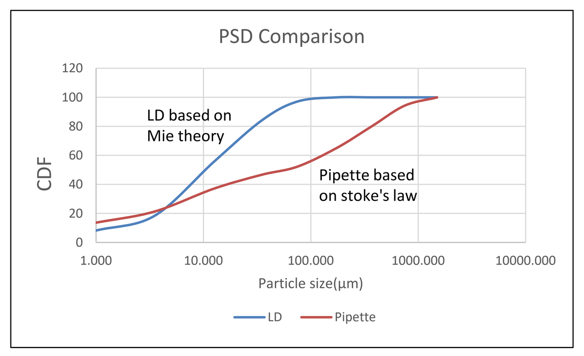



Fig: LD and Pipette PSDs for same soil

Fig: Laser Diffraction with CILAS 1190

Fig: Pipette method

- Corrections currently exist for sand, silt and clay (Eshel et. al., 2004), but not for the whole PSD.
- A correction for the whole PSD is important to compare data generated by Laser Diffraction versus Pipette methods.

## OBJECTIVE

- To model PSD data obtained from Pipette method and Laser Diffraction method using a Weibull distribution.
- To develop and validate a relationship between the Weibull fitting parameters (α and β) generated for the same samples when analyzed with Pipette and Laser Diffraction.

## METHOD

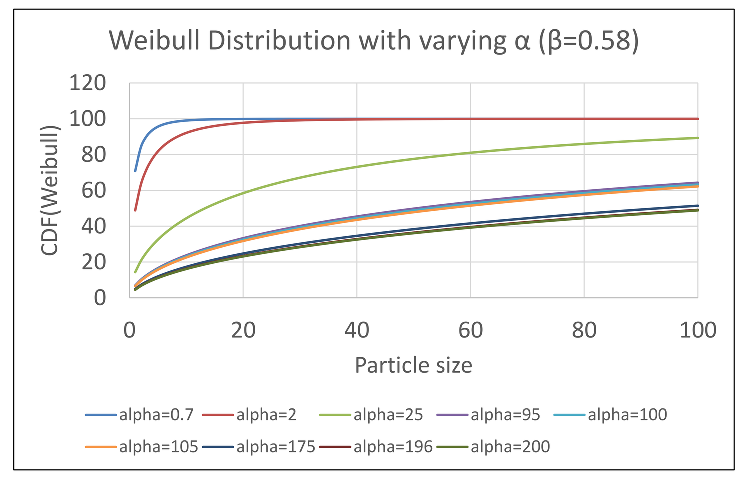
- To prepare the sample for Laser Diffraction, 1 ml soil (2 mm sieved) was added to a solution of 1 ml NaHMP (10%) + 19ml distilled water and was shaken overnight.
- To take a representative sample from the soil slurry mixture, a dropper was used. The sample was stirred using the same dropper and sample was taken from the bottom of the mixture, as we pull up the dropper.
- 100 soil samples were analyzed using both the Laser Diffraction (using CILAS 1190) and Pipette methods.
- We modeled the PSD data, F(D), using a Weibull distribution:

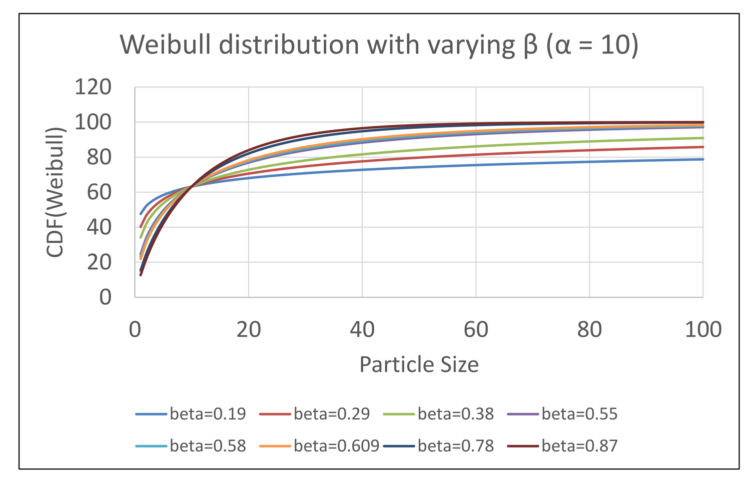
  F(D)=100-100*EXP(-((D/α)^β))

  where D is the particle size and α and β are fitting parameters. α is a scale parameter and β is a shape factor.
- We performed a sensitivity analysis of α and β parameters in Weibull distributions.
- Soil samples were divided into twelve groups according to sand and clay content (based on LD data).
- Regression analysis was done to correlate α between the two methods for each group.
- A mean β value was used per group (see sensitivity analysis).
- We validated the obtained regression by plotting regression obtained CDF, CDF obtained by manually fitting Weibull data to pipette data, CDF from Pipette and CDF from LD.
- We checked sum of square errors (SSE) between CDF obtained from Pipette and LD method. We also checked sum of square errors between CDF obtained from Pipette and Regression obtained CDF. For the proposed modeling and regression to be effective, SSE between Pipette and regression should be comparatively lower.

## RESULTS and DISCUSSION

### Sensitivity Analysis

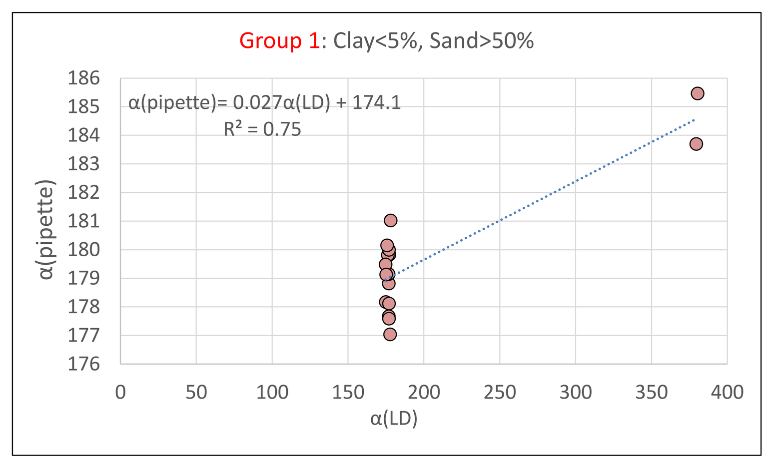


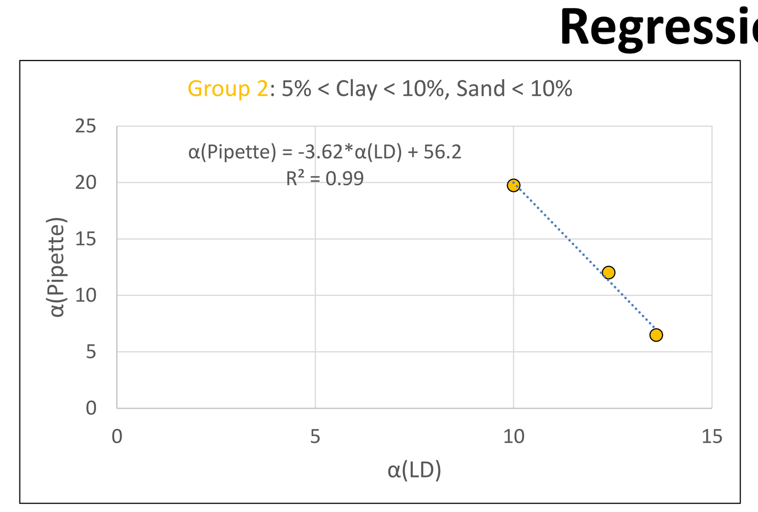



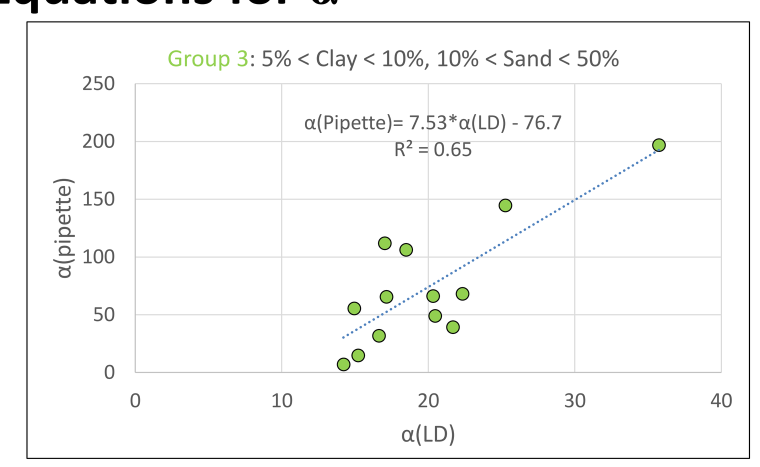

| Group: Clay (C) and Sand (S) Range | Mean β | Std. Dev. β |
|---|---|---|
| Group 1: C < 5%, S > 50% | 18 | 1.2 |
| Group 2: 5% < C < 10%, S < 10% | 0.43 | 0.11 |
| Group 3: 5% < C < 10%, 10% < S < 50% | 0.47 | 0.090 |
| Group 4: 5% < C < 10%, S > 50% | 0.45 | 0.065 |
| Group 5: 10% < C < 25%, S < 10% | 0.38 | 0.07 |
| Group 6: 10% < C < 25%, 10% < S < 50% | 0.40 | 0.12 |
| Group 7: 10% < C < 25%, S > 50% | 0.38 | 0.039 |
| Group 8: C > 25%, S < 10% | 0.26 | 0.070 |
| Group 9: C > 25%, 10% > S > 50% | 0.21 | 0.040 |

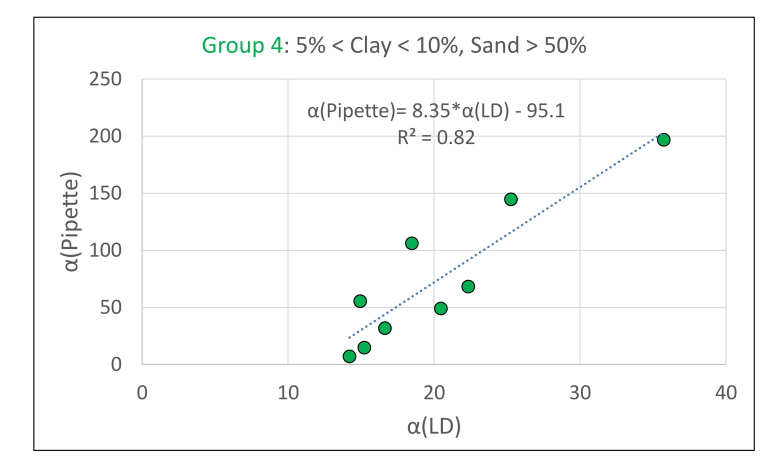
- Sensitivity analysis shows that the Weibull distribution is more sensitive to α compared to β.
- β also did not vary much within each group, as shown by the standard deviation value (Table 1).
- For these reasons a mean β was used for each group.

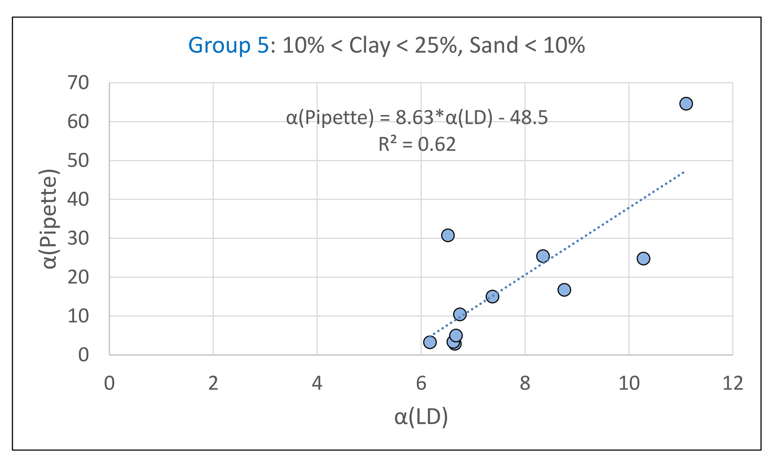
### Regression Equations for α

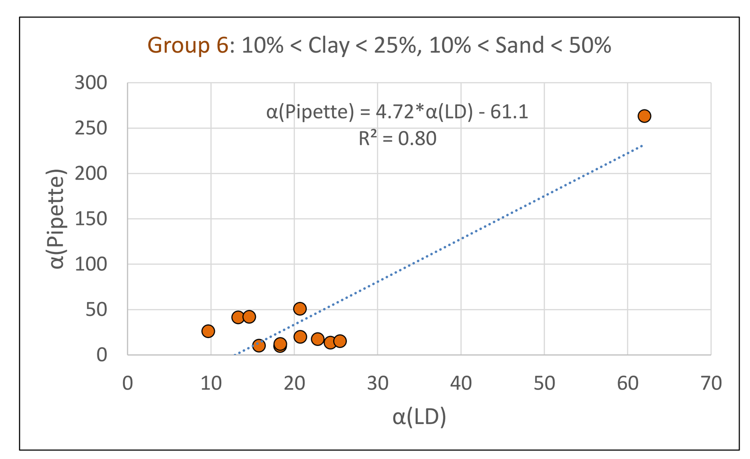


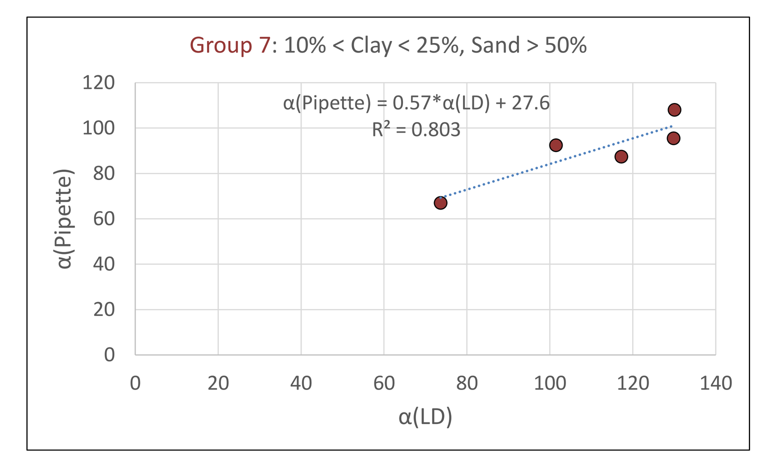



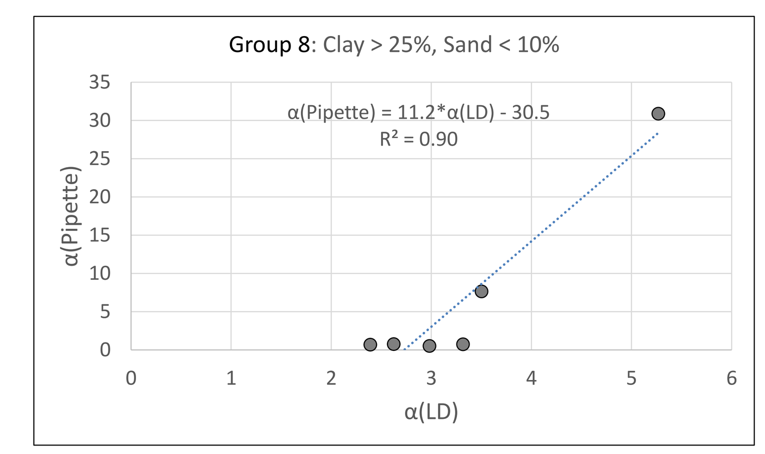



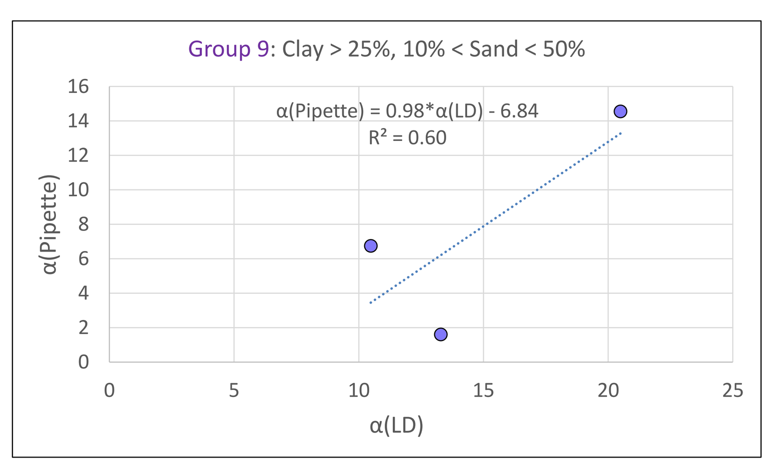



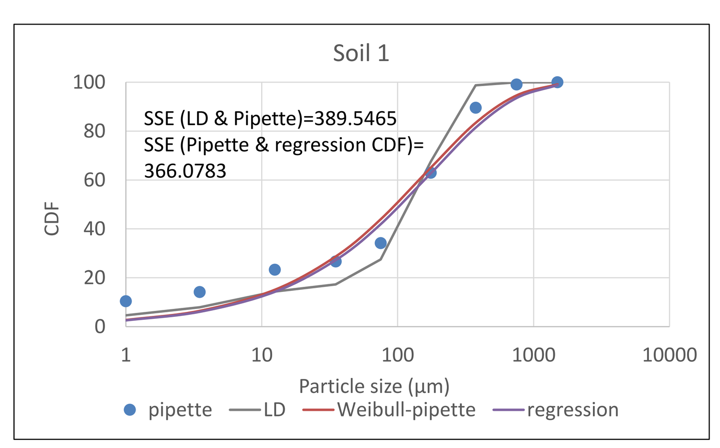



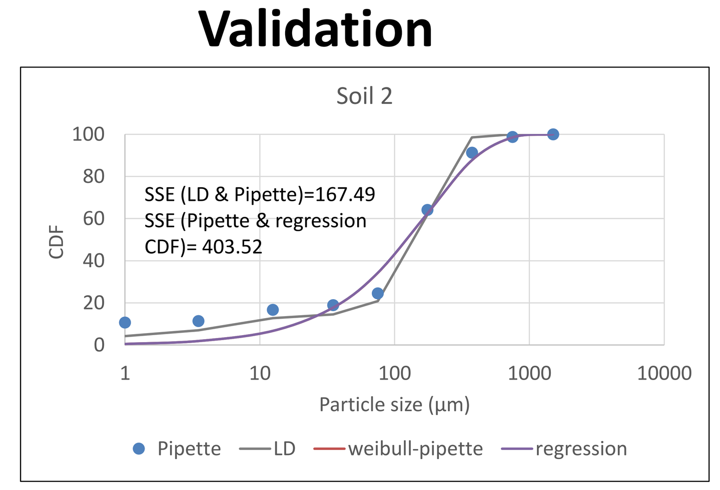



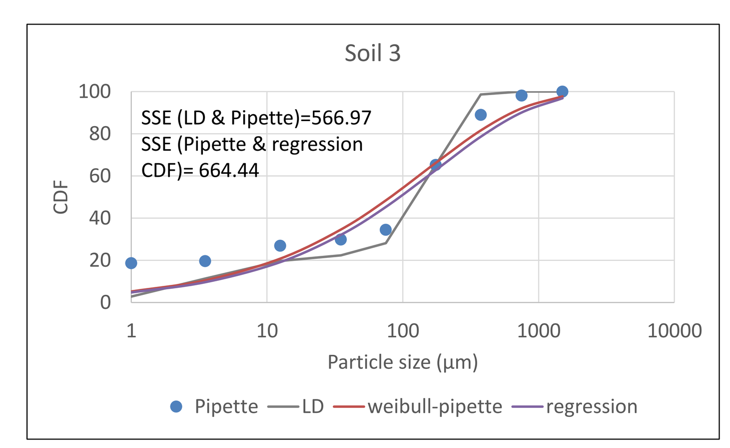



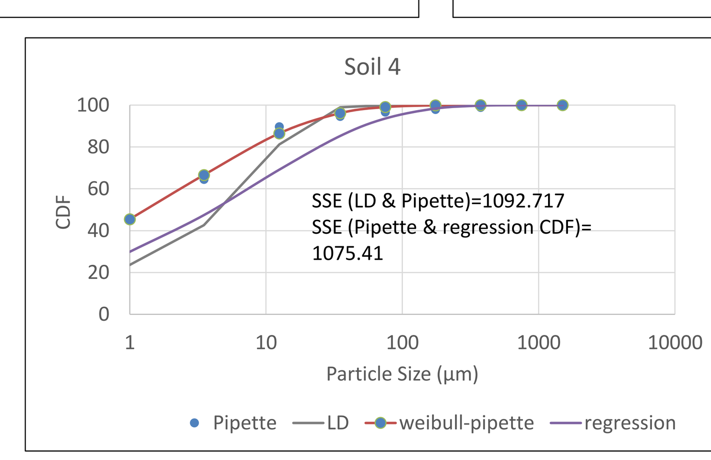

- Among the 12 groups, we only obtained samples in 9 groups (more data is needed for the missing 3 groups).
- Regression analysis of the α parameter between Pipette and Laser Diffraction revealed that dividing the data into groups based on clay and sand Content gives more accurate data than a single overall regression for all data points (data not shown).
- Within each of the 9 groups, α obtained from two methods was found to be well correlated, with $R^2$ values from 0.60 to 0.99.

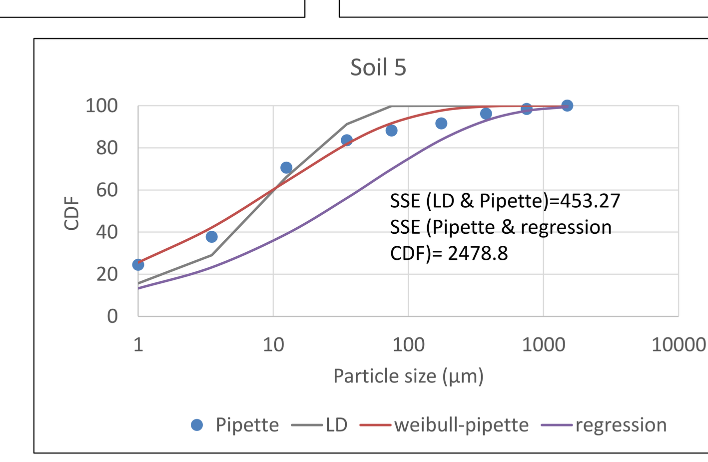
### Validation




- The validation effort shows varying results when using the regression data to correct LD data to match Pipette data. For Soils 1 and 4, the regression equation gave slightly lower relative SSE values compared to the raw LD data, while for Soils 2, 3 and 5 the regression equation caused higher relative SSE values.
- The regression obtained CDF is still underestimating clay content for all 5 soils.
- These errors may be due to the lack of flexibility in Weibull distribution. The Weibull distribution only fits the Pipette data well for soils with large clay content (Soils 4 and 5).
- These findings suggest that additional model refinement is needed to reconcile Pipette and LD methods.

## SUMMARY

- The Weibull distribution shows higher sensitivity to α as compared to β.
- α shows high correlation between Laser Diffraction and Pipette methods, when soils are grouped by texture.
- Weibull distribution seems to fit particle size distribution (PSD) data only in samples with high clay content. It is not flexible enough to fit all PSD data.
- Therefore, future work will explore the use of a 3 parameter model (refinement to Wiebull).
- We will also run more samples to obtain data for each group and see if a 3-parameter model can improve our regression and validation results.

## REFERENCES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