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Sieving Error from Dry-Separating Silt-Sand-Gravel Soils

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Abstract

The dry-separation method is an alternative to the wet-preparation in the current European Standard for the determination of particle size distributions by the sieving of soils. Due to the risk of error, dry-separation is cautioned against in the standard; however, there is no additional guidance as to when it is unsuitable nor for the magnitude of error that it may introduce. This study investigates the dry-separation method as an alternative by comparing with the conventional method of Wet-preparation in terms of particle-size distributions of eight cohesionless sand-gravel soils with varying amounts of nonplastic fines. The findings indicate a gradually increasing sieving error for fractions at minus 0.5 mm with the amount of fines in the soil, and depending on the fines content of the soil, dry-separation introduced errors upwards of 45% in silt-sand-gravel soils. An empirical best-fit formula is proposed for the estimation of the error using the dry-preparation method on this type of soil. Furthermore, to avoid sieving errors, the results suggest that the dry-separation method should not be used for silt-sand-gravel soils exceeding 2% silt size fractions.

Keywords

Laboratory Tests, Particle-Scale Behavior, Silts, Sands, Gravels, Standards & Codes of Practice

1. Introduction

The process of obtaining the particle size distribution (*i.e.*, the gradation) of a soil incorporates several sequential steps that are usually comprised of an initial weighing, an initial oven-drying, a second weighing, washing (removal of the fines), *i.e.*, particles finer than 0.063 mm according to the current European Standard [1] or 0.075 mm according to the American equivalent [2], a

second round of oven-drying, then a third stage of weighing, and finally the sieving of the remaining fractions of the soil. The sieving is usually performed by shaking the soil through a stack of sieves of different size opening. The sample results can thereafter be determined by the weight in terms of the size ranges. The final product, the particle-size distribution curve, is used in geotechnics for many purposes, *i.e.*, analysis, design, prospecting, and for determining engineering properties [2], to name a few. The oven-drying stage is the most time-consuming step; at 110˚C ± 5˚C it typically requires 24 hours to complete.

When the process includes removing the fines by washing, it is called wet-preparation [1]. Dry-separation, on the other hand, is an alternative method to wet-preparation in the European Standard (but not in [2]) that allows one to bypass the washing stage and continue straight to the sieving stage. In the following discussion, these methods will be abbreviated as "wet-prep" and "dry-sep", respectively. Naturally, a dry-sep method will save processing time; however, ref. [1] cautions against it by stating that "Wet preparation is preferred for soils with particles smaller than 0.063 mm, as use of dry-separation method may introduce significant errors". However, no further guidance is given as to when the dry-sep method is unsuitable nor to the magnitude of the error that it may introduce if it is used inappropriately. Since it is less time-consuming, the dry-sep approach is advantageous when there are time- or economic constraints and in special cases, such as when the original soil must be preserved. However, sieving errors may arise for other reasons, *i.e.*, sieve overloading (or under), errors due to particle properties and shape [3] or due to the formation of fine-particle aggregates that may lump together [4].

In this paper, particle-size distributions from the dry-sep method are compared to those of the conventional wet-prep method. Eight nonplastic silt-sand-gravel soils with varying amounts of fines are studied. It will be shown that the sieving error caused by using the dry-sep method increases with the amount of fines, generally resulting in errors in the minus 0.5-mm range, which may produce a notable underestimation of the finer fractions of the soil (e.g., the fines content).

2. The Sieving Stage

The sieving stage involves placing a dry soil sample on top of a stack of sieves where each sieve comprises a specific opening size that becomes gradually finer towards the bottom-placed catch pan. The sieve-stack is agitated to facilitate the movement of particles, usually by a sieve shaker, such that the particles pass through the stack until ultimately reaching a sieve with openings that will retain them. The specific size ranges are thereafter determined by weight, which defines the gradation when plotted in a semilogarithmic diagram. The overall stages of obtaining the particle-size distribution, indicating the differences in the wet-prep and the dry-sep approaches, are shown in **Figure 1**.

Wet-prep is the conventional method during which the soil is washed to

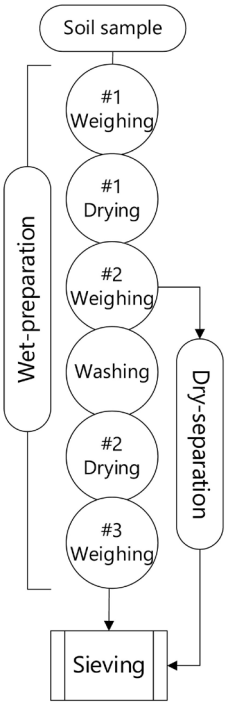

Figure 1. Overview sieving-procedure (after [1]).

remove fines before sieving, whereas this stage is bypassed in the dry-sep method [1]. Ref. [3] indicates that not removing fines prior to sieving may cause a high powder loss, and the adherence of small particles to larger ones. Furthermore, an aspect also likely to introduce sieving errors are clustering of fine-grained particles (*i.e.*, clay) that may form domains and subsequently microaggregates, which eventually forms crumbs or aggregates [4]. For full disclosure, Ref. [1] acknowledges that "significant errors" might occur if fines are not removed prior to sieving but fail to specify to what effect, which may encourage unsuitable use of the dry-sep method.

3. Method

Eight silt-sand-gravel samples with varying amounts of nonplastic fines were analyzed. The soils are of glacio-fluvial origin. The samples are denoted according to **Table 1**, where the first and second numbers indicate fines content as determined by the dry-separation and the wet-preparation methods, respectively. For example, sample A14/26 indicates soil A, for which the fines content from the wet-prep and dry-sep methods are 14.1% and 26.2%, respectively. The respective gradations are shown in **Figure 2**, where the dry-sep gradations are illustrated by continuous lines and the wet-prep ones by dashed lines. The fines content values of the samples (from the wet-prep method) vary from 1.5% to 26.2% (**Table 1**) and the corresponding sand fractions (in the range of 0.063 - 2 mm) vary from 10.0% to 41.2%. **Figure 1** shows the standardized sieving

Table 1. Gradingcharacteristics.

Sample	Fines content, $F_{0.063}$, Wet-prep (%)	Fines content, $F_{0.063}$, Dry-sep (%)	Sand fraction (0.063 - 2 mm) Wet-prep (%)	Sand fraction (0.063 - 2 mm) Dry-sep (%)
A14/26	26.2	14.1	32.4	43.4
B7/10	10.7	7.3	41.8	45.2
C5/7	7.1	5.0	34.3	35.3
D10/13	13.0	9.7	27.0	31.6
E6/10	9.7	6.1	22.0	25.8
F4/5	4.8	4.2	14.0	14.7
G1.5/1.5	1.50	1.48	10.0	10.3
H11/19	18.9	10.6	31.5	39.5

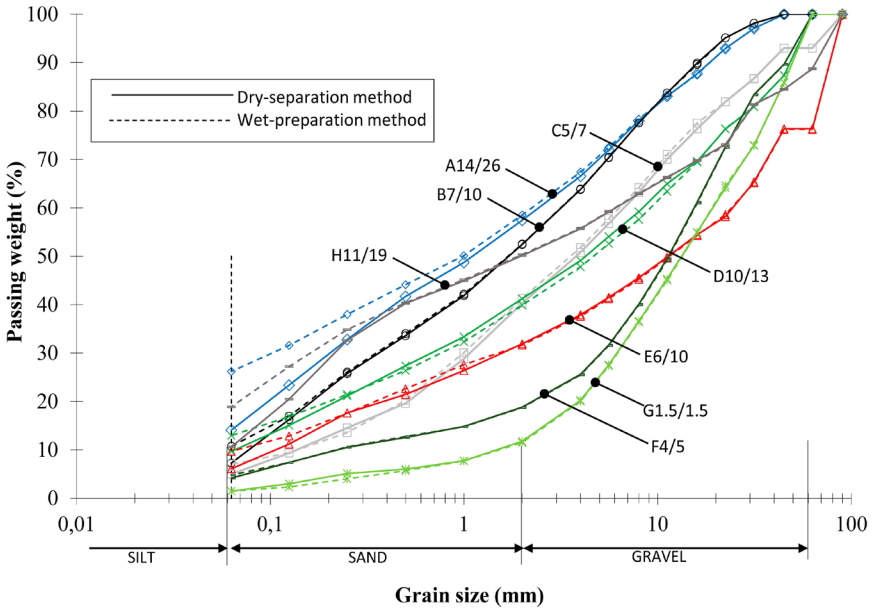

Figure 2. Particle-size distributions using wet-prep (dashed line) and dry-sep (continuous line) method.

procedure. Each sample was initially sieved by dry-separation, and thereafter re-constituted carefully in order to go through a second sieving process, but this time by the wet-prep method (washing to remove fines). The sieve stack used during the tests was comprised of sieves with the following aperture sizes: 90; 63; 45; 31.5; 22.4; 16; 11.2; 8; 5.6; 4; 2; 1; 0.5; 0.25; 0.125; and 0.063 mm.

4. Sieving Error

Table 1 shows the discrepancies between the results achieved from the wet-prep and dry-sep methods in terms of the fines content (European Standard [1], thus, D < 0.063 mm) and the sand fractions (the amount of soil in the range of 0.063 - 2 mm). It reveals that a greater difference in the fines content values generally is

accompanied by a larger difference in the sand fraction values of these two methods, as indicated by samples A14/26 and H11/19. Figure 3 illustrates the distribution of the grain-sizes with respect to the ratio of the passing weights by the dry-sep and wet-prep methods in which a contour line of 100% indicates unity between the methods (similarly in Figure 4); the distribution suggests that the most vulnerable grain sizes for errors are those that were minus 0.5-mm. The differences increase towards the more finer-grained fractions indicating that the gradations with the greatest amount of fines are the ones exhibiting the greatest discrepancy between the two methods (*i.e.*, error), which, at the extreme, approaches 45% at the wet-prep fines content of 26%. Thus, the dry-separation leads to an underestimation of the amount of the finer soil fractions, as put in Ref. [4]: "…wet sieving resulted in a movement in distribution towards smaller particles (than dry sieving)". In addition to the creation of larger particles by the aggregation of smaller particles during dry sieving, the underestimation of fines content may also be affected by the cementing (or plastering) of fines on sand-sized or coarser particles. Surprisingly, the sample G1.5/1.5, which shows the least difference in fines content, exhibits an unexpected deviation over the minus 0.5-mm fractions, but it is inverted, so that $F_{Dry\text{-}sep}$ is greater than $F_{Wet\text{-}prep}$ (Figure 3), an anomaly that is likely due to the low percentage of soil in the 0.063 - 1.0 mm range resulting in an exaggerated $F_{Dry\text{-}sep}/F_{Wet\text{-}prep}$ ratio despite very moderate differences in the particle size distributions (compare with Figure 2).

Figure 4 plots specifically the fines content values, $F_{0.063}$, from the dry-sep method against those of the wet-prep method that again reveals an increasing deviation of dry-sep and wet-prep fines values with increasing fines content in the soil. A very strong correlation (Power trend line, $R^2 = 0.99$) is achieved between the dry-sep fines content values ($F_{0.063(Drysep)}$), in %), and those of the wet-prep equivalent ($F_{0.063(Wetprep)}$, in %) by:

$$F_{(0.063,\text{Drysep})} = 1.14F_{(0.063,\text{Wetprep})}^{0.78} \tag{1}$$

Hence, with (Equation (1)) the sieving error in using the Dry-sep method in terms of the fines content ($E_{r,0.063}$, in %, as indicated in Figure 4) can be estimated with (Equation (2)):

$$E_{r(0.063,\text{Drysep})} = 100 - \frac{114}{F_{(0.063,\text{Wetprep})}^{0.22}} \tag{2}$$

(Equation (2)) is visualized in Figure 4, which suggests that the sieving error arising from the use of the dry-sep method occurs already at 2% wet-prep fines content. It subsequently increases rapidly up to 20% error at only 5% fines content, whereby the increase becomes gradually lower at higher fines content values. Thus, Figure 4 indicates that to avoid any influence of error, the dry-sep method should not be under consideration if the fines content is greater than 2% (wet-prep determination). However, although the error, $E_{r,0.063}$, becomes significant at only 5% fines content, such 20% error has relatively little influence; the

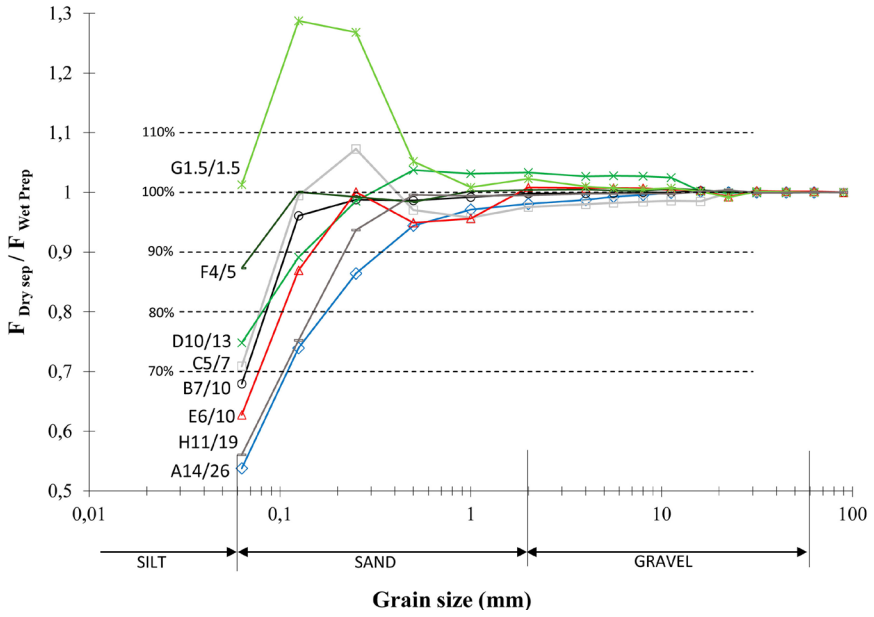

Figure 3. Difference in grain-size characteristics obtained by the dry-sep and wet-prep method.

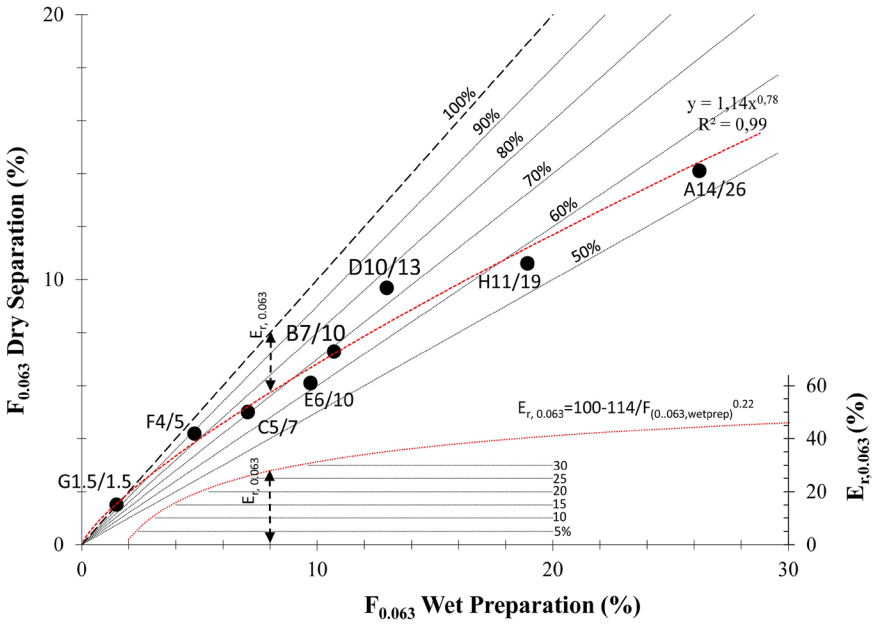

Figure 4. Fines content ($F_{0.063}$, mm) by the dry-sep and wet-prep method and resultant error ($E_{r,0.063}$, %).

actual fines content using the wet-prep method is 5%, whereas the dry-sep method would yield a value of 6% (due to 20% error). This is a margin of error that, in some circumstances, might be acceptable.

5. Conclusions

By investigating eight glacio-fluvial silt-sand-gravel soils with varying amount of

nonplastic fines, the difference and potential error using the dry-separation method in relation to the wet-preparation can be summarized as follows:

- the sieving error increases with the amount of fines, which will result in an underestimation of fines.
- errors occur in the minus-0.5 mm range and increase towards the finer fractions of the soil.
- errors upwards of 45% occur at fines content in the mid-twenty percent range; however, the most rapid increase in error is exhibited in the 2% to 5% fines range.
- although further research is needed, preliminary results indicate that the dry-separation method should not be used for silt-sand-gravel soils exceeding 2% fines if errors are to be avoided.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] ENISO (2016) Laboratory Testing of Soil Part 4: Determination of Particle Size Distribution. *European Standard EN ISO* 17892-4:2016 *for Geotechnical Investigation and Testing*, November 2016.

[2] ASTM (2017) Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis. *ASTM D*6913/*D*6913*M*-17, ASTM International, West Conshohocken, PA, 2017. www.astm.org

[3] Allen, T. (2003) Chapter 4 Particle Size Analysis by Sieving. In: *Powder Sampling and Particle Size Determination*, Elsevier Science, Amsterdam, 682. https://doi.org/10.1016/B978-0-444-51564-3.X5000-1

[4] Robertson, J., Thomas, C.J., Caddy, B. and Lewis, A.J.M. (1984) Particle Size Analysis of Soils: A Comparison of Dry and Wet Sieving Techniques. *Forensic Science International*, **24**, 209-217. https://doi.org/10.1016/0379-0738(84)90186-5

Notations and nomenclatures

$F_{0.063}$: fines content (< 0.063 mm) (%).

F: mass passing (%).

$E_{r,0.063(Drysep)}$: error in obtained fines content by dry-separation (%).

R^2: goodness-of-fit of trend line.

Fines: amount, by weight, of soil finer than 0.063 mm (European Standard) or 0.075 mm (American Standard) (%).

Dry-sep: dry-separation method.

Wet-prep: wet-preparation method.