“Reply to Discussion of Analysis of the internal stability of granular soils using different methods”

By N. Moraci, M.C. Mandaglio, and D. Ielo

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Introduction

The authors wish to thank the discussers for the interesting comments that allowed us to deepen further the published paper. The method proposed by the authors (Moraci et al. 2014) summarizes the generally used criteria to evaluate the internal stability of cohesionless sand-gravel soils (i.e. Kezdi, 1969; Sherard, 1979; and Kenney and Lau, 1985 and 1986). The results of the method proposed by the authors are obtained as the average of Sherard (1979) and Kenney and Lau (1985 and 1986) methods. Therefore, the authors' method results are conservative for soils for which both the used methods provide conservative results. Kezdi's criterion has not been considered in the reply because it is similar to Sherard's criterion and it is more conservative than the Sherard's one.

About the grain size distributions of soils analyzed by Ni et al. (2014)

The soils analyzed in the discussion by Ni et al. (2014) are silt sand-gravel and clay-silt-sand-gravel soils. Some of the soils reported in Figures 1 and 2, show many potential zones of instability, in contrast with those considered by Moraci et al. (2014) in the published paper. For these soils the evaluation of S and F is complex and requires a more detailed explanation. Therefore, in order to apply the method to all the cohesionless soils, in the following paragraphs it will be explained how evaluating F and S considering that the choice of the values depends on the shape of the grain size distribution.

About the choice of F

The research topic of the Moraci et al. (2014) paper is the study of fine particles suffusion inside the solid skeleton constituted by coarse particles. Therefore, according to Skempton and Brogan (1994), the maximum value considered for the fine fraction in weight (F) has been 35%. This value has been chosen because, for fine fraction larger than 35%, the coarse particles do not belong to the solid skeleton but they are immersed in a matrix constituted by the fine particles. For this reason, for the analysis of the soil 11/WF, studied by the discusser, the authors suggest to use other methods such as the one proposed by Moraci et al. (2012a).

In the proposed method the F value is evaluated as the mean value between F1, evaluated by means of Kenney and Lau’s method, and F2, evaluated by means of Sherard’s method.

Evaluation of F1

The value of F1 is determined, in the range of finer percentage (F) from 0% to 35%, corresponding to the minimum value of (H/F) obtained by the graph H/F vs. F (Figg. 3b-d, 4b-d, 5b-d, 6b-d, 7b-d).

Evaluation of F2

F2 is generally determined corresponding to the absolute or relative maximum value of Ir nearby to maximum theoretical limit value for which the fine particles suffusion, inside the solid skeleton constituted by coarse particles, occurs, assumed according to Skempton and Brogan (1994) equal to 35% (Figg. 4c and 7c).

If the Ir vs. F is a decreasing monotonic curve and it intercepts the limit line of internal stability index, Ir=5, F2 is taken at the intersection with the limit line (Figg. 3c and 6c).

On the other hand, if the Ir vs. F is a decreasing monotonic curve and it is located below the limit line (Ir=5), Fig. 5c, F2 is equal to 0, corresponding to the maximum value of Ir.

About the choice of S

Once the values of F1 and F2 have been evaluated, the S value is evaluated as average between S1 and S2, determined on the S versus F curves respectively according to Kenney and Lau method (for F1) and according to Sherard method (F2), as follows:

$$S = \frac{[S1 + S2]}{2} \qquad (1)$$

In the following, it is explained how the curves S vs. F are determined according to the two different methods.

According to Kenney and Lau method, the S versus F curve is evaluated, for each diameter (D_a) of the soil grain size distribution, as the secant slope in the range from D_a to $4D_a$, as follows (Fig. 8):

$$S(F_a) = \frac{Y_e - Y_a}{X_e - X_a} = \frac{F_e - F_a}{log4D_a - logD_a} = \frac{F_e - F_a}{log4} \qquad (2)$$

According to Sherard method, the S versus F curve is determined, for each diameter (D_a) of the soil grain size distribution, as the secant slope, as follows (Fig. 8):

$$S(F_a) = \frac{Y_c - Y_b}{X_c - X_b} = \frac{F_c - F_b}{logD_c - logD_b} = \frac{0.15}{log\frac{D_c}{D_b}} \qquad (3)$$

Where:

the point A corresponds to $Y_a = F_a$ and $X_a = logD_a$;

the Point B corresponds to $Y_b = F_b = 0.85F_a$ and $X_b = logD_b$;

the Point C corresponds to $Y_c = F_c = Y_b + 0.15 = 0.85F_a + 0.15$ and $X_c = logD_c$.

For example the determination of S1 and S2 for some soils analyzed by the discusser are shown, respectively, in Figures 3f, 4f, 5f, 6f, 7f (for S1) and in Figures 3e, 4e, 5e, 6e, 7e (for S2).

Analysis of soils studied by Ni et al. (2014) using the method proposed by the authors ("butterfly wings" chart method)

The soils studied by Ni et al. (2014) have been analyzed according to the selection criteria of F and S, as previously illustrated, and the results are shown in the "butterfly wings" chart proposed by the authors (Fig. 9). In the chart, the Kezdi's criterion has not been shown because it is similar to the Sherard's criterion and it is more conservative than the Sherard's one.

The comparison between the results obtained using the method proposed by Moraci et al. (2014) and the experimental results obtained, using different laboratory procedures, by Kenney and Lau (1985), Skempton and Brogan (1994), Wan and Fell (2004) and Sadaghiani and Witt (2011), is summarized in Table 1.

The figure 9 shows that the soils 23/KL, 21/KL, 20/KL, 1/KL, 2/KL, 3/KL, As/KL and C/SB fall in the stable zone of "butterfly wings" according to the different experimental results.

The soils Ds/KL, D/SB, Ys/KL, B/SB, fall in the uncertain zone A; these soils according to the different experimental tests result stable (Ds/KL, D/SB) or unstable (Ys/KL, B/SB).

The soils 3R/WF and A/KL fall in uncertain zone B; the soil 4R/WF falls to the border line between the unstable zone and uncertain zone B. According to the different experimental results, the soils 3R/WF and 4R/WF result stable while the soil A/KL results unstable.

The soils Y/KL, X/KL, RD/WF, 1,1A/WF, 2R/WF, A3/WF, 9/WF, SOIL/SW, B1/WF, B2/WF, D1/WF, C1/WF, A2/WF, 10/WF, fall in the unstable zone. Almost all these soils result unstable according to the different experimental results; only the soils RD/WF, 9/WF, 1,1A/WF and 2R/WF result experimentally stable.

About the filtration tests

For broadly graded granular soils and especially for silt sand-gravel and clay-silt-sand-gravel soils the experimental results of filtration tests could be affected by different test factors. The first one is related to the difficulty to reconstitute homogeneous soil specimens (generally for these soils in order to obtain homogeneous specimens the slurry deposition technique should be used, Kuerbis and Vaid, 1988). In the case of non-homogeneous specimens, the procedure used by Wan and Fell (2004) to assess the size of the largest particles eroded by suffusion process and the fraction of materials eroded by the process could be approximated.

The second one is linked to the fact that the soil subjected to filtration tests is in contact with a gravel layer that, for some soils, could behave as filter and, therefore, could affect the movement of soil particles.

Moreover, the results of seepage tests could be affected by the presence of air inside the soil specimens, if deaired water is not used in the tests and the soil specimens have not been saturated.

For these soils, for which is really complex to perform proper experimental tests, the authors suggest to use geometric-probabilistic methods, such as the Simulfiltr method proposed by Moraci et al. (2012b, c). These methods are capable to simulate the real soil grain size distribution considering different soil relative density (or porosity) and to simulate the fine particles movement inside the pores of solid skeleton constituted by the coarse particles (regardless of interaction with filter) .

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Figure Captions

Fig.1 Stable soils according to experimental results obtained by different authors (Ni et al. 2014).

Fig.2 Unstable soils according to experimental results obtained by different authors (Ni et al. 2014).

Fig.3. Example of evaluation of F and S for soil 3R/WF: a) soil grain size distribution; b) shape curve according to Kenney and Lau (1985 and 1986); c) Ir vs. F curve according to Sherard (1979); d) H/F vs. F curve according to Kenney and Lau (1985); e) S vs. F curve according to Sherard (1979); f) S vs. F curve according to Kenney and Lau (1985).

Fig.4. Example of evaluation of F and S for soil 10/WF: a) soil grain size distribution; b) shape curve according to Kenney and Lau (1985 and 1986); c) Ir vs. F curve according to Sherard (1979); d) H/F vs. F curve according to Kenney and Lau (1985); e) S vs. F curve according to Sherard (1979); f) S vs. F curve according to Kenney and Lau (1985).

Fig.5. Example of evaluation of F and S for soil 23/KL: a) soil grain size distribution; b) shape curve according to Kenney and Lau (1985 and 1986); c) Ir vs. F curve according to Sherard (1979); d) H/F vs. F curve according to Kenney and Lau (1985); e) S vs. F curve according to Sherard (1979); f) S vs. F curve according to Kenney and Lau (1985).

Fig.6. Example of evaluation of F and S for soil Ds/KL: a) soil grain size distribution; b) shape curve according to Kenney and Lau (1985 and 1986); c) Ir vs. F curve according to Sherard (1979); d) H/F vs. F curve according to Kenney and Lau (1985); e) S vs. F curve according to Sherard (1979); f) S vs. F curve according to Kenney and Lau (1985).

Fig.7. Example of evaluation of F and S for soil B1/WF: a) soil grain size distribution; b) shape curve according to Kenney and Lau (1985 and 1986); c) Ir vs. F curve according to Sherard (1979); d) H/F vs. F curve according to Kenney and Lau (1985); e) S vs. F curve according to Sherard (1979); f) S vs. F curve according to Kenney and Lau (1985).

Fig. 8. Example of determination of S (F) according to Kenney and Lau (1985) and Sherard (1979) methods.

Fig. 9. Butterfly wings chart: results obtained for the soils analyzed by Ni et al. (2014).

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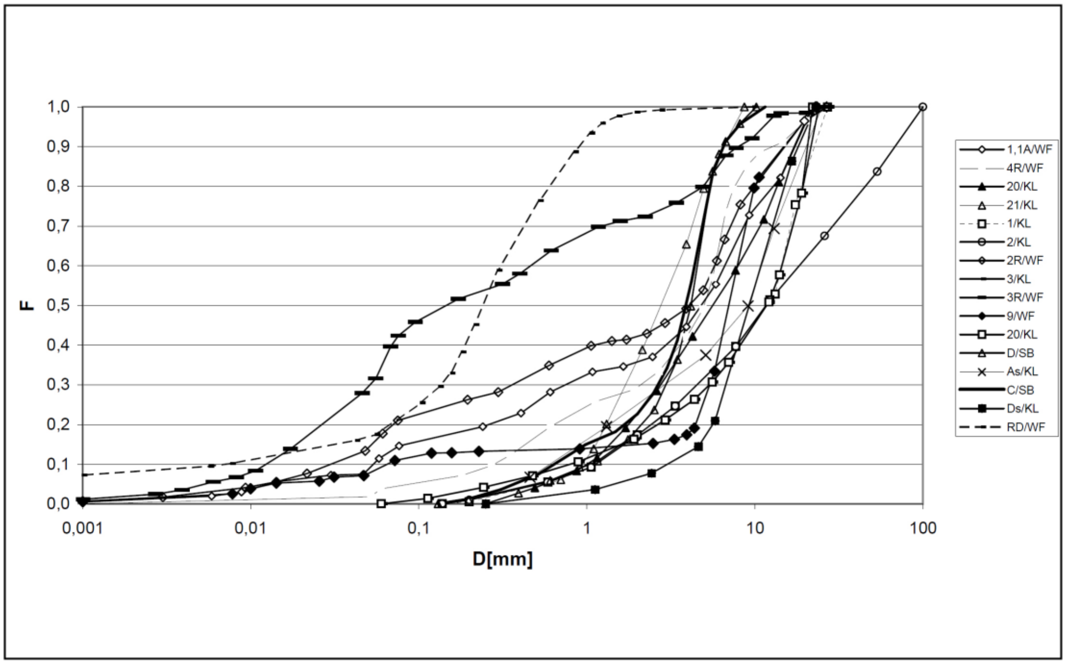

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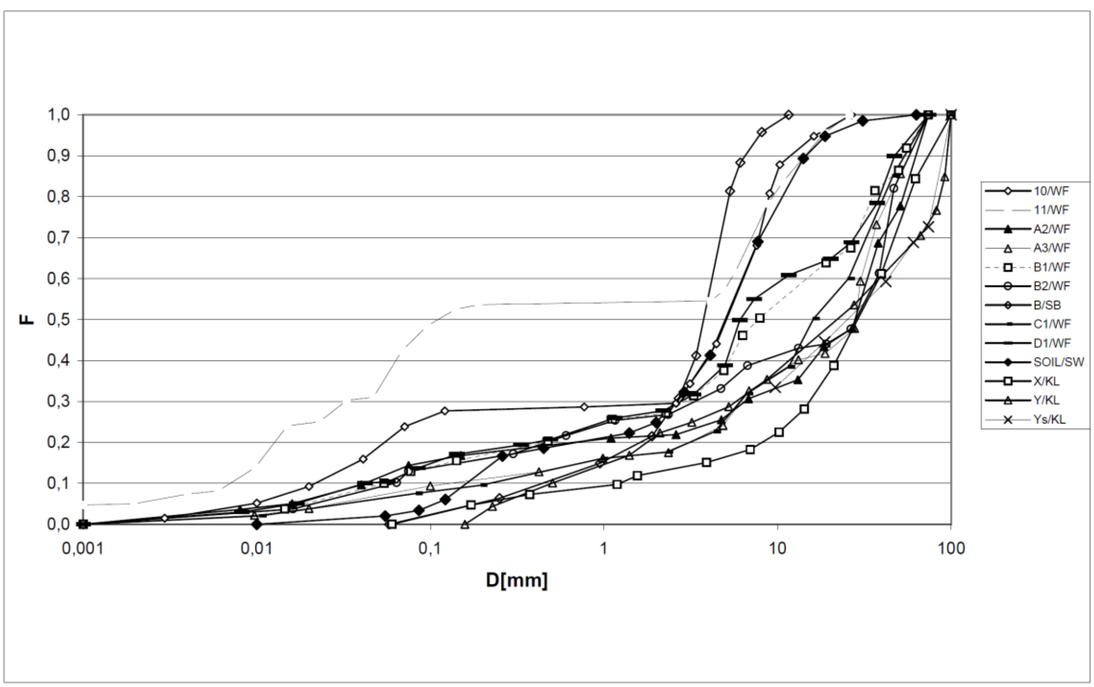


Fig.2 Unstable soils according to experimental results obtained by different authors (Ni et al. 2014).

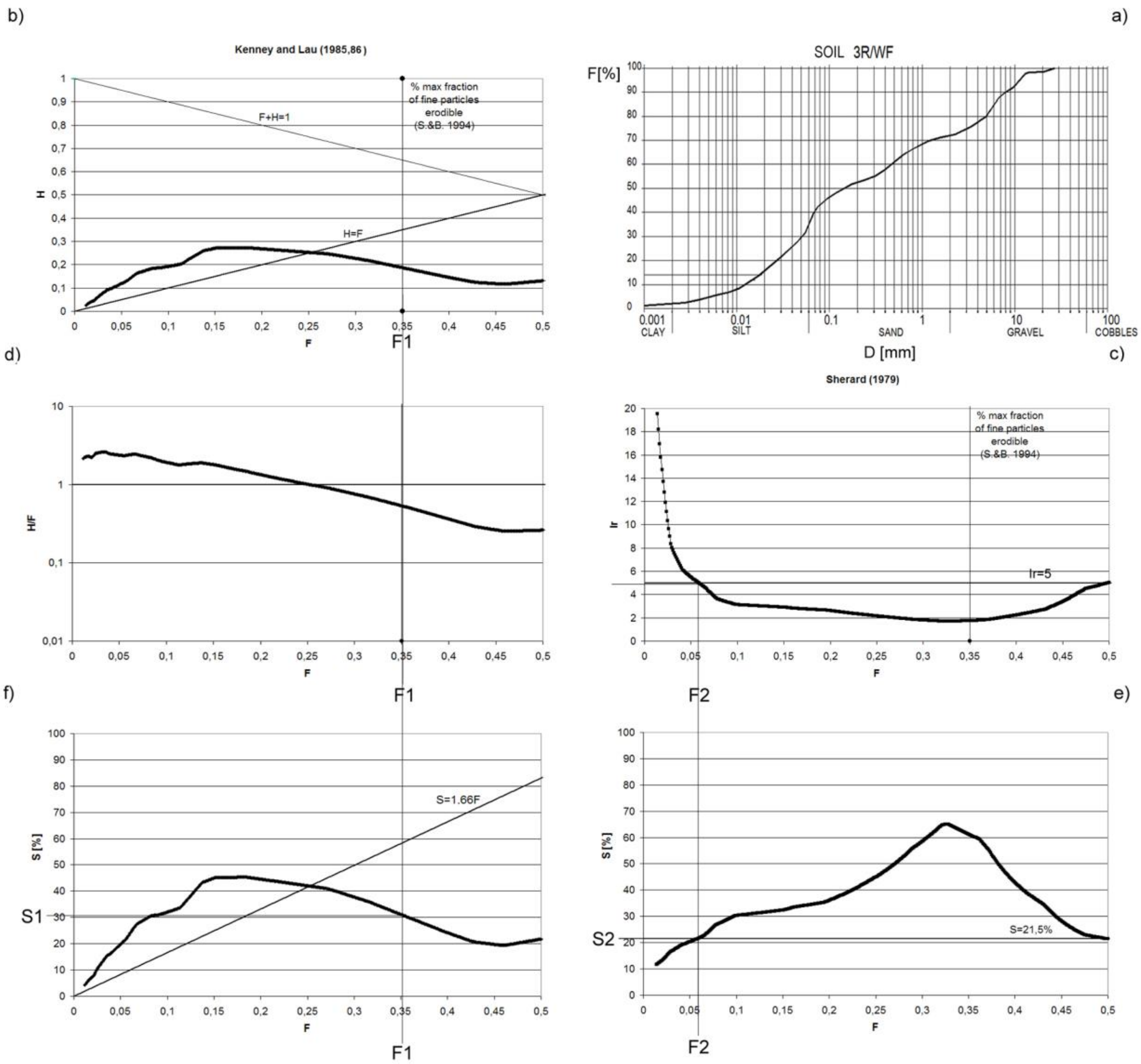
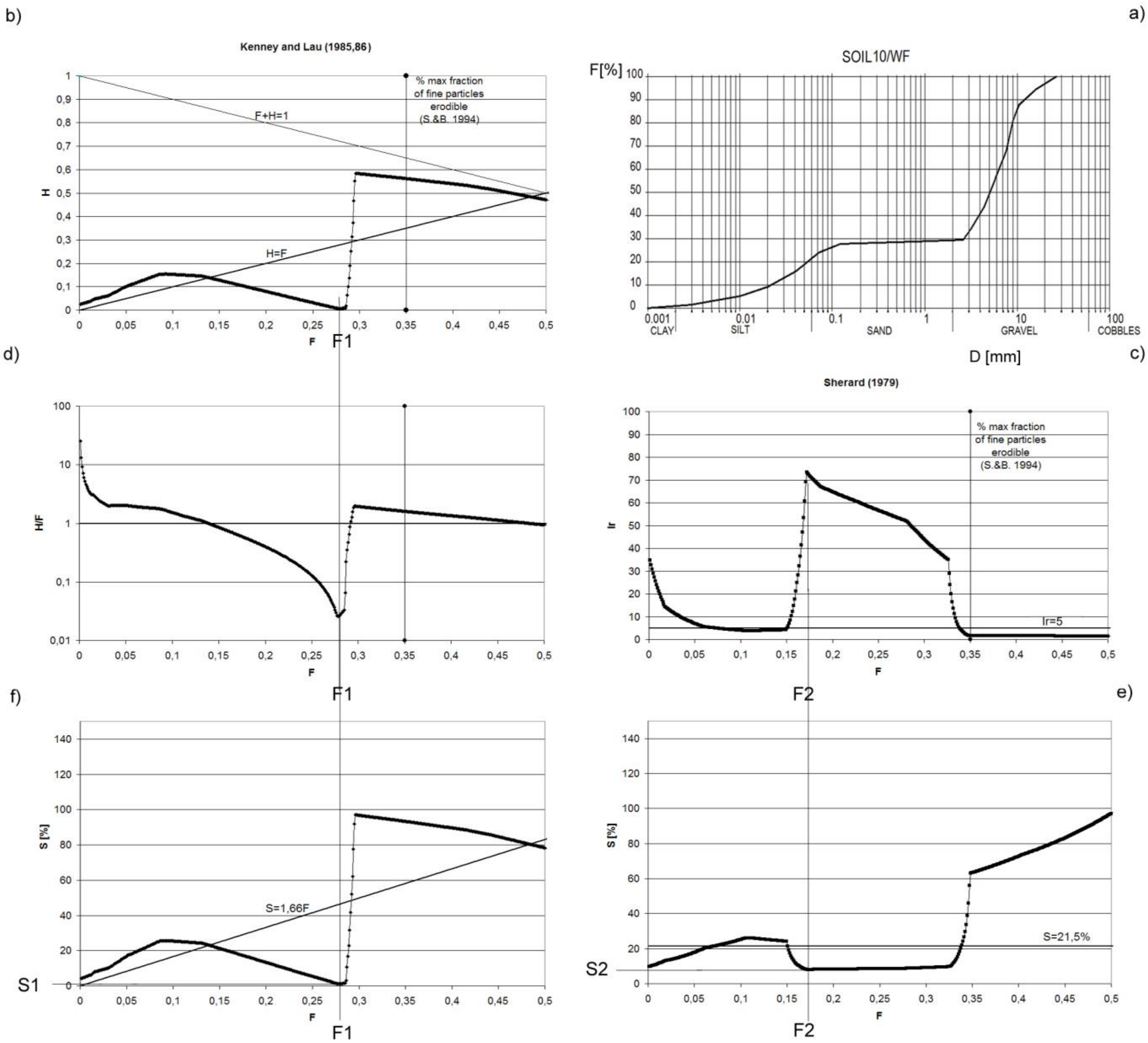


Fig. 3. Example of evaluation of F and S for soil 3R/WF: a) soil grain size distribution; b) shape curve according to Kenney and Lau (1985 and 1986); c) Ir vs. F curve according to Sherard (1979); d) H/F vs. F curve according to Kenney and Lau (1985); e) S vs. F curve according to Sherard (1979); f) S vs. F curve according to Kenney and Lau (1985).



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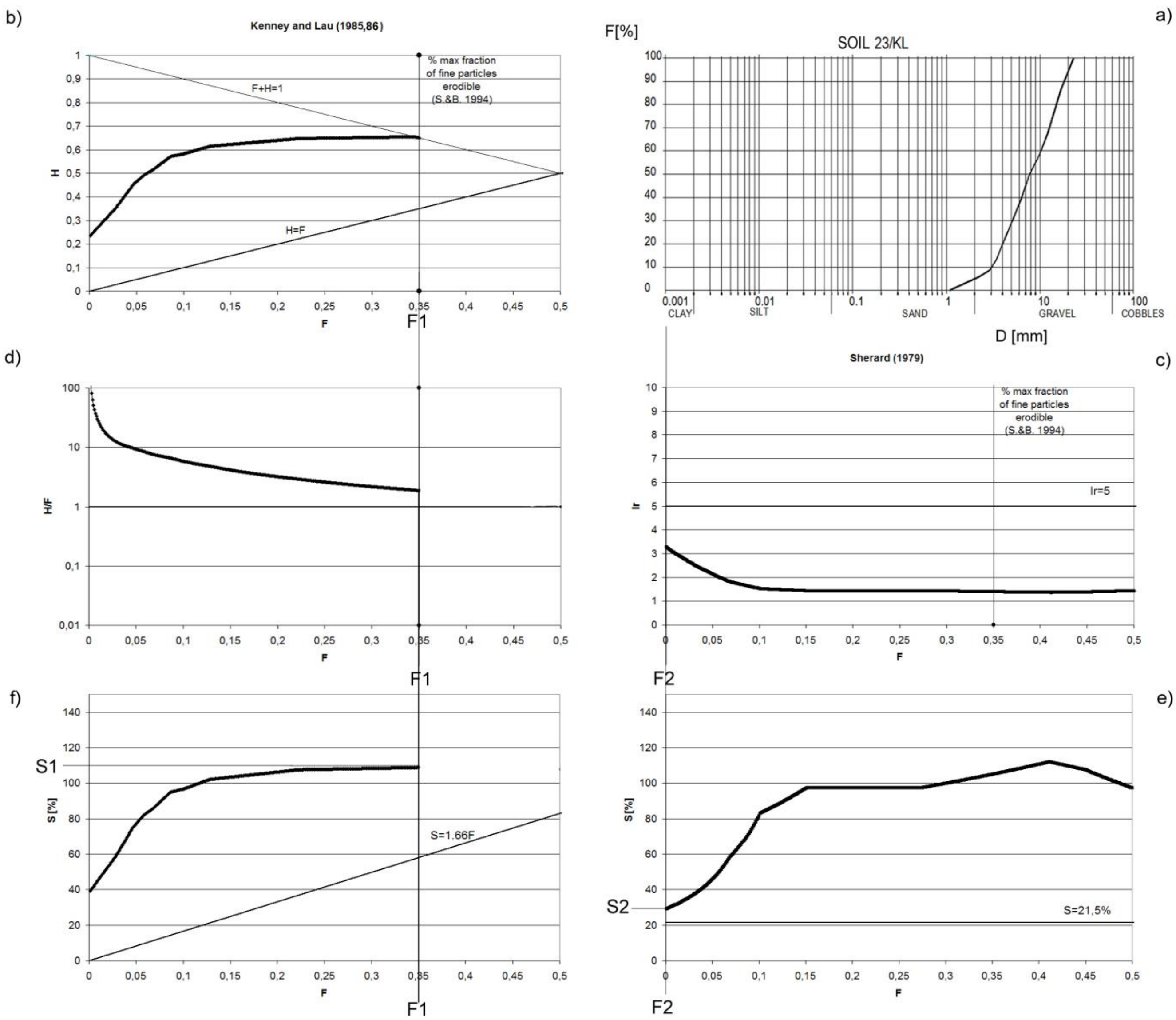

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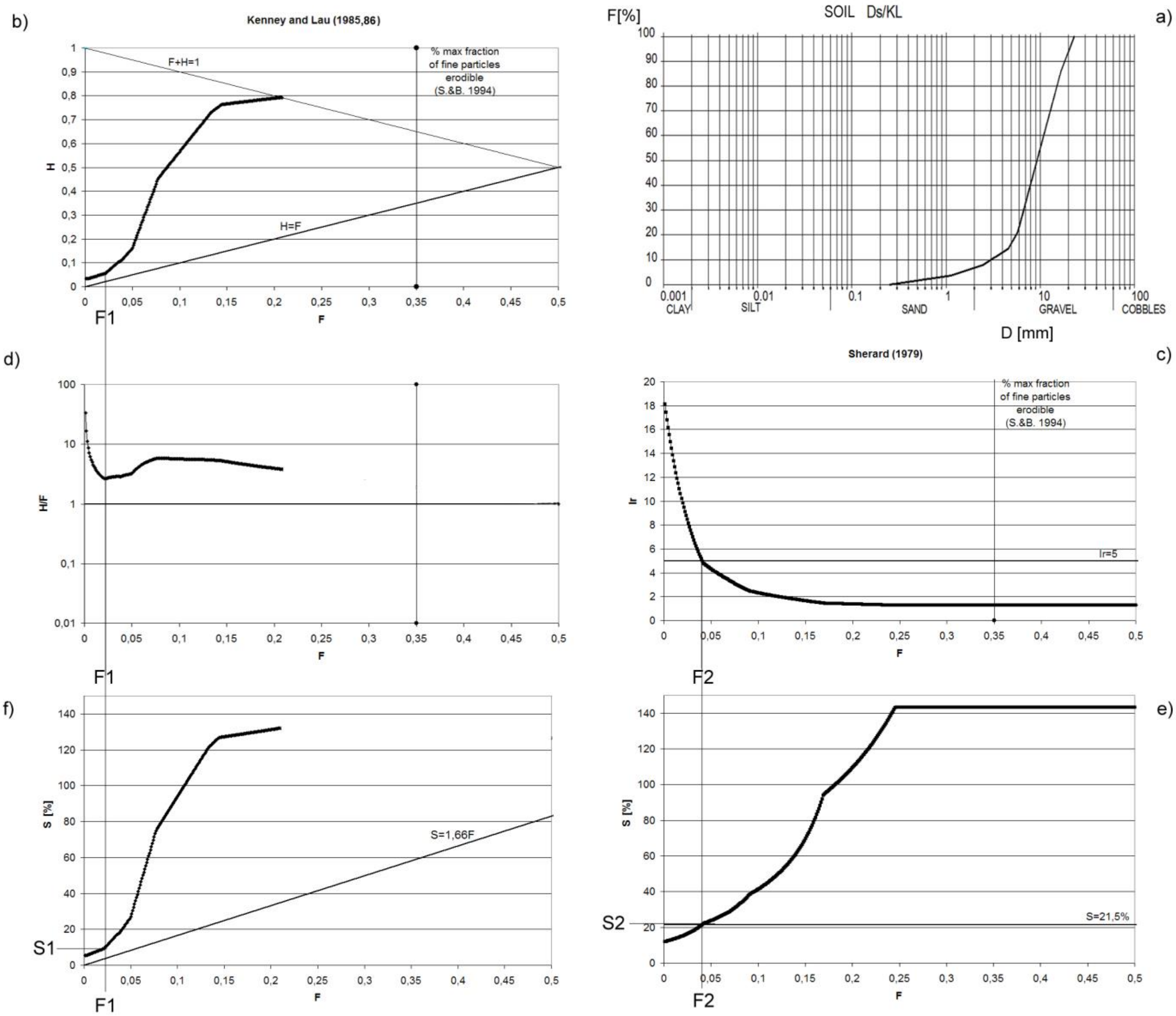

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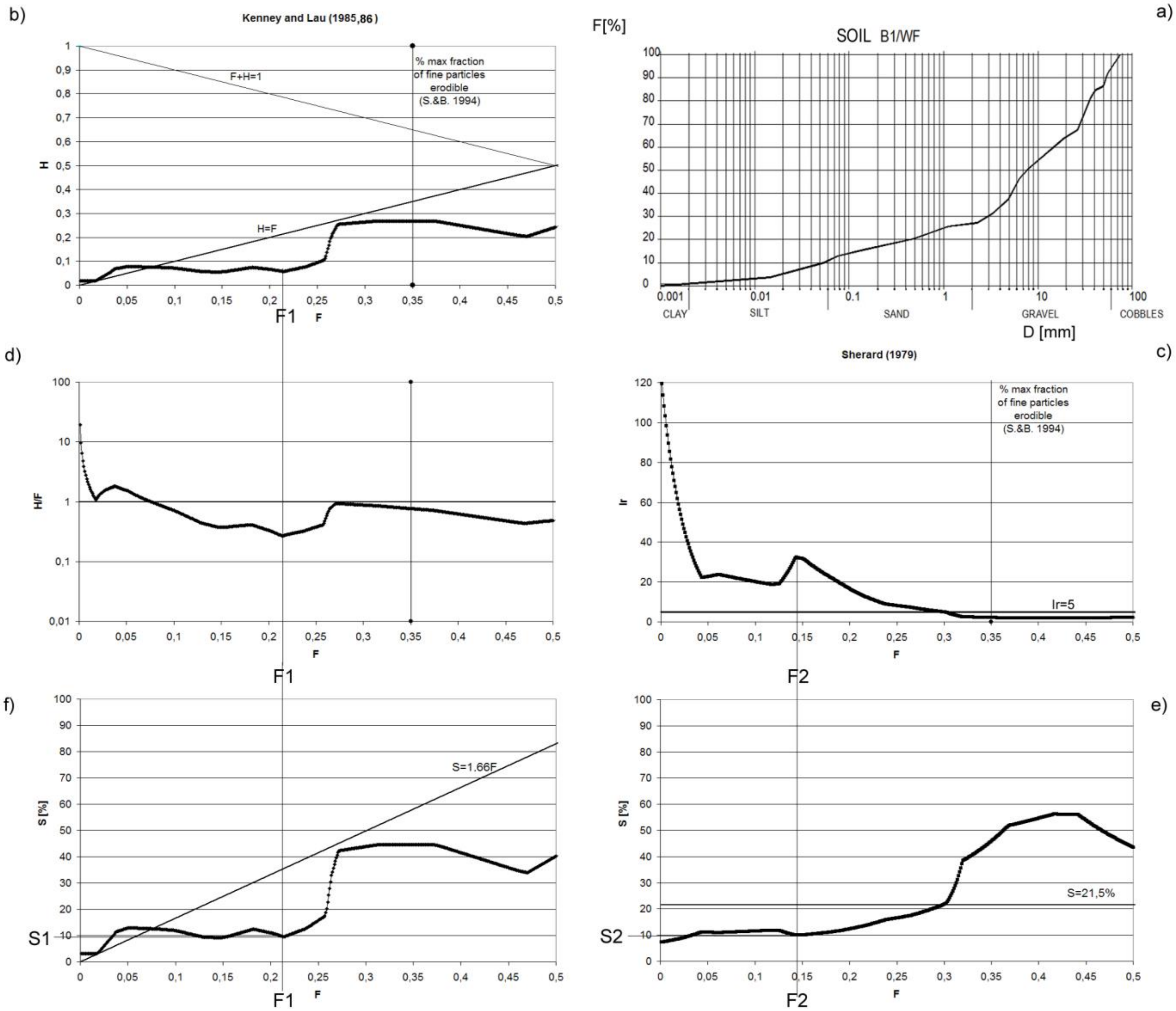

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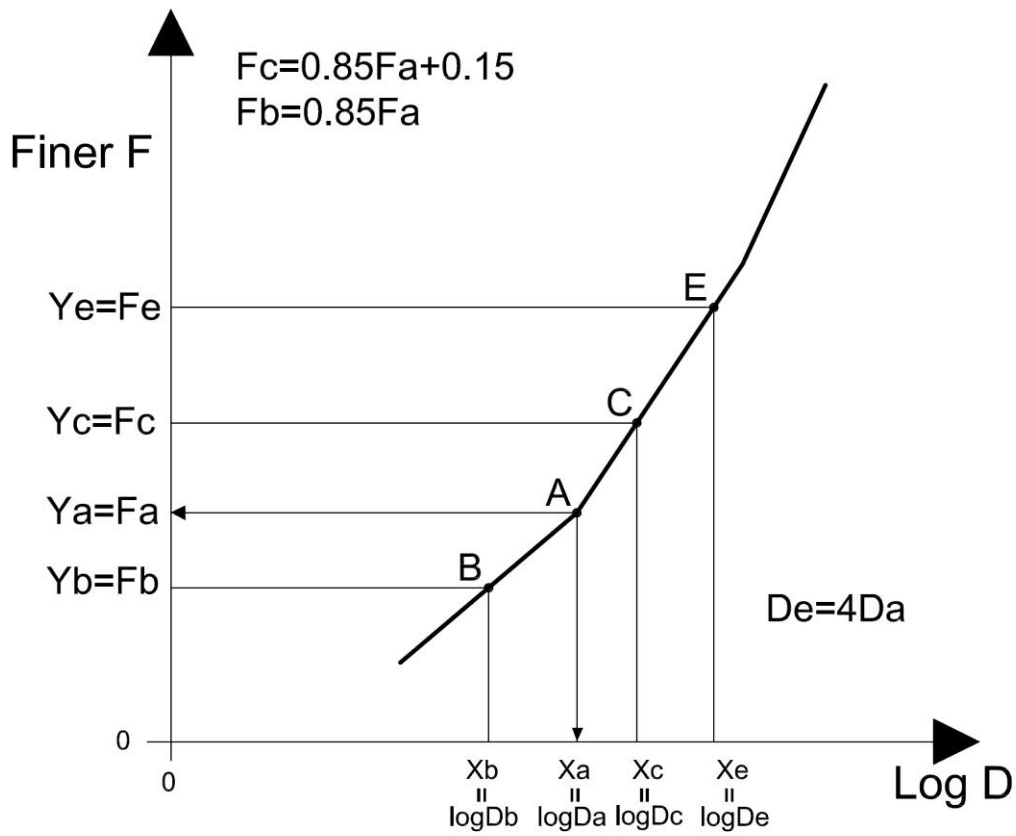

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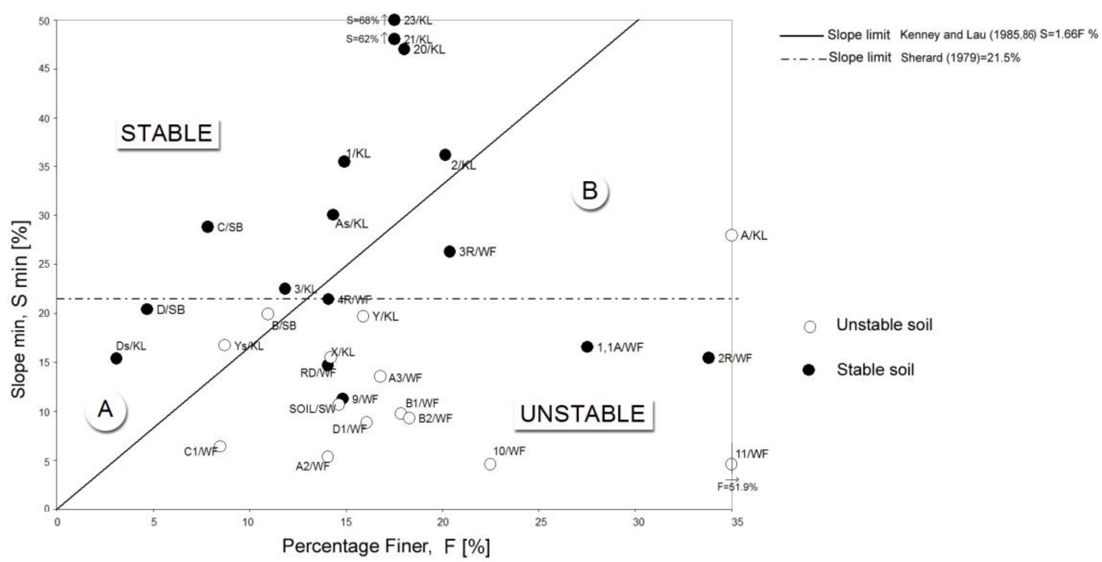

Fig. 9. Butterfly wings chart: results obtained for the soils analyzed by Ni et al. (2014).

Table 1. Comparison between “butterfly wings method” results and experimental results

Soil	Butterfly wings method results	Experimental results according to the different authors
1,1 A	Unstable	Stable (WF)
2R	Unstable	Stable (WF)
10	Unstable	Unstable (WF)
B2	Unstable	Unstable (WF)
B1	Unstable	Unstable (WF)
D1	Unstable	Unstable (WF)
A2	Unstable	Unstable (WF)
C1	Unstable	Unstable (WF)
SOIL	Unstable	Unstable (SW)
9	Unstable	Stable (WF)
11	Unstable *	Unstable (WF)
A3	Unstable	Unstable (WF)
RD	Unstable	Stable (WF)
X	Unstable	Unstable (KL)
Y	Unstable	Unstable (KL)
As	Stable	Stable (KL)
Ys	Uncertain A	Unstable (KL)
B	Uncertain A	Unstable (SB)
Ds	Uncertain A	Stable (KL)
D	Uncertain A	Stable (KL)
4R	Unstable, Uncertain B	Stable (WF)

3R	Uncertain B	Stable (WF)
A	Uncertain B	Unstable (KL)
3	Stable	Stable (KL)
C	Stable	Stable (SB)
1	Stable	Stable (KL)
2	Stable	Stable (KL)
20	Stable	Stable (KL)
21	Stable	Stable (KL)
23	Stable	Stable (KL)

* in the soil 11 the coarser fraction is floating in the finer fraction

WF= Wan and Fell (2004), SW= Sadaghiani and Witt (2011), SB= Skempton and Brogan (1994), KL= Kenney and Lau (1985).