Suggested Revision of the Pinhole Test Erosion Classes

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SUMMARY The Pinhole Test as developed by Sherard et al (1976a) is an excellent test of erodibility in fine grained soils. However it is not a reliable measure of dispersion, which is just one of a number of processes which can contribute to erodibility in soils. In view of this we suggest the test classes to which samples are assigned following testing be revised to remove the dispersive - non-dispersive implication inherent in the original classification.

1. INTRODUCTION

A common laboratory test method used in erodibility analysis is the pinhole test, as developed by Sherard et al (1976a). The test was originally proposed for recompacted fine grained soils and found particular application in the testing of piping resistance in potential core material for earth dams. Evans (1977) modified the method to test undisturbed insitu samples of Banks Peninsula loess and the pinhole test has been used to assess insitu soil erodibility in this material since that time (see for example Wilms, 1979; Saul, 1979; Evans & Bell, 1981; Schafer & Trangmar, 1981; Crampton, 1985; Yetton, 1986; Bell et al, 1986). Yetton (1990) discusses the relevance of the test in subsurface erosion investigation.

The test procedure is briefly as follows. Water under head flows through a 1 mm pinhole in an undisturbed soil sample and the degree of erosion enlargement of the pinhole is assessed. The head is increased in increments from 50 mm to 1000 mm, and each head is sustained for 10 minutes. The total test time is between 10 and 40 minutes, depending on the erodibility of the soil tested.

The original test class classification of Sherard et al (1976a) was based on colour of the eroding water and rate of water flow, and two basic classes of D and ND were suggested defining dispersive and non-dispersive behaviour.

Advantages of the test include:

(1) The comparatively realistic modelling of subsoil erosion conditions;

(2) The ability to test both insitu undisturbed and recompacted samples;

(3) Fast test time;

(4) Reproducible results;

(5) The equipment is simple and takes up little space in the laboratory.

2. ERODIBILITY AND DISPERSION

An erodible material is defined here as a rock or soil which undergoes the particle by particle removal of grains, aggregates or flocs through the action of flowing water. Erosion occurs when the shear stresses induced by the fluid flow, either on or in the soil, are great enough to cause the removal of these particles (see Arulanandan & Perry, 1983).

The fundamental properties controlling the erodibility of fine grained soils are soil grain size, cohesion and soil propensity to undergo slaking and dispersion. Intuitively it could reasonably be expected that soil erosion is dependant on the interaction of these various properties rather than on any single property.

The term "dispersion" was originally introduced to the literature as a pseudonym for clay mineral deflocculation and many authors define and use the term in this manner (Emerson, 1967; Ryker, 1977; Holmgren & Flanagan, 1977; Bell, 1978; Liggins, 1979; Schafer, 1982).

Sherard et al (1976a) redefine the term dispersion to mean "colloidal erodibility" and propose the pinhole test result be used as a dispersion index. Thus if the water running through the sample under the lowest test head erodes the sample and carries a cloudy coloured suspension, and this suspension does not settle out over the 10 to 15 minutes of testing, then the sample is classified as dispersive (D1 or D2). Samples in which only limited erosion has occurred, with little or no cloudiness, are prefixed by ND (non-dispersive) and by various number grades depending on the head required to initiate erosion (ND1-4).

3. DIFFICULTIES IN USING THE TEST TO MEASURE DISPERSION

Results from a number of studies of different soil types suggest the pinhole test is not a reliable indicator of dispersion defined in the most widely used sense (i.e. clay mineral deflocculation).

Sherard et al (1976b) in a comparison between various dispersion test methods after developing the pinhole test, noted a discrepancy between the crumb test for dispersion and the pinhole test. The crumb test for dispersion consists of immersing a crumb of soil in a beaker of water and observing the extent of the colloidal halo, and was first introduced by Emerson (1967). Sherard et al (1976b) found about 40% of the crumb samples which displayed non-dispersive clay mineral behaviour were classified as "dispersive" by the Pinhole Test.

An examination of existing data available for undisturbed samples of Banks Peninsula loess also indicates a poor correlation between dispersion measured by the crumb test and pinhole "dispersion" (see Figure 1). If dispersion was the only variable being measured by erosion in the pinhole test a straight line relationship could be reasonably expected. In Figure 1 no such relationship is apparent.

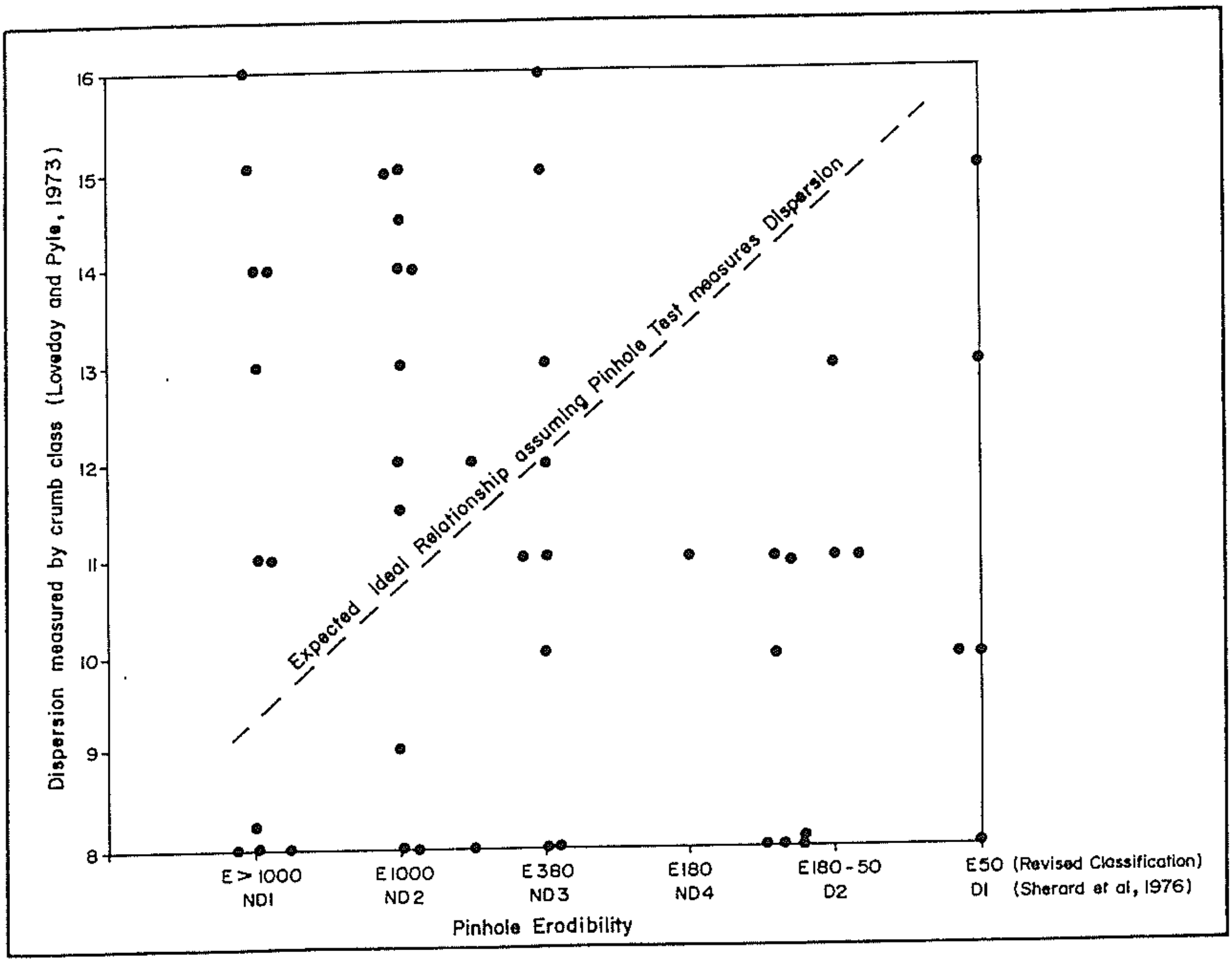

FIGURE 1: The relationship between pinhole test results and dispersion (measured by the crumb test) for 47 samples of Banks Peninsula Loess (data from Yetton 1986; Crampton 1985 and Saul 1979)

To further highlight this discrepancy a sample of loess was cleaned of the clay sized fraction which ensured a crumb of the resulting sandy silt showed no dispersion (colloidal cloudiness) in the crumb test. When this sample of sandy silt was pinhole tested it proved to be the most erodible material tested in the writers' experience, and thus the corresponding Sherard et al (1976a) classification class was Dispersive 1 (D1).

Other tests for dispersion fail to correlate with the pinhole test results. Schafer & Trangmar (1981) present a comparison of data for recompacted loess from Banks Peninsula and adjacent areas. In their study they compared pinhole test results with the porewater analysis and the SCS dispersion tests (refer Sherard et al, 1976b for details of these test methods). Schafer & Trangmar conclude that although there was reasonable correlation, in many cases neither the SCS test nor the porewater analysis method, correlate completely with the pinhole test.

More recently Craft and Acciardi (1984) noted discrepancies between the pinhole test results and the pore water analysis test for dispersion of sampled soils (see Figure 2). Once again materials classified as non-dispersive by the pore water test were classified "dispersive" by the pinhole test. Figure 2 also shows the results of Goldsmith and Smith (1985), who found clayey silts from the Auckland region to be dispersive as measured by both the porewater analysis method and the SCS test, yet were classified as non-dispersive (ND1) by the pinhole test.

The results outlined above confirm that although the pinhole test measures erodibility, it is not always an accurate indicator of dispersion. While in some soils, high erodibility may indicate the presence of dispersive clay minerals, in most soils high erodibility is the result of the interaction of a number of key soil properties, only one of which is dispersion.

4. RECOMMENDED MODIFICATIONS TO THE PINHOLE TEST CLASSIFICATION

The conclusions above do not invalidate the pinhole test as an effective measure of erodibility, rather they suggest a reclassification of the pinhole test result classes is required to remove the dispersive - non-dispersive implication inherent in the original.

Minor modifications of the pinhole test classification have been suggested by Evans (1977) and Bell (1981). These changes both emphasise the extent of erosion under the various heads as the principal criteria separating the classes. The degree of water cloudiness is less important. The D - ND terminology of Sherard et al (1976a) is retained. Schafer & Trangmar (1981) define a quantitative "erosion index" based on the volume increase in the pinhole size as calculated from the volume of eroded soil in the test water. Scaling equations adjust the index for different pinhole diameters and flow rates. This is an improvement on the original classification as it removes the dispersive - non-dispersive distinction, however the collection, evaporation and weighing of sediment in the test water, along with the calculations required, are all time-consuming.

A relatively quick and simple classification procedure, outlined briefly below and in more detail in the appendix, is proposed here for use. During the test the usual record is kept of water discharge per unit time which is plotted up as a graph at the test

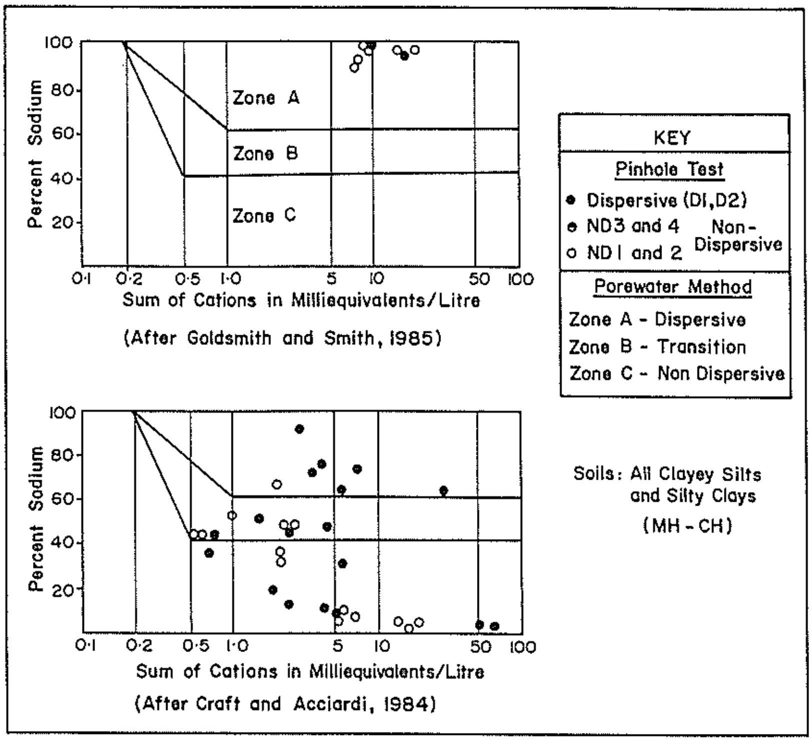

FIGURE 2: Discrepancies between the pinhole test results and the Porewater Analysis method of dispersion testing

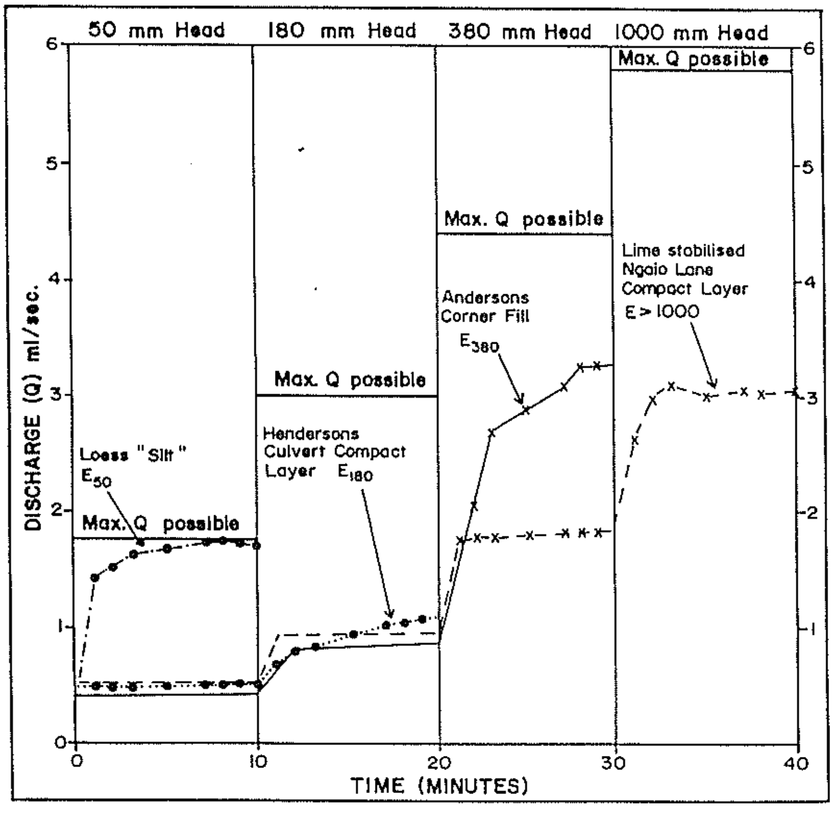

FIGURE 3: Examples of suggested erodibility classification classes (data from Yetton, 1986)

completion. From this graph the head at which sustained erosion first occurs is established. This is first defined as the head which produces a progressive increase in discharge over three or more minutes (see examples in Figure 3). An erosion category is then assigned according to this head i.e. for 50 mm head = E_{50}, for 180 mm head = E_{180}, etc. If significant erosion first occurs at a low head, but only becomes sustained at the next higher head, then intermediate classes can be used i.e. $E_{180-380}$.

Although "E" by convention is the symbol for the modulus of elasticity in soil and rock mechanics, we consider it is unlikely to be confused with erodibility by virtue of the subscript and the quite different context in which this test would normally be used.

The general correlation of Sherard's classes with those proposed in this new classification is as follows:

D1	=	E_{50}
D2	=	E_{180-50}
ND4	=	E_{180}
ND3	=	E_{380}
ND2	=	E_{1000}
ND1	=	$E_{>1000}$

In principle the gradient of the discharge - time graph during the period of sustained erosion could be quantified and used to further refine the separation of sample erosion characteristics should this ever be required.

5. CONCLUSION

While the pinhole test as originally proposed by Sherard et al (1976a) is an excellent test of erodibility in fine-grained soils, it is not a reliable indicator of dispersion. This does not invalidate the test but does indicate the need for reclassification of the test result classes. We suggest a simple system based on the head at which sustained erosion first occurs.

6. ACKNOWLEDGEMENTS

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APPENDIX: RECOMMENDED TEST PROCEDURE AND CLASSIFICATION SYSTEM

Procedure

An undisturbed tube sample of soil (normally 35 mm diameter) is obtained in the field and kept at insitu moisture content until testing is performed.

The tube sample is trimmed to a standard length of 50 mm and a truncated conical depression is countersunk in the centre top of the sample.

A hole is drilled through the entire 50 mm sample centred in this conical depression. By using a 1 mm diameter surgical needle in a light drill press, a hole only slightly larger than 1 mm is normally obtained.

The sample is then set up in the apparatus (refer Figure 4) and water passes through the sample pinhole under increasing increments of head (50 mm, 180 mm, 380 mm, and 1000 mm), each maintained for a 10 minute period.

N.B. The plastic nipple in the apparatus, which is centred in the countersunk depression and leads into the sample pinhole should be at least 1.5 mm in diameter.

The water emerging from the sample pinhole is collected in a graduated cylinder and the water volume at 1, 2, 3, 5, 7, 8, 9, and 10 minutes recorded at each head.

The classification of pinhole erodibility is based on the measured flow rate (Q) averaged over each minute.

Notes

Although the test normally runs over 40 minutes, a rough check can be kept of the flow rates for any obvious acceleration in flow during the test. Where erosion clearly exceeds the criteria below, the test can be halted.

The test equipment should be run <u>without a sample</u> at some stage before or after the test to obtain the maximum possible flow under the various heads. This is essentially a function of the diameter of the hole in the plastic nipple and providing the same nipple is maintained in the equipment, this check need only occur periodically.

The maximum possible flow rate for each head without sample restriction is required to insure that any observed levelling off in increase in flow rate reflects sample characteristics and <u>not</u> the capacity of the equipment. This can be a particular problem in highly erodible material.

Classification

From the record of water volume over time the average flow rate (in ml/sec) is calculated for each minute period.

A graph is prepared with flow rate (Q) on the y axis and time (minutes) on the x axis. Vertical lines marking the 10 minute head changes, and the maximum flow rates possible without restriction by the sample, are shown on this.

The data is plotted and the points connected by straight lines. <u>Ignoring the first minute after each head change</u>, the head at which sustained erosion first occurs and continues over three or more minutes is noted. Sustained erosion is defined as <u>that which produces a significant progressive increase in flow rate greater than 0.1 ml/sec over a three minute period</u>.

The head determined above is subscripted to "E" e.g. E_{50}, E_{180} etc.

Note

If significant erosion first occurs at a low head, but only becomes sustained at the next higher head, then intermediate erosion classes can be adopted e.g. $E_{180-380}$.

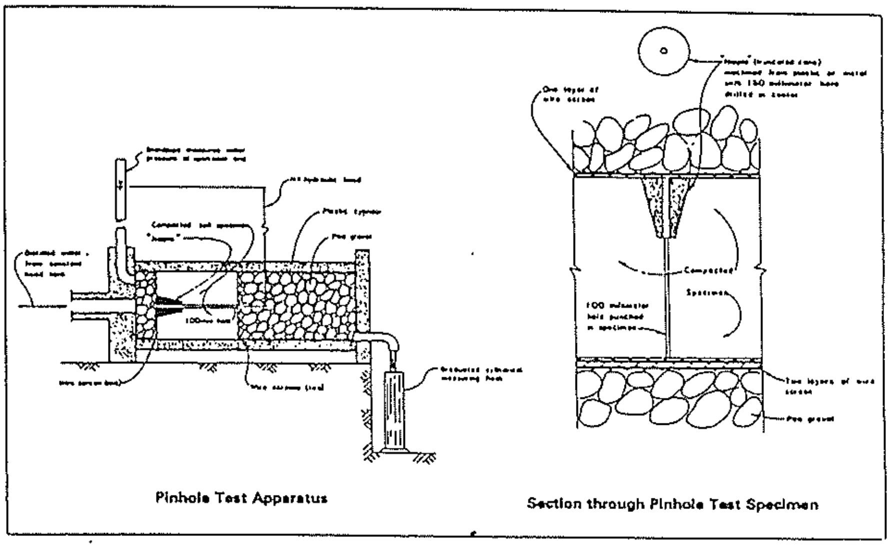

FIGURE 4: Pinhole erosion test apparatus and section through test specimen (from Sherard et al, 1976a)