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Evaluation of Dispersive Soil Characteristics in Cambodia

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Abstract: *Problematic soils, including dispersive and swelling types, create major construction obstacles for projects in Southeast Asia and Africa. In Cambodia, soil conditions have caused two major problems: irrigation system failures and riverbank erosion. This research examines the dispersive properties of soils in Cambodia through laboratory analysis of 17 soil samples, which were gathered from Kandal, Kampong Chhnang, Pursat, and Battambang Provinces. Three ASTM standard methods were applied: the Crumb Test (ASTM D6572), the Double Hydrometer Test (ASTM D4221), and the Pinhole Test (ASTM D4647). The Crumb Test evaluated turbidity and particle cloud formation to visually classify soil dispersibility and was used for preliminary observation. The Double Hydrometer Test used the percentage dispersion ratio (Dp) to measure dispersibility. The Pinhole Test measured flow rate and turbidity at different hydraulic heads. The results show that most of the soils from various provinces in Cambodia were classified as dispersive soils.*

Keywords: Problematic soil, Dispersive soil, Crumb test, Double hydrometer test, Pinhole test, Cambodia

1. INTRODUCTION

In construction projects in certain countries, such as those in Southeast Asia and Africa, specific projects may face difficulties due to problematic soils, particularly expansive soils and dispersive soils. These problematic soils, rarely encountered in Japan, are found worldwide. Implementing effective countermeasures for such soil problems in construction projects is challenging. Furthermore, risks associated with problematic soils include potential changes to planned construction work, increased costs, and delays in the construction schedule.

Cambodia has problematic soils, including dispersive soils and expansive soils, with reported cases such as slope failures in irrigation facilities [1] and Mekong Riverbank collapses [2].

As part of research on problematic soils, this study conducted a foundation laboratory soil test on the properties of dispersive soil from various provinces in Cambodia. This study presents the results and offers some observations to evaluate the effectiveness of standard laboratory testing of three different tests.

2. SAMPLE COLLECTION

Samples were collected from Kandal Province, Kampong Chhnang Province, Pursat Province, and Battambang Province in the Kingdom of Cambodia, with a total of 17 samples. Laboratory tests were conducted to evaluate the dispersibility of these soils. Fig. 1 shows the sample locations and the sample process. As shown in Fig. 1, erosion marks caused by rainwater, etc., were observed, and holes (dragon holes) were frequently formed in the center of the road surface (Fig. 1(c)) and the erosion mark along the irrigation canal systems in Kampong Chhnang province, as shown in Fig. 1(b).

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(a) Kandal Province (b) Kampong Chhnang Province

(c) Battambang Province (d) Pursat Province

Fig. 1. Field survey and sample collection

3. METHODOLOGY

Dispersive soil determination tests were conducted using the Crumb Test Method (ASTM D6572), the Double Hydrometer Test Method (ASTM D4221) and the Pinhole Test Method (ASTM D4647). These tests illustrate how the soils were dispersed in the natural state and in the compacted state in both natural and compacted states. An overview of each test method is provided below.

2.1 Crumb test

The Crumb Test is one method used to investigate the dispersing characteristics of dispersive soils.

The test method is as follows.

(1) Using an undisturbed sample, a specimen was formed and prepared to be approximately a 15 mm cube.

(2) The specimen was placed at the bottom of a white porcelain dish containing 250mL of distilled water and was immersed.

(3) The water temperature was recorded, and the degree of dispersing was visually assessed and recorded after 2 minutes, 1 hour, and 6 hours.

The degree of dispersion was assessed based on the dense cloud of particles spreading from the soil clump and the turbidity. Dispersibility was rated on a four-point scale as shown in Fig. 2: Grade 1 (Nondispersive), Grade 2 (Intermediate), Grade 3 (Dispersive), and Grade 4 (Highly Dispersive) [3].

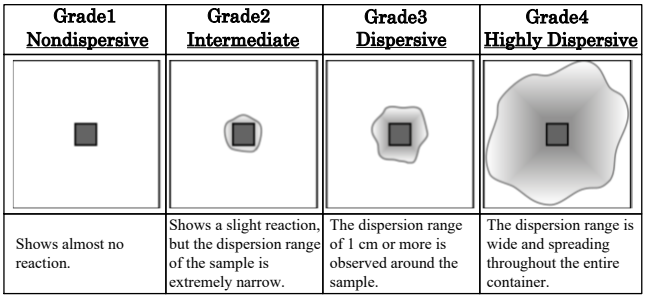


Fig. 2 Classification of soil dispersibility by the crumb test

2.2 Double hydrometer test

The test method overview is as follows. This test determines the dispersibility of a sample by comparing the clay content (particles ≤ 5 μm) in the grain size distribution obtained from a standard sedimentation analysis method with and without a dispersing agent, both performed on the same sample (Fig. 3). The dispersibility of the sample was determined by evaluating the dispersing ratio (Dp: Percentage Dispersion) obtained from the test according to the criteria [4].

$$\text{Percentage Dispersion}\,(D_p) = \frac{A \times 100}{B} \qquad \text{(Eq. 1)}$$

$Dp \leq 30\%$	Nondispersive
$30\% < Dp < 50\%$	Intermediate
$Dp \geq 50\%$	Dispersive

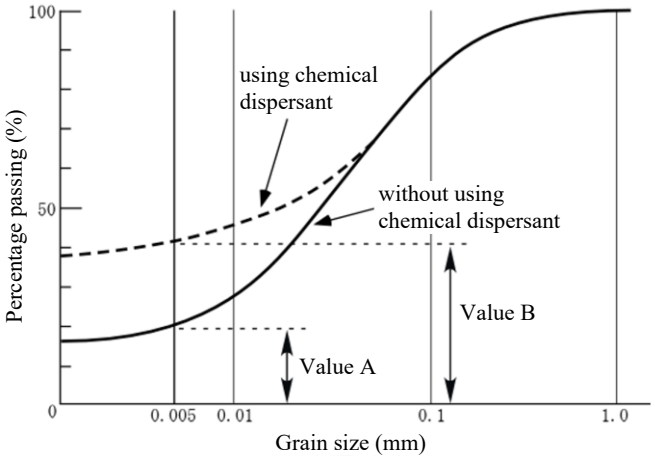


Fig. 3. Schematic diagram of double hydrometer test results

2.3 Pinhole test

The pinhole test measures the dispersibility of fine-grained soil by allowing water to flow through a small orifice with a size of 1 mm, similar to a pin [5].

Fig. 4 shows the condition of the pinhole test apparatus, which was designed based on the ASTM standard and manufactured by the authors.

Fig. 5 indicates the outline of the pinhole test which the water flows through the small orifice of the soil specimen. The specimen is about 50mm in diameter and 38mm in length. The test was conducted continuously by letting distilled water flow through at pressure heads of 50 mm, 180 mm, 380 mm, and 1020 mm for 5 minutes at each pressure head [5]. The dispersibility of soil can be evaluated based on the flow rate and turbidity. From the Table 1, the results were evaluated by classifying into 6 classes, such as D1 and D2 classified as dispersive soil, ND3 and ND4 classified as intermediate dispersive soil, and ND1 and ND2 classified as nondispersive soil. Additionally, the classification of dispersive soil is based on the final hole size after testing in mm, as indicated in Table 2.

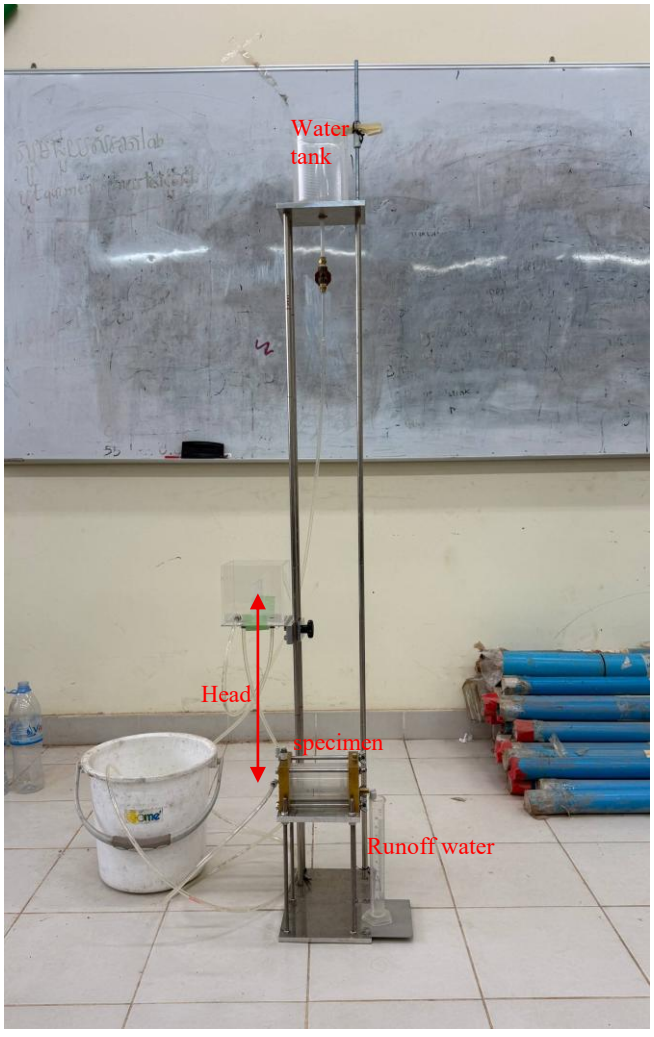


Fig. 4 Pinhole test setup

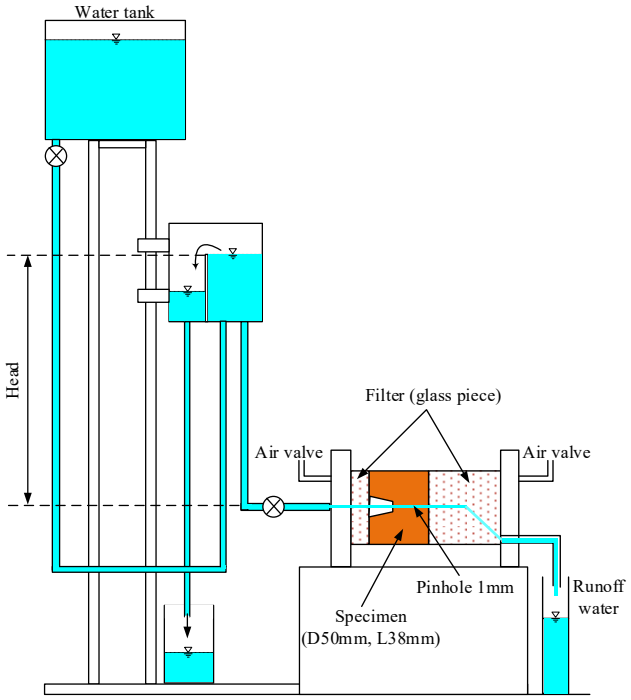


Fig. 5 Outline of the pinhole test

Table 1 Criteria for evaluating pinhole test results based on flow rate in mL/s (ASTM D4647)

Dispersive Classification	Head (mm)	Test time for the given head (min)	Final flow rate through the specimen (mL/s)
D1	50	5	1.0 – 1.4
D2	50	10	1.0 – 1.4
ND4	50	10	0.8 – 1.0
ND3	180	5	1.4 – 2.7
	380	5	1.8 – 3.2
ND2	1020	5	> 3.0
ND1	1020	5	≤ 3.0

Table 2 Criteria for evaluating pinhole test results based on hole size in mm (ASTM D4647)

Dispersive Classification	Head (mm)	Test time for given head (min)	Hole size after test (mm)
D1	50	5	≥ 2.0
D2	50	10	> 1.5
ND4	50	10	≤ 1.5
ND3	180	5	≥ 1.5
	380	5	
ND2	1020	5	< 1.5
ND1	1020	5	1.0

4. RESULTS AND DISCUSSION

Table 3 summarizes the results obtained from the crumb test, the double hydrometer test and the pinhole test of various samples in four locations in Cambodia. Dispersibility was judged as "Dispersive" if either test result indicated "Dispersive." As shown in Table 3, while some test results were classified as nondispersive or intermediate, many samples were classified as dispersive soils. Fig. 6 show the plots Dp against the crumb test grade. Even samples judged as Nondispersive (Grade 1) in the crumb test can be classified as Dispersive with a Dp of 50% or higher. Therefore, the crumb test should be used for preliminary assessment, while final judgment based on Dp and flow rate is preferable. For evaluating dispersibility and internal erosion of soil, the pinhole test is preferable. Fig. 7 shows an example of the crumb test in progress. One hour after immersion, the specimen is already widely dispersed and disintegrated within the water. Fig. 8 shows an example of a double hydrometer test result. Since Dp = 80% is greater than or equal to 50%, the soil was determined to be dispersive.

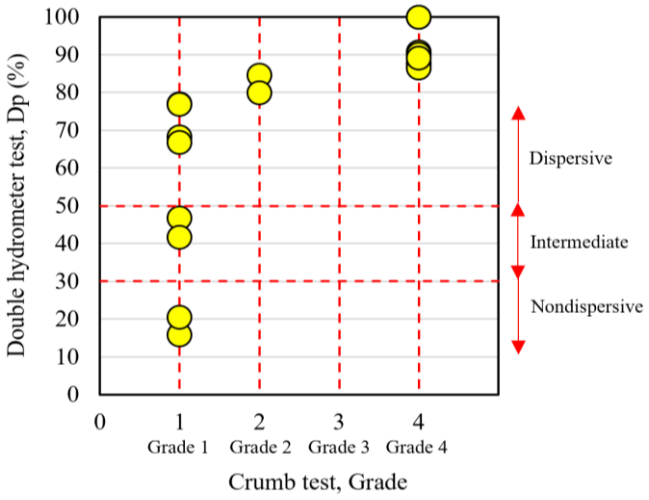


Fig. 6 Comparison of test results of double hydrometer test and crumb test

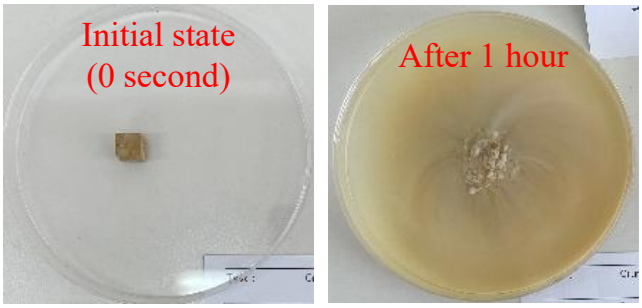


Fig. 7 Example of crumb test (sample No. 2)

Table 3 Results of the double hydrometer test, crumb test, and pinhole test in different locations

No	Double hydrometer Dp (%)	Crumb Test	Pinhole Test	Judgement	Sample Location
1	100	Grade 4	D1	Dispersive	Kandal
2	100	Grade 4	D1	Dispersive	Kandal
3	87.62	Grade 4	-	Dispersive	Kandal
4	90.72	Grade 4	-	Dispersive	Kandal
5	84.62	Grade 2	-	Dispersive	Kandal
6	68.25	Grade 4	-	Dispersive	Kandal
7	76.94	Grade 1	-	Dispersive	Kampong Chhnang
8	46.8	Grade 1	-	Intermediate	Kampong Chhnang
9	76.82	Grade 1	-	Dispersive	Kampong Chhnang
10	15.77	Grade 1	ND3	Nondispersive	Kampong Chhnang
11	20.45	Grade 1	-	Nondispersive	Kampong Chhnang
12	66.84	Grade 1	-	Dispersive	Kampong Chhnang
13	41.65	Grade 1	-	Intermediate	Kampong Chhnang
14	90.13	Grade 4	D1	Dispersive	Battambang
15	86.48	Grade 4	-	Dispersive	Battambang
16	89.12	Grade 4	D1	Dispersive	Pursat
17	80	Grade 2	D1	Dispersive	Pursat

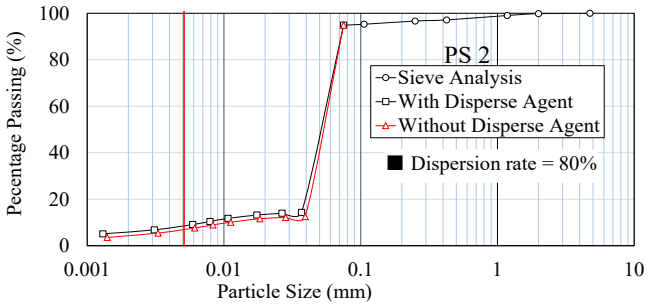


Fig. 8 Example of double hydrometer test (sample No. 17)

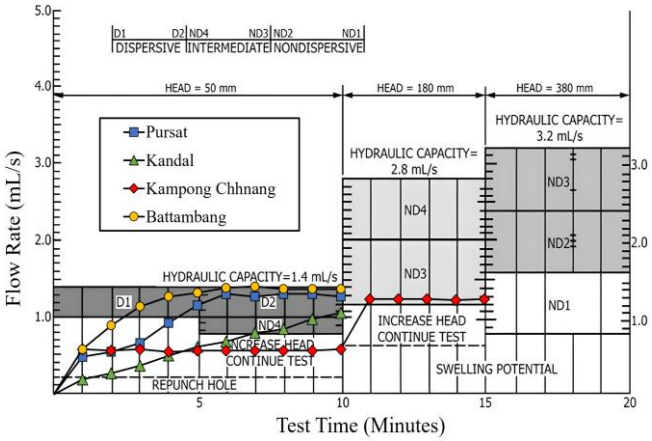
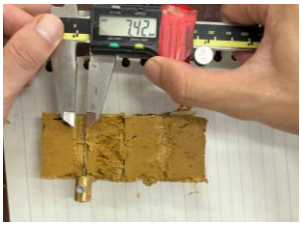


Fig. 9 Results of the pinhole test by comparing the flow rate and test time



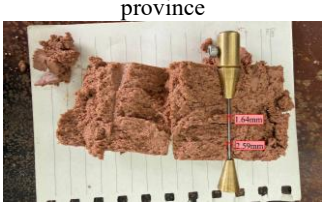
(a) Sample from Kandal province



(b) Sample from Pursat province



(c) Sample from Battambang province



(d) Sample from Kampong Chhnang province

Fig. 10 Final hole of soil specimens after pinhole testing

Fig. 9 shows the results of flow rate versus testing time of four different soils from Kandal, Pursat, Kampong Chhnang and Battambang provinces. The results show that the soil from Pursat and Battambang provinces is classified as dispersive soil class D1, with the flow rate higher than 1.0 mL/s during the first 5 min of the test. The soil in Kandal province is classified as dispersive soil class D2, while the soil from Kampong Chhnang province is defined as intermediate dispersive soil in the class of ND3. The classifications of soil were based on flow rate, as shown in Table 1.

Furthermore, Fig. 10 Indicates the final hole after pinhole testing. The soil in Kandal province shows the final hole size of about 7.42 mm, which is classified as Dispersive soil (D2), which is greater than 1.5 mm, as shown in Fig. 10(a). Fig. 10(b), (c) show the hole size of about 14.28 mm (a) and 21.47 mm (b), which are greater than 2.0 mm, so it can be classified as Dispersive (D1). The soil in Kampong Chhnang shows the hole size ranging from about 1.64 mm to 2.50 mm, which is greater than 1.5 mm to be classified as Intermediate (ND3) based on Table 2.

The observation of cloudy colloidal of the outlet water should be noted as shown in Fig. 13. At the head of 180 mm, the cloudiness of flow at the end of the test is very dark; however, when the head increased to 380 mm, the cloudiness of flow became slightly dark.

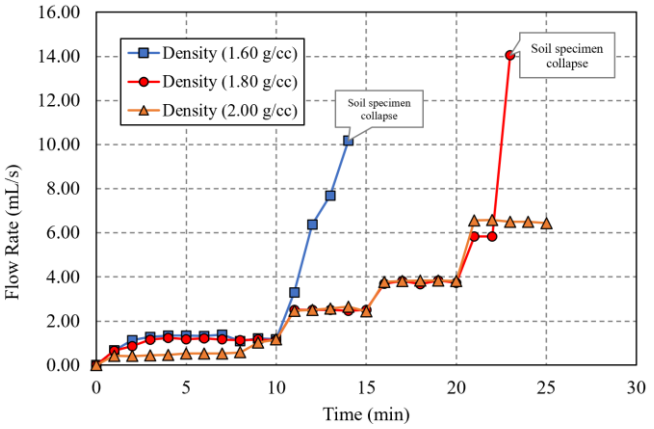


Fig. 11 Results of flow rate (mL/s) vs. test time (mn) of various density of soil

Fig. 11 indicates the results of the flow rate in various densities of soil. The flow rate of soil decreases when the soil density increases. Furthermore, the soil specimens with a density of 1.60 g/cm^3 collapsed at a pressure head of 180mm, and the specimens with a density of 1.80g/cm^3 collapsed when the pressure head was higher than 380mm, as shown in Fig. 12. The specimens with a density of 2.00 g/cm^3 did not collapse during the test. Notably, when the density increases, the flow rate decreases during the first 10 minutes of testing. It is defined that the dispersity of soil is affected by compactivity and density of the soil specimen.



Fig. 12 The failure of the soil specimen during the test occurred when the increasing of pressure head

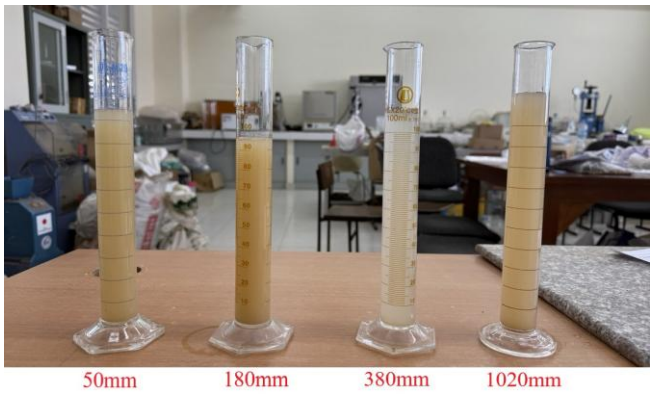


Fig. 13 Comparison of the cloudy colloidal appearance of water flowing through the dispersive specimen at different pressure heads

5. CONCLUSIONS

The findings obtained from this study are as follows:

(1) Although this investigation focused on four provinces in central Cambodia (Kandal Province, Kampong Chhang Province, Pursat Province, and Battambang Province), the presence of dispersive soils in all four indicates that such soils may also be distributed in other provinces, which could lead to the collapse of ground structures or slope failures.

(2) It was confirmed that the crumb test is useful for preliminary identification, while the double hydrometer test and pinhole test are effective methods for identifying dispersive soils.

(3) Further testing on dispersive soils will be conducted in the future, and research on countermeasures and related studies will be further pursued.

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