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INTEGRATED PHYSICO-CHEMICAL CHARACTERIZATION AND LIME STABILIZATION OF DISPERSIVE SOILS IN FLOOD RETENTION POND PROJECTS

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ABSTRACT: Dispersive soils constitute a critical geotechnical and environmental concern in flood retention pond systems due to their propensity for deflocculation, internal erosion, and turbidity generation under low-electrolyte conditions. This study presents an integrated physical, chemical, and mineralogical characterization of soils excavated from flood retention pond projects in Prachin Buri province, Thailand, and evaluates the efficacy of lime stabilization in mitigating dispersive behavior. Physical dispersion tests (crumb, double hydrometer, and pinhole) were complemented by chemical indices including %Na, sodium adsorption ratio (SAR), and concentrations. X-ray diffraction identified montmorillonite as the dominant clay mineral governing high dispersivity, while compaction parameters (MDD-OMC) and fines content elucidated the mechanical susceptibility of these soils to moisture-induced breakdown. Stabilization trials using high-purity hydrated lime (98.35% CaO), confirmed via XRF, demonstrated substantial improvements; lime dosages of 0.5-2.5% reduced the degree of dispersion from 87% to 13% and altered pinhole classifications from D1 to ND1, indicating a transition to non-dispersive behavior. Turbidity measurements reached up to 19.63 NTU in dispersive-soil zones, corroborating sodium-induced colloidal release observed in laboratory testing. Taken together, the findings underscore the necessity of integrating physical, chemical, and mineralogical criteria for reliable identification of dispersive soils and confirm that lime stabilization is a highly effective intervention for reducing dispersivity, controlling turbidity, and enhancing the environmental performance of flood retention pond infrastructure.

Keywords: Dispersive soils, Lime stabilization, Chemical properties, Turbidity, Flood retention ponds

1. INTRODUCTION

Flood retention ponds are essential components of Thailand's water-management strategy, providing flood mitigation, water storage, and sustainable resource utilization [1-2]. Construction of these ponds generates large volumes of excavated soil that may be reused in embankments, road bases, and earth structures. However, a portion of this material may consist of dispersive soils, which are prone to deflocculation, internal erosion, and piping when exposed to low-salinity water [3]. If not properly identified and managed, dispersive soils can compromise structural stability, reduce reservoir performance, and cause persistent turbidity and environmental degradation [4].

Field observations from flood retention pond projects in Prachin Buri Province have revealed clear signs of dispersive behavior, including surface erosion, gully formation, and turbidity in adjacent water bodies. These features are not readily detected using conventional soil classification methods such as Atterberg limits or grain-size distribution [5-6]. Inadequate stockpiling and zoning practices have further led to mixing of dispersive and non-dispersive soils, complicating reuse decisions and exposing limitations in routine soil assessment. Elevated turbidity observed in several ponds suggests ongoing clay deflocculation and highlights the environmental risks associated with dispersive soil exposure.

Dispersive behavior is primarily governed by chemical and mineralogical factors. High exchangeable sodium (Na^+), low ionic strength, and smectite-dominant clay minerals promote diffuse double-layer expansion and weaken interparticle bonding. Indicators such as percent sodium (%Na), Sodium Adsorption Ratio (SAR), and exchangeable cation composition are therefore critical for identifying dispersive soils [7-8], although these parameters are rarely included in geotechnical investigations in Thailand. The presence of montmorillonite, a high-surface-charge clay mineral, further increases dispersion potential in fine-grained soils [9].

Engineering properties also influence dispersivity. High fines content, elevated optimum moisture content (OMC), and low maximum dry density (MDD) are commonly associated with weaker soil fabric and increased susceptibility to moisture-induced breakdown [10]. These interactions emphasize the need for integrated assessment approaches that combine physical, chemical, and mineralogical indicators.

Mitigation of dispersive soils commonly relies on chemical stabilization, with lime treatment being among the most effective methods. Calcium ions (Ca^{2+}) supplied by lime promote cation exchange and flocculation, improving soil structure and reducing dispersion. The effectiveness of this process depends on lime purity, as high-CaO lime provides greater reactivity [11]. XRF analysis can be used to verify lime composition prior to application.

Despite extensive international research on dispersive soils, studies in Thailand have rarely integrated chemical characterization, turbidity assessment, mineralogical analysis, and lime stabilization into a single framework. This study addresses this gap through an integrated physical-chemical-mineralogical evaluation of soils excavated from flood retention pond projects in Prachin Buri Province. The research examines dispersivity, links soil chemistry with observed turbidity, and evaluates lime stabilization using high-purity hydrated lime. The findings support improved soil management, reduced environmental impacts, and sustainable reuse of excavated soils in line with Thailand's Bio-Circular-Green (BCG) Economy Model [2].

2. RESEARCH SIGNIFICANCE

This research provides an integrated physical-chemical framework for identifying and improving dispersive soils excavated from flood retention pond projects, a topic rarely addressed in Thailand despite its engineering and environmental implications. By combining dispersivity tests, detailed chemical indicators, mineralogical analysis, turbidity assessment, and lime stabilization trials, the study establishes a comprehensive approach for evaluating problematic soils and mitigating their risks. The findings contribute to safer soil reuse, improved turbidity control, and more sustainable management of flood retention infrastructure in alignment with Thailand's BCG development strategy.

3. MATERIALS AND METHODS

3.1 Study Area

Following the work of Thiamthong and Nontananandh [13], this study was conducted at five water resource development projects in Prachin Buri Province, Thailand an area with extensive flood retention initiatives under national water management plans. The province was selected for its representative geology, frequent use of flood retention ponds in rural infrastructure, and the variety of excavation and stockpiling practices observed in recent RID projects. These factors make it a suitable location for evaluating the dispersive characteristics of excavated soils. The selected sites include the Talad Mai Flood Retention Project, Sapa Khon Public Pond Dredging Project, Saphan Hin Pumping Station Project, Noen Na-ngam Flood Retention Project, and Wang Takhian Flood Retention Project all under the Prachin Buri Agricultural Research and Development Center. Conducted between 2021 and 2023, these projects differ in excavation volume, stockpiling methods, and field conditions, which are expected to influence the geotechnical behavior of the soils [6]. Table 1 summarizes key project characteristics, including excavation volumes, stockpile height, and compaction status.

Table 1. Excavation volume, stockpile height, and compaction status

Project Name	Excavation Volume (x 10^4 m^3)	Stockpile Height (m)	Compaction
Taladmai	12.50	4.00	Yes
Sappakho	3.15	1.00	No
Saphanhin	2.37	1.00	Partial
Noennangam	10.61	1.00	No
Wangtakhian	50.00	2.00	No

3.2 Soil and Water Sampling and Field Observation

Disturbed soil samples were collected from stockpiles at five study sites following RID's soil sampling guideline [12]. Test pits were excavated at depths of 1.0 and 1.5-2.0 meters using a crawler-mounted backhoe. The sampling depths were selected based on typical excavation depths during pond construction and preliminary field observations of soil dispersivity with depth. Approximately 20 kilograms of soil were collected per sample for laboratory testing and sealed in moisture-retaining containers. Water samples were collected from each reservoir surface using standard grab methods in line with MWA standards, which are modified from WHO guidelines [14-15]. Turbidity was measured in the laboratory using portable meters under ISO 7027.

3.3 Laboratory Testing

The collected soil samples were tested to determine their basic physical properties and dispersive potential. Geotechnical properties were evaluated through grain size analysis using the combined sieve and hydrometer method (ASTM D422-72) [16], liquid limit (ASTM D423-72) [17], plastic limit (ASTM D424-71) [18], and classification based on the Unified Soil Classification System (USCS) per ASTM D2487-17 [19].

To assess dispersivity, three physical tests were conducted: the Crumb Test and Pinhole Test standards, and the Double Hydrometer Test following Royal Irrigation Department (RID) guideline.

Chemical testing was conducted. Soluble cations were analyzed to evaluate soil sodicity. A 1:5 soil-water extract was prepared from samples passing the 2-mm sieve, shaken for 1 hour, and filtered. Concentrations of Na^+, Ca^{2+}, and Mg^{2+} in the extract were measured using ICP-OES and converted to milliequivalents per liter (meq/L). Percent sodium (%Na) was calculated using Eq. (1).

$$Na^+ = \frac{Na^+}{Na^+ + Ca^{2+} + Mg^{2+}} \tag{1}$$

The Sodium Adsorption Ratio (SAR) was obtained from Equation

$$SAR = \frac{Na^+}{\sqrt{0.5(Ca^{2+} + Mg^{2+})}} \tag{2}$$

These indices were used to assess sodium-induced dispersion [3] and to support interpretation of the soil's chemical behavior before and after treatment

Mineralogical composition was examined using X-ray Diffraction (XRD) to identify clay minerals relevant to dispersive behavior, particularly montmorillonite, kaolinite, and illite. XRD results provided supporting evidence for understanding clay surface charge characteristics and double-layer behavior that influence dispersion potential[9].

The chemical composition of the hydrated lime used in the stabilization tests was determined using X-ray Fluorescence (XRF). Lime samples were oven-dried, finely ground, and analyzed using a wavelength-dispersive XRF spectrometer. The procedure followed standard cement and lime chemical analysis protocols, enabling quantification of major oxides such as CaO, MgO, SiO_2, Al_2O_3, Fe_2O_3, and SO_3. The XRF results were used to verify the purity and chemical constituents of the lime prior to its use in soil stabilization.

Compaction characteristics, including Maximum Dry Density and Optimum Moisture Content , were determined using the Standard Proctor Test (ASTM D698)[20].These parameters supported the evaluation of the mechanical behavior of the soils and their relationship to fines content and moisture sensitivity, which are known to influence dispersive tendencies.

Water turbidity was measured using a nephelometric turbidity meter following ISO 7027. Turbidity levels were compared with field observations to assess the degree of colloidal suspension resulting from soil dispersion within the retention ponds. These measurements provided additional insight into the environmental implications of dispersive soils on water clarity.

This integrated laboratory testing program enabled a systematic assessment of physical, chemical, and mineralogical mechanisms governing soil dispersivity and provided the basis for evaluating the effectiveness of lime stabilization in improving soil behavior.

4. RESULTS AND DISCUSSION

4.1 Soil Classification and Field Observations from Excavated Samples

Soil samples from eleven locations across five flood retention projects in Prachin Buri Province were analyzed to assess basic geotechnical properties and field behavior. Table 2 summarizes the results, including grain size distribution, plasticity indices, USCS classification, and field observations such as erosion and water clarity.

Among the eleven samples, four were classified as CL or CH, indicating moderate to high plasticity clays. The remaining samples were SM or ML, corresponding to silty sand and low-plasticity silt. Liquid Limit (LL) values for the clayey soils ranged from 44.05% to 52.46%, and Plasticity Index (PI) values from 21.45% to 24.86%, reflecting moderate to high plasticity.

Field observations showed that erosion, dust, and turbid water were mostly associated with CH and CL soils. For example, Sample 1 (Talad Mai) and Sample 3 (Sapa Khon) exhibited turbid water and surface erosion. In contrast, most SM and ML samples, especially those from greater depths, were linked to clearer water.

Plasticity behavior was interpreted using the LL-PI chart (Fig. 1), which relates soil plasticity to erosion resistance categories [21]. Samples 1 to 4, although classified as CL and CH soils, were located within the highest erosion resistance zone, indicating that high plasticity alone does not necessarily imply erosion susceptibility. This interpretation contrasts with field observations of turbidity and erosion. The discrepancy suggests that Atterberg limits alone are insufficient to predict dispersive or erosive behavior, as they primarily reflect consistency characteristics, and should be combined with physical, chemical, and mineralogical indicators.

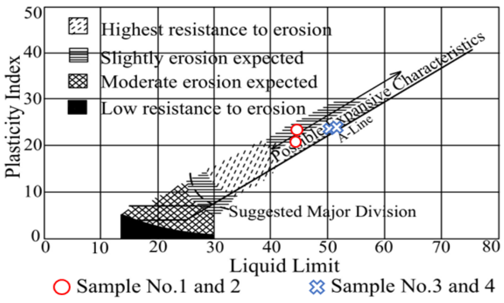

Fig. 1 Correlation between plasticity index and liquid limit for evaluating erosion (Gibbs, 1962)[21]

4.2 Physical Dispersion Test

Three physical tests, namely the Crumb Test, Double Hydrometer Test, and Pinhole Test, were used to assess the dispersive potential of the soil samples. The results are presented in Table 3.

The Crumb Test evaluates soil dispersion based on turbidity observed after immersion in distilled water. According to ASTM D6572, Grade 1 indicates no dispersion, while Grade 4 denotes immediate and strong dispersion. Samples 1, 2, 9, and 10 were rated as Grade 4, indicating high dispersivity. Conversely, Samples 3, 4, 6, 7, 8, and 11 were rated as Grade 1, reflecting non-dispersive behavior.

The Double Hydrometer Test quantifies D4221, dispersion as a percentage. According to ASTM values below 33% are considered non-dispersive, values between 34-67% are intermediate, and values above 68% are classified as highly dispersive. Sample 2 (76%) and 10 (87%) were classified as highly dispersive. Samples 1, 7 and 9 fell within the intermediate dispersive range (34-67%).

The Pinhole Test assesses soil behavior under a hydraulic head. According to ASTM D4647-06, ND1 indicates non-dispersive behavior, while D1 and D2 denote dispersive behavior. Most samples were classified as ND1, which corresponds well with their Crumb Test and hydrometer results. However, Sample 10 exhibited D1 behavior, confirming its highly dispersive nature.

4.3 Chemical Dispersion Test

Chemical tests were used to assess dispersion through Percent Sodium (%Na) and Sodium Adsorption Ratio (SAR). Samples 1, 2, and 9 showed high %Na values (73-86%) and SAR greater than the RID threshold of 2.0, indicating chemically dispersive soils. However, dispersive behavior is not governed by %Na, low electrolyte concentration enhances double-layer swelling, causing soils with moderate %Na to disperse more readily. This explains the strong dispersivity observed in the shallow Wang Takhian sample (1.0 m), where low salinity amplified sodium-induced repulsion. These conditions highlight the importance of calcium-based stabilization in suppressing sodium-driven dispersion. Samples 5-8 exhibited low %Na and SAR (<0.4), consistent with non-dispersive behavior, while Sample 11 showed intermediate values. According to the Sherard classification diagram, Samples 1, 2, 3, 4, 9, and 10 fall within the dispersive zone, whereas Samples 5-8 are non-dispersive. Overall, the chemical indices correspond well with physical test results, confirming that sodicity and ionic strength jointly control soil dispersivity.

4.4 XRD Analysis Test

X-ray diffraction (XRD) analysis was conducted to identify the clay mineral composition and its relationship with soil dispersivity. The dispersive soil from Wang Takhian (1.0 m depth) exhibited distinct montmorillonite reflections, with a basal spacing peak at approximately 2θ ≈ 5.8°, indicating the presence of smectite-dominated clay minerals[9]. This mineralogical characteristic explains the high swelling potential and strong dispersive behavior observed in both physical and chemical tests.

In contrast, non-dispersive and slightly dispersive soils showed weaker or negligible smectite peaks, suggesting a lower proportion of expansive clay minerals. The reduced montmorillonite content in

Table 2 Basic geotechnical properties and field observations of soil sample

No.	Project	Depth (m)	%Passing No.4	%Passing No.200	LL (%)	PI (%)	USCS	Pits	Dust	Surface Erosion	Water Clarity
1	Talad Mai	1.0	100	73.05	44.13	24.86	CL	No	Yes	Yes	Turbid
2		2.0	100	94.11	44.05	21.45	CL				
3	Sapa Khon	1.0	100	90.41	52.46	24.77	CH	No	Yes	No	Clear
4		1.5	100	91.85	50.86	23.44	CH				
5	Sa phanHin	1.0	95.38	25.3	NP	NP	SM	No	Yes	Yes	Clear
6		1.5	94.56	25.04	NP	NP	SM				
7	Noen Na-ngam	1.0	66.27	25.25	NP	NP	SM	Yes	Yes	Yes	Turbid
8		1.5	96.13	41.27	NP	NP	SM				
9	Wang Takhian	1.0	98.29	50.01	NP	NP	ML	Yes	Yes	Yes	Turbid
10		1.0	88.49	23.95	NP	NP	SM				
11		2.0	83.01	35.94	NP	NP	SM				

Note : NP = Non-Plastic. 'Turbid' indicates visibly cloudy water observed during field investigation these samples corresponds to their lower sodium-related indices and improved particle stability. Overall, the XRD results confirm that montmorillonite-rich mineralogy plays a key role in governing soil dispersivity and supports the observed differences in erosion potential and turbidity among the study sites.

4.5 XRF Analysis of Hydrated Lime

Table 5 illustrated the XRF analysis indicating that the hydrated lime contains a high CaO content (98.35%), with only minor amounts of MgO, SiO_2, Fe_2O_3 and SO_3. The dominance of CaO indicates strong reactivity and a high capacity for Ca^{2+} release, which is essential for cation exchange with Na^+ on clay surfaces. This exchange collapses the diffuse double layer and promotes flocculation, explaining the significant reduction in soil dispersivity observed after lime treatment. The minor oxides are present at levels too low to affect stabilization performance.

4.6 Lime Treatment

Lime treatment was adopted in this study to reduce the dispersive behavior of the soil. The hydrated lime used contained more than 60% CaO, providing sufficient calcium ions for cation exchange. Trial mixes were prepared at lime contents of 0.5%,1.0%, and up to 2.5% by dry weight of soil to determine the most effective dosage. The evaluation of dispersivity followed the Double Hydrometer Test [9, 22], which generally identifies dispersive soils when the percent dispersion exceeds 15-20%. Clay particles with high exchangeable sodium tend to exhibit strong repulsive forces and readily break apart when submerged in water, consistent with the mechanisms described by Sherard, J.L., Dunnigan, L.P. and Decker, R.S. (1976) [3]

Reducing dispersivity requires replacing exchangeable Na^+ with Ca^{2+} from the lime, which collapses the diffuse double layer and promotes flocculation of clay particles. This principle aligns with the work of Sherard, J.L., Dunnigan, L.P. and Decker, R.S. (1976) [3], who emphasized that cation exchange is the dominant mechanism controlling dispersive soil behavior. The lime dosages tested in this study were therefore selected to evaluate the progressive improvement in soil stability and identify the optimum amount required to mitigate dispersion effectively.

4.7 Post-Treatment Behavior of Sample No. 10

The results (Table 6) for soil sample No.10 clearly show that lime treatment greatly reduced dispersivity. The Double Hydrometer Test (DHT) value dropped from 87% to 13%, the Crumb Test improved from grade 4 to 1, and the Pinhole Test shifted from D1 to ND1, indicating that internal erosion was eliminated. Chemically, both %Na and SAR decreased after

Table 3. Results of Physical dispersivity

No.	Project	Depth (m)	Crumb Test	Degree of Dispersion (%)	Pinhole Test
1	Talad Mai	1	4	36	ND1
2		2	4	76	ND1
3	Sapa Khon	1	1	0	ND1
4		1.5	1	11	ND1
5	Saphan Hin	1	4	29	ND1
6		1.5	1	28	ND1
7	Noen Na-ngam	1	1	36	-
8		1.5	1	11	ND1
9	Wang Takhian	1	4	35	ND1
10		1	4	87	D1
11		2	1	4	ND1

Table 4. Results of Chemical dispersivity

No	Project	Depth (m)	TDS (meq/L)	% Na	SAR	Zone
1	Talad Mai	1	2.202	86	5	A
2		2	2.326	82	4.2	A
3	Sapa Khon	1	1.206	69	2	A
4		1.5	1.639	79	3.3	A
5	Saphan Hin	1	0.503	20	0.23	B
6		1.5	0.66	20	0.26	B
7	Noen Na-ngam	1	0.744	26	0.37	B
8		1.5	1.203	22	0.38	B
9	Wang Takhian	1	3.427	73	3.7	A
10		1	3.909	61	2.8	A
11		2	0.697	42	0.65	C

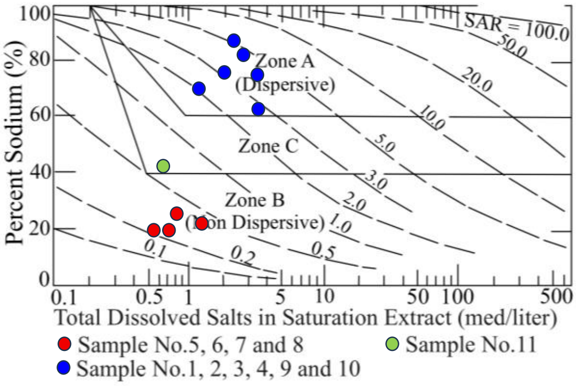

Fig.2 Sherard diagram categorizing samples into dispersive zones based on %Na, SAR, and TDS.[3]

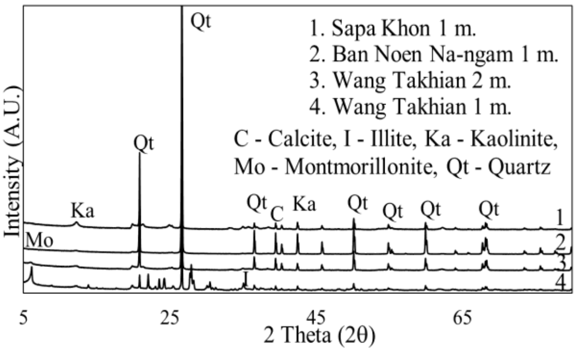

Fig. 3 X-ray diffraction patterns of soils

Table 5. Chemical Compositions of Hydrated Lime

Formula	Concentration
MgO	0.78%
SiO_2	0.58%
SO_3	0.06%
CaO	98.35%
TiO_2	0.01%
Fe_2O_3	0.15%
SrO	0.07%

treatment, confirming effective Ca^{2+}-Na^{+} exchange. Overall, the table demonstrates that lime successfully transformed sample No.10 from a highly dispersive soil into a stable, non-dispersive material.

4.8 Compaction Test

The compaction results show that maximum dry density (MDD) is strongly influenced by the proportion of fines passing the No. 200 sieve (Table 2). Samples with lower fine contents achieved higher MDD due to improved particle interlocking, whereas soils with higher fine fractions exhibited reduced MDD and increased optimum moisture content (OMC), reflecting greater water adsorption and weaker packing efficiency [23]. This effect was most pronounced in dispersive soils, where sodium-dominated clay particles promoted a loose soil structure and limited densification.

For Sample 10 (Fig. 5), lime treatment resulted in a decrease in MDD and an increase in OMC, indicating the formation of a flocculated and more open soil fabric. From an engineering standpoint, this compaction response should not be interpreted as a deterioration of soil performance. Although dry density decreased, the treatment significantly improved soil stability by reducing dispersivity, as confirmed by reductions in DHT, Crumb Grade, and sodium-related indices. These results indicate that, in dispersive soils with high fine content, lime treatment enhances structural stability rather than maximizing dry density [11].

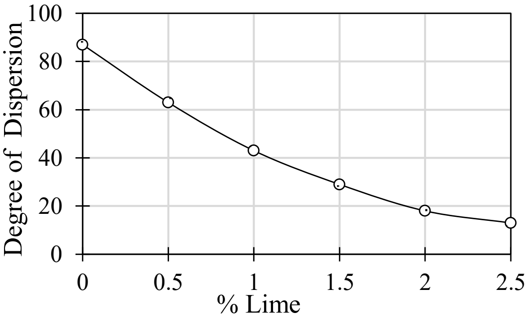

Fig. 4 Effect of Lime Content on Degree of Dispersion (Wang Takhian 1 m.)

Table 6 Summary of Physical and Chemical Test Results Before and After Lime Treatment

Test Category	Test	Before Treatment	After Treatment
Physical Test	DHT (%)	87	13
	Crumb Test	4	1
	Pinhole Test	D1	ND1
Chemical Test	%Na (%)	61	24
	SAR	2.8	0.63

4.9 Water Turbidity Assessment

Field observations were conducted after the construction phase and revealed signs of surface erosion, airborne dust, and runoff-induced washout at multiple locations. Additionally, visual inspection of adjacent reservoir water indicated persistent turbidity at the Talad Mai, Noen Na-ngam, and Wang Takhian sites, whereas water at the Sapa Khon and Saphan Hin sites appeared visibly clear. These observations suggested that the soils at the more turbid locations may exhibit dispersive characteristics.

Turbidity measurements showed (Table 7) that Wang Takhian (19.63 NTU), Talad Mai (9.99 NTU), and Noen Na-ngam (6.55 NTU) exhibited visibly turbid water, consistent with their laboratory identification as dispersive or moderately dispersive soils, where fine particles readily deflocculate and remain suspended. In contrast, Sapa Khon (5.52 NTU) and Saphan Hin (2.95 NTU) displayed clear water, reflecting their lower dispersivity and stable soil structure. This strong correspondence between NTU values, visual clarity, and dispersion indices confirms that sodicity-driven particle repulsion directly influences field water quality. These findings align with the previous study that emphasizes mitigating turbidity at its source through sediment control, improved surface drainage, and the use of constructed wetlands or vegetative filtering systems to capture suspended solids before water enters storage [24]. Such measures are particularly important at highly dispersive sites like Wang Takhian, where elevated turbidity exceeds national water-quality benchmarks and requires targeted management to support long-term reservoir performance.

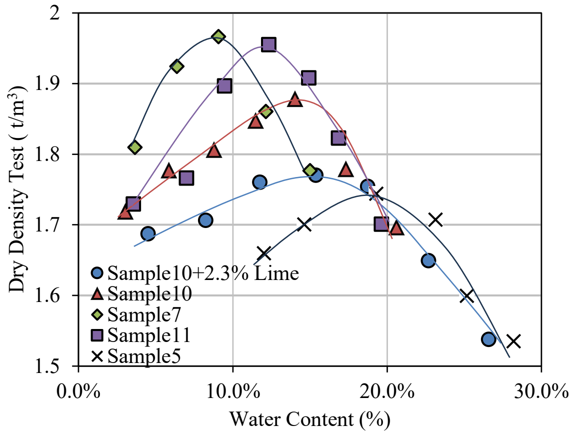

Fig. 5 Compaction Test

Table 7 Turbidity values measured in NTU and visual observations of water clarity at each site

Study Site	Turbidity (NTU)	Visual Observation
Talad Mai	9.99	Turbid
Sapa Khon	5.52	Clear
Saphan Hin	2.95	Clear
Noen Na-ngam	6.55	Turbid
Wang Takhian	19.63	Turbid

4.10 Implications and Recommendations for Excavation and Soil Stockpile Management

This study highlights the need for early excavation planning to avoid dispersive soil layers, as exposure of these horizons can lead to persistent turbidity and environmental risks. Where excavation into dispersive strata is unavoidable, appropriate zoning of excavation and stockpile areas is essential. Site-specific assessment of soil properties and dispersivity should be conducted prior to excavation in accordance with the Ministerial Regulation on Soil Erosion Prevention for Excavation and Landfilling, B.E. 2543 (2000).

A preliminary subsurface investigation at 1-2 locations per site is recommended to identify soil boundaries and guide soil zoning. Representative samples should be collected every 2,000 m³ of excavated soil following RID standards, and potential dispersive soils should be evaluated using combined physical and chemical tests. Soils confirmed as dispersive should be treated using appropriate stabilization methods, such as lime or alum. Where necessary, physical isolation measures (e.g., geomembranes) and surface protection of stockpiles using geotextiles, mulch, or temporary vegetation should be applied to minimize runoff-induced sediment release.

These measures support sustainable excavation practices, reduce environmental impacts, and enhance the long-term resilience of flood-retention infrastructure.

5. CONCLUSIONS

This study demonstrated that soils excavated from flood retention pond projects in Prachin Buri Province exhibit a wide range of dispersive behavior controlled by combined effects of physical properties, chemical composition, mineralogy, and electrolyte conditions. Conventional index properties alone were insufficient to identify dispersive soils, whereas integrated physical dispersion tests, chemical indices (%Na, SAR), and mineralogical analysis provided reliable discrimination. Soils characterized by high %Na (>60%), elevated SAR (>2.0), low ionic strength, and montmorillonite-rich clay mineralogy consistently showed strong dispersivity, surface erosion, and elevated turbidity in adjacent water bodies.

Turbidity measurements provided additional evidence of the environmental implications of dispersive soils observed in the field with NTU values reaching up to 19.63 at highly dispersive sites, while non-dispersive soils maintained clear water conditions. These observations validated the strong linkage between laboratory dispersivity indicators and real-world water-quality impacts. Lime stabilization using high-purity hydrated lime (98.35% CaO) proved highly effective in mitigating dispersive behavior. For the most problematic soil (Sample No. 10), lime treatment reduced the degree of dispersion from 87% to 13%, improved Crumb and Pinhole classifications, and significantly lowered %Na and SAR through Ca^{2+}-Na^{+} exchange. Although lime treatment resulted in a reduction in maximum dry density and an increase in optimum moisture content, this response should not be interpreted as a deterioration of soil performance. From an engineering standpoint, the observed behavior reflects a transition toward a flocculated and more stable soil structure, which is preferable for mitigating dispersive erosion under field conditions.

Taken together, the results indicate that reliance on a single index property is insufficient, and that a combined physical-chemical-mineralogical assessment provides a more reliable basis for identifying and managing dispersive soils in flood retention projects. The study provides practical guidance for excavation planning, soil zoning, stabilization selection, and turbidity control, thereby supporting safer soil reuse, improved environmental performance, and more resilient flood-retention infrastructure in alignment with Thailand's Bio-Circular-Green (BCG). The proposed approach can also be adapted to similar earthwork and water-retention projects in other regions where dispersive soils pose geotechnical challenges.

6. ACKNOWLEDGMENTS

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