คุณสมบัติธรณีเทคนิคของดินเหนียวบางกอกผสมแร่ยิปซัม

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รับเมื่อ 28 มกราคม 2546 ตอบรับเมื่อ 28 สิงหาคม 2546

บทคัดย่อ

งานวิจัยนี้ได้ศึกษาคุณสมบัติธรณีเทคนิคของดินเหนียวผสมแร่ยิปซัม โดยการนำดินเหนียวอ่อนบางกอก จากการก่อสร้างทางโครงการที่ สป. 4100 สาย บ.คลองสวน - บ.คลองกระออม อ.พระสมุทรเจดีย์ จ.สมุทรปราการ ผสมแร่ยิปซัมจากเหมืองแร่ยิปซัม กิ่งอำเภอดงเจริญ จังหวัดพิจิตร ตามอัตราส่วนที่ร้อยละ 0 5 10 15 และ 20 โดยน้ำหนัก ได้ทดสอบคุณสมบัติธรณีเทคนิคของดินเหนียวผสมแร่ยิปซัมทั้งทางด้านกายภาพและทางด้านวิศวกรรม เช่น การกระจายตัวของขนาด ความถ่วงจำเพาะ ขีดจำกัดความข้นเหลว การบดอัดดินแบบมาตรฐาน แคลิฟอร์เนีย แบริ่งเรโช และ ความต้านทานแรงเฉือนแบบไม่ระบายน้ำ

ผลการทดสอบสรุปได้ดังนี้ ค่าความถ่วงจำเพาะของดินเหนียวผสมแร่ยิปซัมตามอัตราส่วนต่างๆ จะมีแนวโน้มลดลงเมื่อเพิ่มยิปซัมในปริมาณที่สูงขึ้น ค่าดัชนีพลาสติกจะมีแนวโน้มลดลงเมื่อเพิ่มปริมาณยิปซัมสูงขึ้น จากการทดสอบการบดอัดดินแบบมาตรฐาน ค่าความหนาแน่นแห้งสูงสุดของดินเหนียวจะลดลงเมื่อผสมแร่ยิปซัมที่ร้อยละ 5 และจะเพิ่มขึ้นเมื่อผสมแร่ยิปซัมในปริมาณที่สูงขึ้น และที่ร้อยละ 20 จะมีค่าความหนาแน่นสูงสุดเท่ากับ 1.42 กรัม ต่อลูกบาศก์เซนติเมตร ในการทดสอบหาค่าแคลิฟอร์เนีย แบริ่ง เรโช ชนิดบ่มในอากาศที่อายุ 7 วัน และ 14 วัน และบ่มในน้ำที่อายุ 7 วัน เมื่อผสมแร่ยิปซัมร้อยละ 5 ค่าแคลิฟอร์เนีย แบริ่ง เรโช จะลดลง เมื่อเทียบกับค่าแคลิฟอร์เนีย แบริ่ง เรโช ที่ร้อยละ 0 ของแร่ยิปซัม นอกจากนี้ค่าแคลิฟอร์เนีย แบริ่ง เรโช จะสูงขึ้นเมื่ออัตราส่วนผสมแร่ยิปซัมที่ร้อยละ 10 15 และ 20 ตามลำดับ สำหรับการทดสอบการบวมตัวพบว่าค่าการบวมตัวมีแนวโน้มลดลงในขณะที่ส่วนผสมปริมาณแร่ยิปซัมสูงขึ้น สุดท้ายค่าความต้านทานแรงเฉือนแบบไม่ระบายน้ำ ที่ได้จากการทดสอบกำลังอัดแบบแรงอัดในแนวแกนเดียวที่อายุตัวอย่าง 1 3 7 14 และ 28 วัน พบว่าค่าความต้านทานแรงเฉือนแบบไม่ระบายน้ำมีแนวโน้มลดลง จนกระทั่งดินผสมมีปริมาณแร่ยิปซัมร้อยละ 10 จากนั้นค่าค่าความต้านทานแรงเฉือนแบบไม่ระบายน้ำจะเพิ่มขึ้นเรื่อยๆ และจนถึงค่าสูงสุดที่ปริมาณแร่ยิปซัมร้อยละ 15 และค่านี้มีแนวโน้มลดลงหลังจากเพิ่มปริมาณแร่ยิปซัมมากกว่าร้อยละ 15 แนวโน้มจะเป็นลักษณะเดียวกันทุกตัวอย่างที่มีอายุการบ่มต่างๆ และที่อายุการบ่ม 28 วัน ค่าความต้านทานแรงเฉือนแบบไม่ระบายน้ำมีค่าสูงสุดเท่ากับ 1.578 กิโลกรัมต่อตารางเซนติเมตร เมื่อใช้ปริมาณแร่ยิปซัมผสมมากกว่าร้อยละ 15 นอกจากนี้ได้สรุปผลการทดลองและให้ข้อเสนอแนะไว้ด้วย

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Geotechnical Properties of Bangkok Clay Mixed Gypsum

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Abstract

This paper described the results of a study which was primarily directed to the determination of geotechnical properties of Bangkok Clay - Gypsum admixtures at 0%, 5%, 10%, 15% and 20% by weight of air-dry clay. Sample of Bangkok Clay was taken from a rural-highway construction project SP.4100 located at Ban Klongsuan-Ban Klongkaom, Prasamuthjadee district, Samuthprakarn province where as Gypsum from Gypsum mine at Doungchalearn district, Pijit province. The physical and engineering properties of studied admixtures such as Grain size distribution, Specific gravity, Atterberg limits, Standard compaction, California Bearing Ratio (CBR) and Undrained shear strength are tested.

The testing results can be concluded as follows. As the variety of admixture proportions, the specific gravity decreased when the quantities of Gypsum in admixture increased. The plastic index decreased when the percentages of Gypsum increased. According to standard compaction test, the results showed that the maximum dry unit weight decreases until the quantity of Gypsum reach at 5% and then continue to increase to the maximum dry unit weight of 1.42 g/cm^3 at 20% Gypsum content. The California Bearing Ratio test which samples soaked at curing time 7 days and unsoaked at curing times 7 and 14 days were carried out. The results indicated that the CBR value of admixture at 5% Gypsum has lower value compared to CBR value of pure clay and the CBR value increase continuously where as the percentage of Gypsum increases. The swelling index from swelling test decreased while the ratio of gypsum increased. Finally, the undrained shear strength from unconfined compression test of samples at curing time 1, 3, 7, 14 and 28 days were carried out. The test results revealed that the undrained shear strength continuously decrease until the amount of Gypsum reach at 10% and then the undrained shear strength increase regularly as the amount of gypsum increase to 15% and showed tendency to decrease when Gypsum content over 15%. All of various curing time samples showed the similar curves and sample at curing time 28 days gave the maximum value of undrained shear strength of 1.578 kg/cm^2 at 15% gypsum content. Conclusion and recommendation also were presented.

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1. Introduction

There are many construction works in Thailand especially highway construction on the soft Bangkok Clay results in a lot of losses later. Due to low shear strength, the damage of construction buildings or facilities may take place or the rate of damage is high. To improve soil properties, more details for understanding the properties of Bangkok Clay treated with Gypsum are carried out. As Gypsum content varied, the property variation of Bangkok Clay - Gypsum admixtures are presented. The result of studies can be used for suitable design in engineering works making more confidence and safer solution and reduce more damages of construction facilities. Data from testing can be used for pre-feasibility study of not only for suitability of Bangkok Clay - Gypsum admixture but also for utilization of Gypsum which is one of Thai mineral resources. Several laboratory tests had been conducted to determine Grain size distribution, Specific gravity, Consistency limits, Standard compaction, California bearing ratio and Undrained shear strength. The test samples of Bangkok Clay - Gypsum are prepared in various Gypsum content at 0%, 5%, 10%, 15% and 20% by weight of the air-dry soil. The details of the tests conducted and the results obtained are discussed herein.

In some papers of Azam, S., *et al.* [1]-[3] many discussion and influence of gypsification of anhydrous calcium sulfate on engineering behavior of clay - gypsum and clay - anhydrite admixtures in the Arabian Gulf coast region were presented. The engineering properties such as water content, dry unit weight, specific gravity, consistency limits and swelling pressure were compared.

Gypsum [4],[5] is one of the more common minerals in sedimentary environments. It is a major rock forming mineral that produces massive beds, usually from precipitation out of highly saline waters. Since it forms easily from saline water, gypsum can have many inclusions of other minerals and even trapped bubbles of air and water. Gypsum [6] has several variety names that are widely used in the mineral trade.

- “Selenite” is the colorless and transparent variety that shows a pearl like luster and has been described as having a moon like glow. The word selenite comes from the Greek for Moon and it means moon rock.

- Another variety is a compact fiberous aggregate called “satin spar”. This variety has a very satin like that gives a play of light up and down the fiberous crystals.

- A fine grained massive material is called “alabaster” and is an ornamental stone used in fine carvings for centuries, even eons.

Chemical formula of Gypsum is $CaSO_4.2H_2O$, Hydrated Calcium Sulfate. Examples of Industrial uses of Gypsum are plaster, wallboard, ingredient in cements, fertilizer, paint filler, ornamental stone, etc.

Colors of Gypsum are usually white, colorless or gray, but it can also be in shades of red, brown and yellow. Luster is vitreous to pearly especially on cleavage surfaces. Crystals are transparent to translucent. Crystal System is monoclinic. Cleavage is good in one direction and distinct in two others. Fracture is uneven but rarely seen. Hardness is 2 of Mohs scale and can be scratched by a fingernail. Specific Gravity is approximately 2.3. Streak is white. For other characteristic, it has a very low thermal conductivity. Gypsum is used in addition to correction and prevention of sodicity, stability of soil organic matter, improved water penetration into soil, and more rapid seed emergence.

2. Laboratory Tests

2.1 Material Used

1. Bangkok Clay: Samples of Bangkok Clay were taken from construction site of Sp. 4100 Ban Krongkraoorm - Ban Krongsuan Prasamutjedee district, Samutprakran province at 2-10 meters depth.

2. Gypsum: Representative samples of Gypsum were taken from Gypsum mine at Doungchalearn district, Pijit province. Random sampling method as bulk weighing 6-8 kilogram were performed at the mine site. Primary size reduction was done by jaw crusher shown in Fig. 1. Secondary size reduction was done by roll crusher. Five different percentages 0%, 5%, 10%, 15%, and 20% of Gypsum were selected for mixing with Bangkok clay. The percentage was calculated in terms of weight of the air-dry soil.

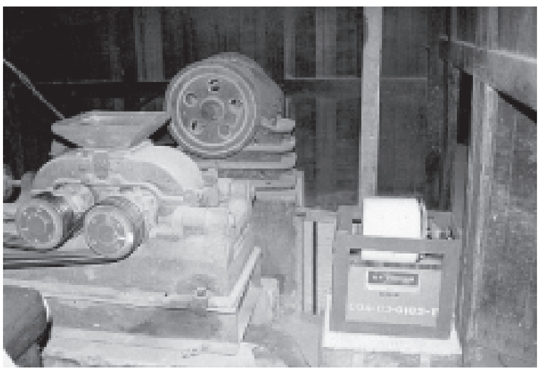

Fig. 1 Jaw crusher and roll crusher

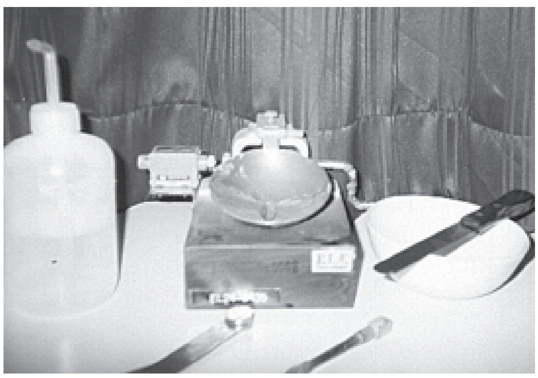

Fig. 2 Liquid limit equipment

2.2 Laboratory Tests

The geotechnical properties of the Bangkok Clay treated with Gypsum were determined by conducting the following laboratory tests:

1. Grain Size Distribution : Sieving analysis and the hydrometer analysis were performed. The test procedure provided in ASTM [7] test designation D422-63 was followed. Hydrometer analysis was performed on the fraction passing U.S. Sieve No. 40 (0.425 mm opening).

2. Atterberg Limits : The liquid, plastic, and shrinkage limits of samples were determined in accordance with ASTM test designation D4318. Fig. 2 demonstrated equipment for liquid limit test.

3. Specific Gravity : The test was conducted following the procedure given in ASTM test designation D854-92. Figure 3 shows some tools for specific gravity test.

Fig. 3 Tools for specific gravity test

Fig. 4 Curing samples for CBR test

4. Standard Compaction : These tests were conducted on the samples passing U.S. Sieve No. 4 (4.75 mm) for determination of the moisture density relationship (ASTM D698). The tests were also performed on Bangkok Clay samples treated with varying amounts of Gypsum.

5. CBR Test : California Bearing Ratio test was conducted using the procedure given in ASTM test designation D1883-94. The samples shown in Fig. 4 were soaked for 4 days before performing the test. A penetration rate of 1.25 mm per minute was used. Fig. 5 displayed the penetration testing machine.

6. Unconfined Compression Test : The specimens were prepared at optimum moisture content as determined from standard compaction tests. The size of specimen was 35.3 mm in diameter and 71.5 mm in height. Samples were cured for 7 and 14 days at room temperature in humid condition. Fig. 6 showed the unconfined compression testing machine.

3. Laboratory Test Results and Discussion

3.1 Grain Size Distribution

The grain size distribution of various Bangkok Clay-Gypsum admixtures showed some variations. The grain size distribution curve for higher gypsum content shifted to the coarser side. The range of grain size distribution as observed was shown in Fig. 7. The fine fraction passing U.S. Sieve No. 200 was generally over 85%. The uniformity coefficient (C_u) was 2 for Bangkok Clay and the values ranged from 7 to 10.5 for admixtures. Moreover, the coefficient of curvature (C_c) was 0.5 for Bangkok Clay and the values ranged between 0.4 and 0.6 for admixtures.

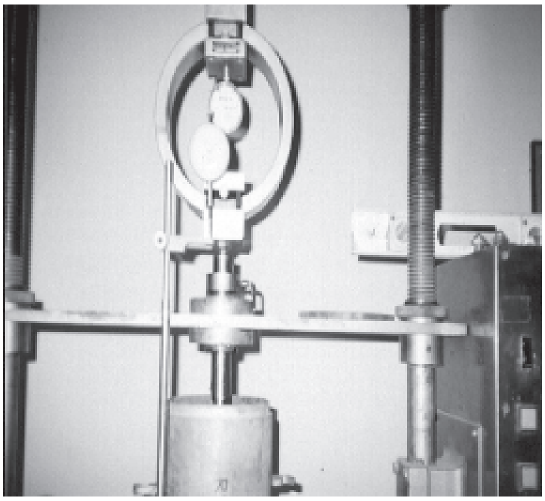

Fig. 5 CBR penetration test

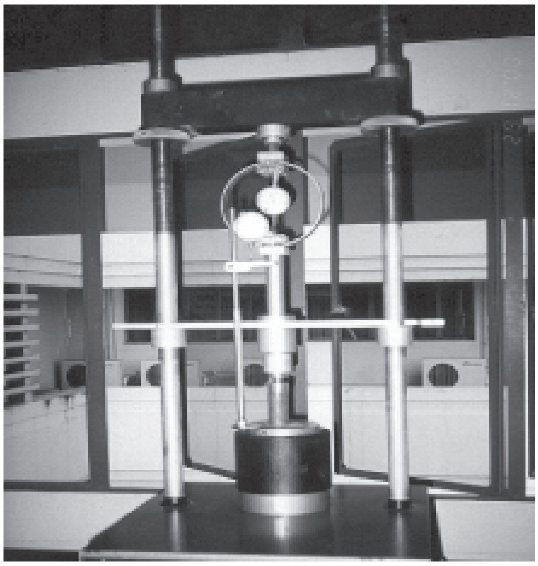

Fig. 6 Unconfined compression test

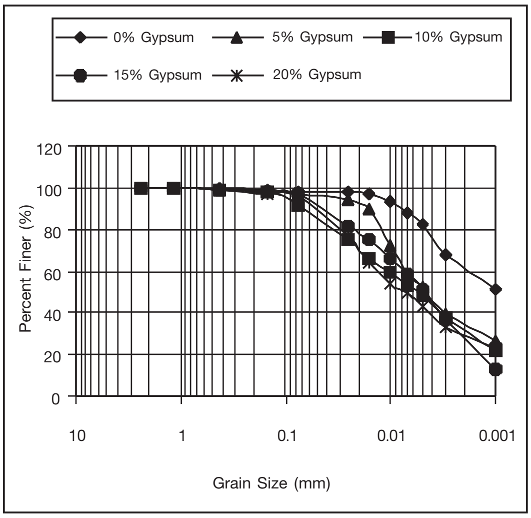

Fig. 7 Grain size distribution

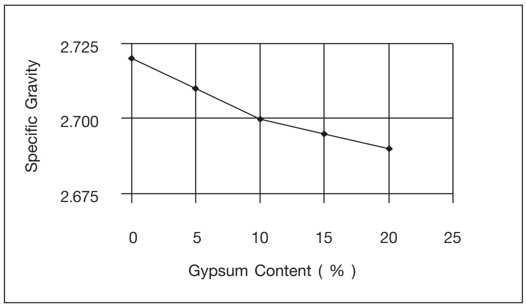

Fig. 8 Relationship between specific gravity of admixtures and Gypsum content

3.2 Specific Gravity

The average specific gravity of admixtures decreased from 2.72 to 2.69 when percentage of Gypsum increased from 0% to 20% as shown in Fig. 8

3.3 Atterberg Limits

The results of Atterberg limits tests were summarized in Table 1. Based on the results of grain size distribution and Atterberg limits, all of samples were classified as OH according to Unified Soil Classification System (USCS). The range of the observed values of Atterberg limits were as follows:

Liquid Limit (LL)	= 68 - 79%	Plastic Limit (PL)	= 37 - 40%
Plasticity Index (PI)	= 28 - 42%	Shrinkage Limit (SL)	= 12 - 20%

Liquid limit and plastic limit values of admixtures substantially decreased with the increasing amount of Gypsum from 0% to 10% and then lightly decreased with the increasing Gypsum content from 10% to 20%. The calcium exchange with cations in clays affected more flocculation in clays when in first 10% Gypsum content and lightly affected when Gypsum content is higher than 10%. However, the increasing of gypsum content from 0% to 20% did not affect the over all soil classification and the soil type was still the same OH group.

Table 1 Atterberg limits and group name

Gypsum Content (%)	Atterberg Limits				USCS Soil Group
	LL (%)	PL (%)	PI (%)	SL (%)	
0	79.54	37.41	42.13	12.53	OH
5	72.05	39.46	32.57	20.77	OH
10	69.51	38.93	30.68	15.45	OH
15	68.39	38.87	29.52	16.23	OH
20	68.93	40.42	28.51	15.98	OH

3.4 Compaction Tests

Fig. 9 showed the typical plots of dry densities obtained at various moisture contents used in the compaction process. The relationship between optimum moisture contents and percentage of Gypsum contents was shown in Fig. 10 The maximum dry density, for example, observed in this test of 0% gypsum sample was 1.39 g/cm^3 and the optimum moisture content was 31.50%. Furthermore, Fig. 11 gave maximum dry densities ranging from 1.36 g/cm^3 to 1.39 g/cm^3 while optimum moisture contents varied from 30.5% to 34.0%.

A comparison of the data of compaction tests on samples of admixtures indicated that with the addition of amounts of 5% Gypsum, the maximum dry density decreases somewhat. However, when the Gypsum content was increased to 20%, the maximum dry density curve contributed higher values. The optimum moisture content did not show any appreciable change during content of Gypsum increased. The results of this study thus indicated that Gypsum content of more than 20% imparted good compaction characteristics.

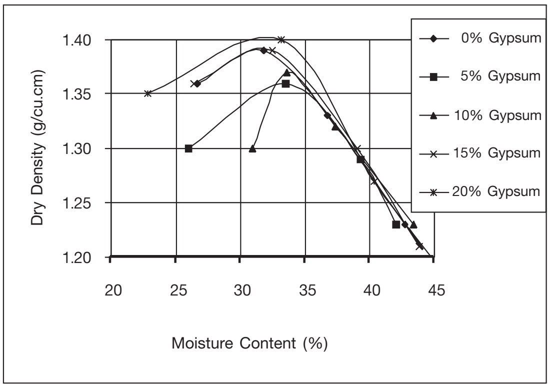

Fig. 9 Typical dry density-moisture content curves from standard compaction tests

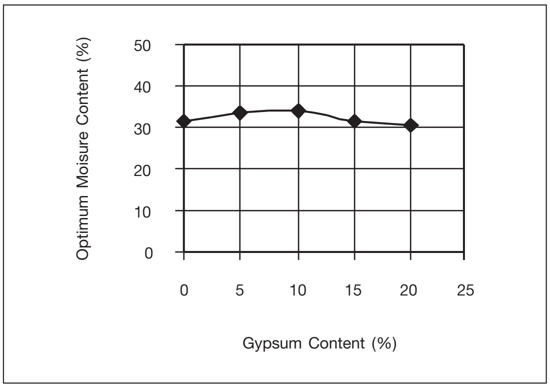

Fig. 10 Optimum moisture contents vs. Gypsum contents

3.5 CBR Tests

The results of CBR tests for various treated and untreated samples of admixtures at curing time 7 and 14 days under unsoaked conditions and 7 days under soaked conditions (3 days for moist curing and 4 days for soaking) were shown in Table 2. These values were based on 2.54 mm penetration. Fig. 12 and 13 showed the relationship between CBR values and percentage of Gypsum contents in various curing times. In Fig. 12, CBR value under unsoaked condition at curing 7 days was 5.57% at 0% Gypsum content and it decreased to be 4.75% at 5% Gypsum content and then it increased to be 5.7%, 6.22% and 7.12% at 10%, 15%, and 20% Gypsum contents, respectively. In case of 14 curing days, the trend of CBR value was similar to the case of 7 curing days which gave lower value. For soaked condition, the CBR value was 1.72% at 0% Gypsum content and it decreased to be 1.295% at 5% Gypsum content and then it continuously increased from 2.5% to 2.85% while Gypsum content increased from 10% to 20% as shown in Fig. 13 Comparison of CBR values for the different tests indicated that the significant improvement in CBR values can be achieved by treating samples of Bangkok Clay with considerable amount of Gypsum.

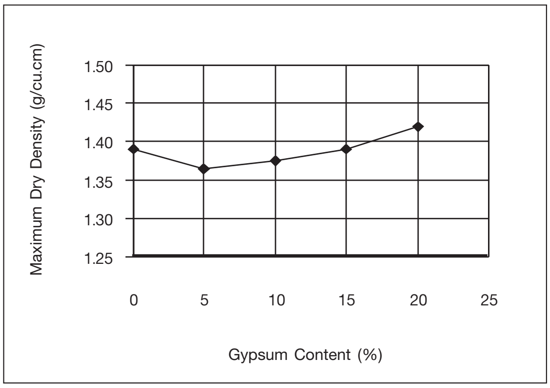

Fig. 11 Maximum dry densities vs. Gypsum content

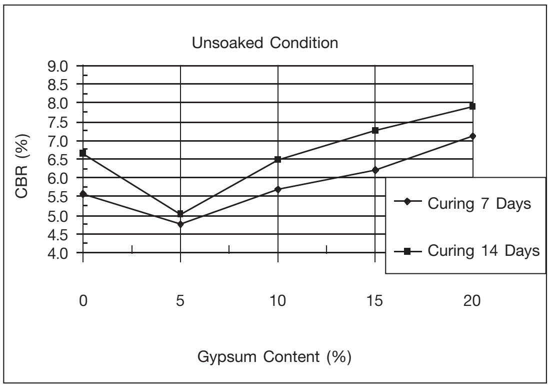

Fig. 12 CBR values vs. Gypsum contents after curing for 7 and 14 days

3.6 Swelling Tests

Fig. 14 showed the swelling values and percentage of Gypsum contents of admixtures at 12, 25, and 56 blows per layer. It was shown that pure Bangkok Clay give the high swelling value and swelling values decreased when Gypsum contents increased from 0% to 10% and swelling values were constant when Gypsum contents were more than 15%. The reason was as cations in clays were replaced by calcium from Gypsum. The behavior affected more flocculation in clays when in first 10% Gypsum content and did not affect when Gypsum content is higher than 10%. It can be concluded that swelling values can be reduced by treating Bangkok Clay with Gypsum contents over 10%.

Table 2 Results of California Bearing Ratio test

Gypsum Content (%)	% CBR at 100 Standard Compaction		
	Curing 7 days		Curing 14 days
	% Unsoaked CBR	% Soaked CBR	% Unsoaked CBR
0	5.57	1.72	6.65
5	4.75	1.925	5.61
10	5.70	2.50	6.48
15	6.22	2.81	7.26
20	7.12	2.82	7.89

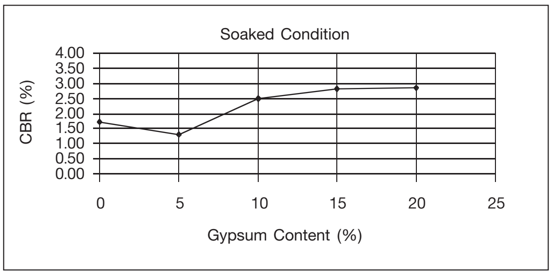

Fig. 13 CBR values vs. Gypsum contents after soaking for 7 days

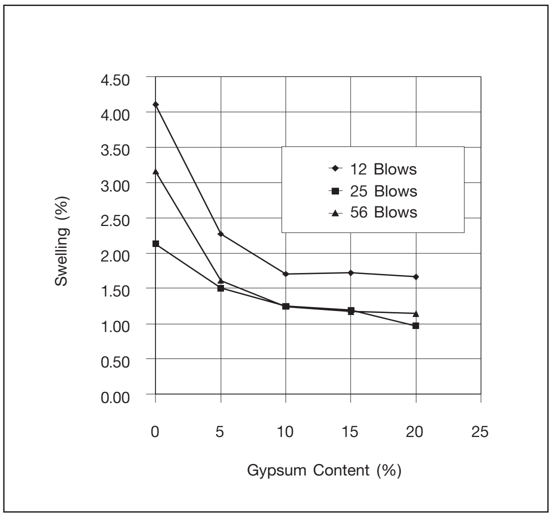

Fig. 14 Swelling vs. Gypsum contents

3.7 Shear Strength Tests

The undrained shear strengths of admixtures from unconfined compression test in various curing times were shown in Table 3. Typical plots of stress versus axial strain for untreated and Gypsum-treated samples of Bangkok Clay were shown in Fig. 15 The magnitude of average stress at failure for admixtures treated with 0%, 5%, 10%, 15%, and 20% Gypsum contents of 1 day curing time were 2.58, 2.09, 1.56, 2.39, and 2.5 kg/cm^2 respectively. Fig. 16 displayed relationship between undrained shear strengths and Gypsum contents at 0%, 5%, 10%, 15%, and 20% of the samples in term of 1, 3, 7, 14, and 28 curing days. The undrained shear strength of pure Bangkok Clay was higher than the undrained shear strengths of admixtures treated with 5% to 10% Gypsum contents for all curing times. The undrained shear strength showed tendency to increase and gave maximum value of 1.578 kg/cm^2 at 15% Gypsum content for the 28 days curing sample. However, when the Gypsum contents exceed 15%, the undrained shear strength showed a tendency to decrease.

Table 3 Results of undrained shear strength

Curing Time (Days)	Undrained Shear Strength (kg/cm^2) Gypsum Content				
	0%	**5%**	**10%**	**15%**	**20%**
1	1.290	1.046	0.776	1.197	1.250
3	1.100	0.689	0.690	0.944	1.122
7	1.034	0.641	0.680	1.148	1.063
14	1.211	0.658	0.800	1.318	1.236
28	1.283	0.850	0.784	1.578	1.297

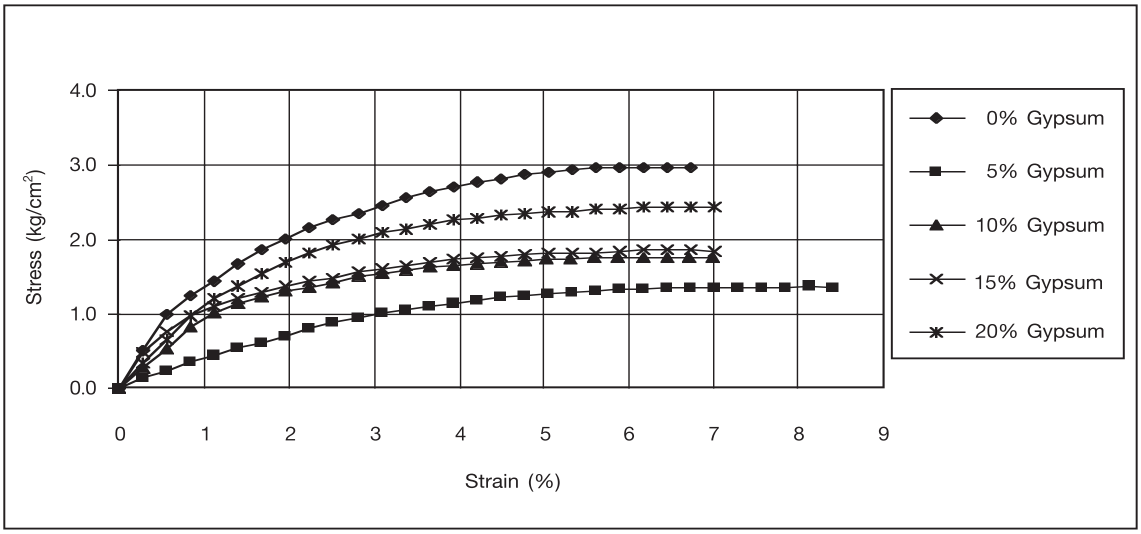

Fig. 15 Typical stress and strain curves

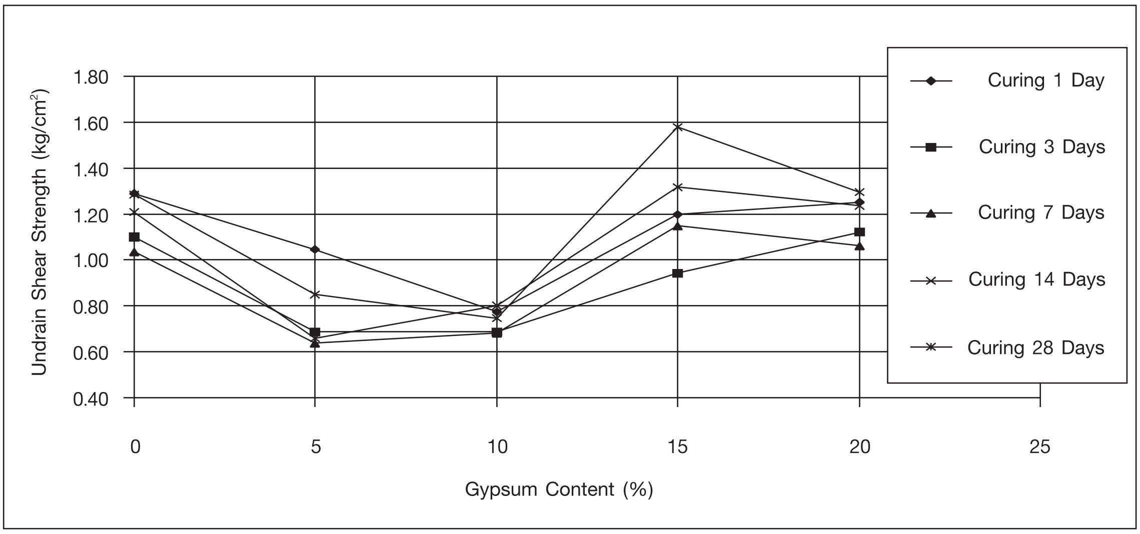

Fig. 16 Relationship between undrained shear strengths and Gypsum contents at various curing days.

4. Conclusions

Based on the results of different tests conducted on untreated and treated samples of Bangkok Clay with Gypsum, the following conclusions may be drawn:

1. The Bangkok Clay alone treated with suitable proportions of Gypsum may be compacted to achieve maximum dry densities ranging from 1.39 to 1.42 g/cm^3 at Gypsum content between 15 - 20%.

2. There was no significant change of optimum moisture contents at Gypsum content increased.

3. It can be concluded that undrained shear strength cannot be improved by treating Bangkok Clay with Gypsum. Significant benefit of reduction of swelling value is prominent.

4. CBR values indicated that the significant improvement in CBR values can be achieved by treating Bangkok Clay with Gypsum.

5. In situation where improvement in strength is primary objective, treatment of Bangkok Clay with 10 to 15% Gypsum may be useful. It is therefore necessary that adequate investigations such as triaxial test, consolidation test, and permeability test are carried out before the Bangkok Clay - Gypsum admixtures can be adopted for use in engineering construction such as highway embankments or subbase courses.

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