Al-Azhar University Civil Engineering Research Magazine (CERM)
Vol. (44) No. (2) April . 2022

Assessment of Bentonite Pile Mixture for Secant Piles Wall Technical Note

Hammam, Adel Hashem[1], and Abdelfadil, Mostafa[2]

[1].Prof., Soil Mechanics Institute, HBRC, Egypt. E-mail: adelhamam@yahoo.com
[2].Ass. Prof., Soil Mechanics Institute, HBRC, Egypt. E-mail: mostafa.abdelfadil@yahoo.com

الملخص العربى:

تتكون الخوازيق المتقاطعة المستخدمة فى سند جوانب الحفر من خوازيق البنتونيت التى تنفذ أولا ، والخوازيق الخرسانية التى تنفذ بعدها لتتقاطع معها مكونة الستارة الخازوقية الساندة. وقد ورد فى الكود المصرى لميكانيكا التربة خلطة استرشادية لخوازيق البنتونيت. وقد وجد من الناحية العملية أن هذه الخلطة تعطى إجهادات كسر عالية نسبيا مما يؤدى أحيانا إلى صعوبة تنفيذ الخوازيق الخرسانية لتتقاطع مع خوازيق البنتونيت وبخاصة فى حالة التنفيذ اليدوى كما فى خوازيق ستراوس الشائع استخدامها في مصر. وفى هذا البحث تم عمل خلطتين أخريين بجانب الخلطة المذكورة فى الكود. وقد أظهرت النتائج زيادة كل من جهد الكسر والكثافة الجافة للعينات مع زيادة نسبة الأسمنت إلى البنتونيت ، وعلى العكس تلاحظ نقص كل من معامل النفاذية ومحتوى الماء إلى الأسمنت بزيادة نسبة الأسمنت إلى البنتونيت. وقد أعطت خلطة الكود إجهاد كسر 8400 كن/م^2 بعد 15 يوما، ومعامل نفاذية 10x1.0^{-8} سم/ثانية بعد 7 أيام. وهذه القيم أعلى من متطلبات الكود. بينما أعطت الخلطتان الأخريان إجهاد كسر 3500 ، 1700 كن/م^2 ، ومعامل نفاذية 10x2.40^{-8} ، 10x3.20^{-8} سم/ثانية على الترتيب. وبذلك تحقق هاتان الخلطتان متطلبات الكود ، كما أنهما أقل تكلفة من الخلطة المذكورة فى الكود.

Abstract:

Secant Pile Walls are formed by constructing mortar piles, which called bentonite piles, and then reinforced pilings are implemented to intersect with them. There is a guiding mixture for bentonite piles mentioned in the Egyptian Code for Foundations and Soil Mechanics. However, in practice, it was found that this mixture gives higher compressive strengths, which leads to the difficulty of implementing reinforced piles that are intersected with bentonite piles, especially if it is manually executed as in the case of Strawas Piles which are commonly used in Egypt. So, this research aims to propose another suitable mixture for the requirements of the code and to be easy of implementation. Two proposed mixtures besides to the guiding mixture mentioned in the Egyptian code were experimented. The results showed that, the compressive strength and dry density were increased with increasing cement/bentonite ratio. On the other hand, the coefficient of permeability and water/cement ratio were decreased with

increasing cement/bentonite ratio. The mixture mentioned in Egyptian code gave a compressive strength of 8400 kN/m^2 after 15 days and permeability coefficient of $1.0x10^{-8}$ cm/sec, which are higher than the requirements of the code. The two proposed mixtures gave compressive strength of 3500, 1700 kN/m^2 and permeability coefficient of $2.4x10^{-8}$, $3.2x10^{-8}$ cm/sec respectively. These mixtures are considered to be less expensive, practical and achieve the strength requirements of the code.

1- Introduction

Secant piling is one of the systems used for the side excavation support. It is usually used in case of weak clay soil or in case of the ground water level is higher than the excavation level (Noel, 2013). Secant piles shoring is executed by intersecting two combinations of piles (Universal Piling Company, 2019). The first is reinforced concrete piles, it is also known as secondary piles. The second is non-reinforced piles which called primary piles. In practice, the primary piles are cast first and consist of a soft pile mix, typically cement and bentonite or cement, bentonite and sand with a characteristic compressive strength of 1.0-3.0 N/mm^2, then reinforced piles are implemented cutting through the edges of the bentonite piles to intersect with them, thus providing a closed structure to act as a barrier in water bearing soils, and to prevent the ingress of soil between the piles (G&B, 2011). Bentonite piles mixture must achieve an adequate compressive strength after a period usually ranging from five to fifteen days in order to have the opportunity to implement the reinforced piles intersecting with it relatively easily. There is a guiding mixture for bentonite piles mentioned in the Egyptian Code for Foundations and Soil Mechanics. It is composed from (200 to 300) kg of cement, (900 to 1100) kg of sand and (50 to 100) kg of bentonite and water/cement ratio ranges between (1.2 to1.3). It is assumed that this mixture will give compressive stresses ranging from 1500 to 3500 kN/m^2 after fifteen days and permeability coefficient ranging between $1x10^{-5}$ to $1x10^{-6}$ cm/sec. In practice, however, it was found that this mixture gives more fracture stresses, which leads to the difficulty of implementing reinforced piles intersected with them, especially, if it is done manually as in case of Strawas piles which are considered very common in Egypt. So, this research aims to discuss the guiding mixture mentioned in the Egyptian code of foundations and soil mechanics for the bentonite piles and to propose another suitable mixes achieve the requirements of the code and ease of implementation.

2- Laboratory Test Program

Three different bentonite mixtures were prepared. The first one represented the mixture mentioned in the Egyptian code of soil mechanics, which is composed of 200 kg of cement, 100 kg of bentonite and 1000 kg of sand and the water/cement ratio was equal to 1.25. The other two proposed mixtures were composed of 150 & 100 kg of cement, 200 & 300 kg of bentonite, 1000 kg of sand and water/cement ratio of 2.0 & 3.5 respectively. Cubic specimens of 10x10x10cm were prepared and have been cured with water until tests. Compression tests were carried out to determine the compressive strength for different mixtures. Other cylindrical specimens were prepared and tested in order to conduct permeability coefficient using falling head test method. The details and results of these tests are explained as follows.

2.1- Compression Tests

The primary purpose of the compression test is to obtain the compressive strength of the different mixtures. Specimens for compression tests were prepared according to above mentioned water/cement ratios in cubic shapes of dimensions 10x10x10 cm, and tested after different periods (3, 7 and 15 days). Fig. (1) shows relationship between compressive strength and period of time obtained from compression tests for different cement/bentonite (C/B) ratios. The test results of the compressive strength for the different C/B ratios after 15 days are shown in Fig. (2). Dry densities (Υ_d) were calculated and plotted against C/B ratios as shown in Fig. (3). Both water/cement ratio and water/bentonite ratio were plotted against C/B ratio as shown in Fig. (4) and Fig. (5) respectively. Also, all these results were summarized in Table (1). It can be seen that, both of compressive strength, dry density and water/bentonite ratio were increased with increasing of C/B ratio. While, the water/cement ratio decreased with increasing of the C/B ratio. Also, it can be noticed from table (1) that, the curing time had more effect on the amount of compressive strength at the higher (C/B) ratio.

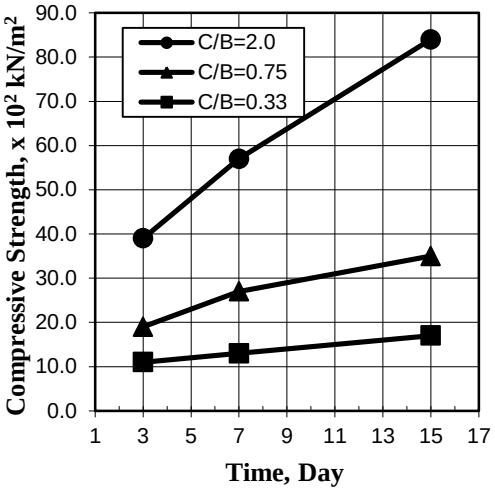

Fig. (1) Compressive Strength – Time Relationships for Different (C/B) Ratios

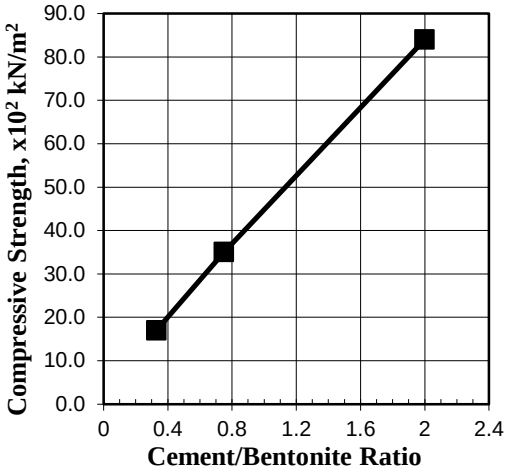

Fig. (2) Compressive Strength Versus (C/B) Ratio After 15 days

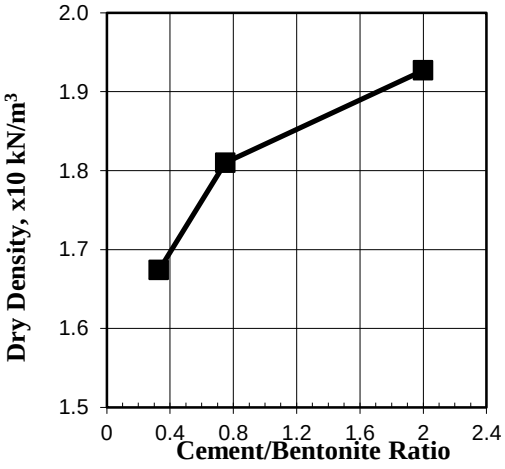

Fig. (3) Dry Density Versus (C/B) Ratio

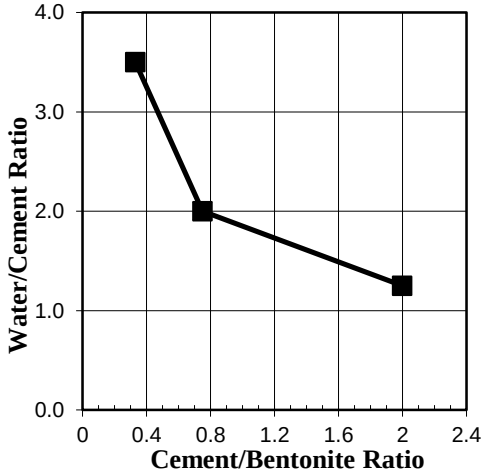

Fig. (4) Water/Cement Ratio Versus C/B Ratio

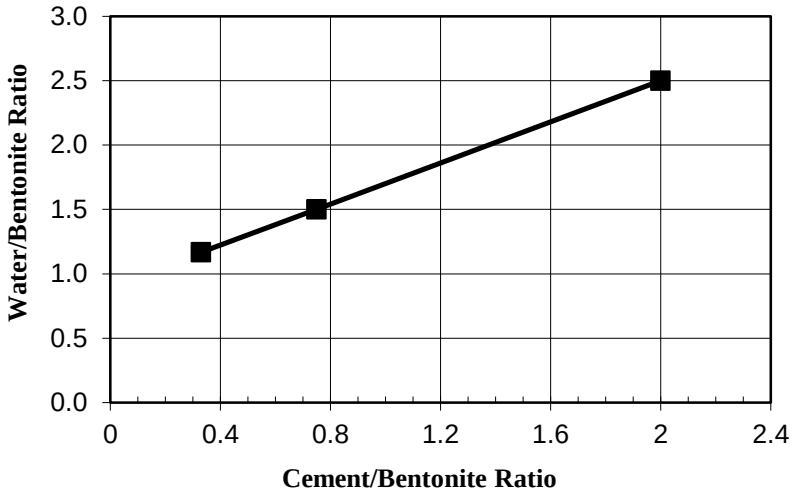

Fig. (5) Water/Bentonite Ratio versus C/B Ratios

Table (1): Results of Compression Tests

Mix. Content	C/B Ratio	Compressive strength (kN/m^2)			Υ_d (kN/m^3)
		3days	7days	15days	
(Code mix.)200kg cement+100kg bentonit+1000kg sand+ w/c=1.25	2.0	3900	N.A.	8400	19.3
150kg cement+200kg bentonit+1000kg sand+ w/c=2.0	0.75	1900	2700	3500	18.1
100kg cement+300kg bentonit+1000kg sand+ w/c=3.5	0.33	1100	1300	1700	16.7

2.2- Permeability Tests

Permeability tests were carried out according to ASTM D3080 on cylindrical specimens of 100mm diameter and 100mm height. The specimens were prepared at specific water/cement ratio compacted on a cylindrical mold and tested after curing for 15-days. Permeability coefficient (k) versus (C/B) relationship was plotted as shown in Fig. (6). These results are summarized in Table (2). It can be noticed that the permeability coefficient (k) decreased with increasing the (C/B) ratio. Nevertheless, the values of the permeability coefficients for the proposed mixtures meet the requirements of the code and are suitable for use in secant piles as they are sufficient to prevent water from leaking into the excavation.

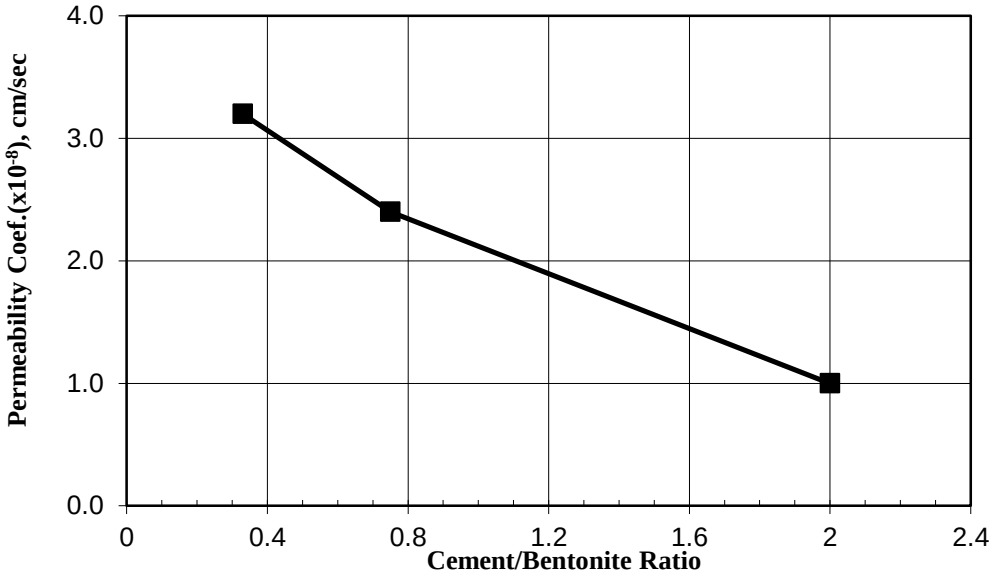

Fig. (6) Permeability Coefficient (k) versus (C/B) Ratios

Table (2): Permeability Coefficient (k)

Mix. Content	C/B Ratio	k cm/sec
(Code mix.) 200kg cement+100kg bentonit+1000kg sand+ w/c=1.25	2.0	$1.0x10^{-8}$
150kg cement+200kg bentonit+1000kg sand+ w/c=2.0	0.75	$2.4x10^{-8}$
100kg cement+300kg bentonit+1000kg sand+ w/c=3.5	0.33	$3.2x10^{-8}$

3- Conclusions

1. The results of laboratory tests indicated that the mixture of bentonite piles with (C/B) ratio of 2.0 that proposed by the Egyptian code of foundations and soil mechanics gave a compressive strength of 8400 kN/m^2 and coefficient of permeability of $1.0x10^{-8}$ cm/sec. These results are much higher than the limits mentioned on the code.

2. Compressive strength for the new proposed mixtures with (C/B) ratios of 0.75, and 0.33 after 15 days were 35 and 17 kN/m^2 respectively, which are within the required limits in the code.
3. Coefficient of permeability for the new proposed mixtures with (C/B) ratios of 0.75, and 0.33 after 15 days were $2.40x10^{-8}$, and $3.20x10^{-8}$ cm/sec respectively, which will match with the required limits in the code.
4. We recommend using mixes with (C/B) ratios of 0.75 which is less expensive, easier to implement and fulfill the requirements of the code.

4- References

1. Egyptian Code of Foundations and Soil Mechanics, part no. 202/4, 2005.
2. G&P Geotechnics SDN BHD, July, 2011, "Specification for Secant Pile Walls"
3. M. Noel, June, 2013, "Method Statement for Building Secant Pile Wall and the Necessary Shoring".
4. Universal Piling Company, August, 2019, "All You Want to Know About Secant Piling Method".