المؤتمر العلمي الدولي الثالث للهندسة و العلوم

The 3RD Scientific International Conference in Engineering & Science

http://bwu.edu.ly/icse2024

Received 25/07/2024 Revised 22/08/2024 Published 10/09/2024

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The Impact of Replacement Ratios of Clay Extracted from Groundwater Drilling on the Mechanical Properties of Cement Mortar

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Abstract: The negative environmental impacts of Portland cement as a binder in the construction industry have increasingly driven the development of alternative sustainable binders. Waste materials derived from nature can be used as pozzolanic alternatives to cement. This study examines the effect of burned clay on producing cement mortar with good specifications and high durability. A series of (60) samples were prepared and cast, with six cubes taken as reference samples. The remaining (54) cubes were divided into groups with cement replaced at ratios of (25%, 50%, and 75%) and burned at temperatures of (400, 600, and 800) degrees Celsius. The results indicated that the (25%) replacement level was optimal in terms of compressive strength, which then decreased beyond this replacement ratio. The compressive strength achieved for the cement alternative samples was (19.75 MPa) at a (25%) replacement ratio and a burning temperature of 600 degrees Celsius for (7) days. The strength decreased as the clay proportion in the mix increased. This study showed that clay extracted from well drilling has the potential to produce good quality cement mortar at certain replacement ratios.

Keywords: (Cement morter,pozzolanic clay,additives,green concrete).

Introduction

Concrete and cement mortar are among the most important construction materials that have been used and are still used today in building and engineering constructions. There is no field in civil engineering where concrete and cement mortar do not top the list of primary construction materials. This is due to the engineering properties of these two materials, which distinguish them from other construction materials in terms of economic feasibility, high durability, and formability, as well as their high resistance to heat and the ability to be cast at various times. Cement mortar, in general, is a mixture composed of fine aggregate, cement, water, and some other additives (solid or chemical) in specific and studied proportions. Among the most important factors affecting the quality and type of cement mortar are the type and quantity of both cement and fine aggregate, the mixing water, as well as the methods of mixing, compacting, and curing. Several researchers have emphasized the necessity of using additives to improve the mechanical properties of cement mortar and increase durability in concrete structures. Laboratory studies to understand the engineering properties of cement mortar and various additives receive considerable attention due to the impact these additives have on enhancing the physical, chemical, and mechanical properties of structural elements that rely on cement, concrete, and cement mortar components.

Clay is disposed of as an unprofitable waste material and is not sufficiently utilized in any construction industry. With the increasing application of cement mortar and concrete worldwide, various methods are being employed to enhance their performance and strength.

This study aims to achieve a highly effective bonding material in cement mortar that possesses high hardness, is unaffected by weather conditions, and meets the required performance standards. This study is particularly significant as it explores the possibility of producing compressive strength in cement mortar by partially replacing fine aggregate with clay. Additionally, the use of clay is not common in the Libyan construction sector, making this study crucial in enhancing the understanding of the suitability of clay as an alternative material. Significant efforts have been made globally to utilize natural waste and by-products as fine and supplementary materials to improve the properties of cement mortar and concrete.

In 2016, researcher (KALEESWARI. G,Dr.DHANALAKSHMI. G,MANIKANDAN.N) used clay as a partial replacement (5%, 10%, 15%, 20%) for Portland cement. By incorporating both untreated raw clay and chemically treated clay into mortar, they observed an increase in workability and compressive strength. The study concluded that raw clay replacement is effective due to the presence of aluminum oxide, iron oxide, and calcium, which enhance pozzolanic activity strength. When raw clay is chemically treated with potassium hydroxide and calcium oxide, compressive strength increases by 15%.

In 2018, (Marangu J. Mwiti, Thiong'o J. Karanja, and Wachira J. Muthengia) conducted a study on the thermal resistance of cement based on chemically activated calcined clay. Sodium sulfate and sodium hydroxide were used as activating solutions, and the chemical composition of the clay samples was determined using a specific technique. The calcined clay was burned, poured with the activating solution, and cured in water. The researchers concluded that chemically activated cement mortar has higher thermal resistance compared to non-activated mortar

In a study conducted in 2019 by (Oluwarotimi Olofinnade, Anthony Ede, Julius Ndambuki, David Omole, Precious Francis, Cynthia Chigere, and Kehinde Oyeyemi) crushed clay brick waste was reused as a replacement for cement in mortar for sustainable construction. The chemical composition of crushed clay brick indicates that it can be classified as a pozzolanic material. The strength of the mortar was significantly improved with the incorporation of brick at a rate of up to 20%, with the highest strength observed at 20% after 28 days of curing.

In 2020,(J. M. P. Q. Delgado) reused clay brick waste in mortar and concrete. The aim was to confirm that the application of recycled clay brick not only addresses the issue of disposing of demolished solid waste but also reduces environmental damage caused by over-exploitation of resources. Clay brick powder shows pozzolanic activity and can be used as a cement substitute. The potential uses of clay brick waste as a binding agent and aggregate replacement in mortar and concrete were summarized in several key points:

- Recycled clay brick aggregate can be used to produce recycled clay brick concrete, although the mechanical properties of recycled clay brick concrete were inferior to those of ordinary concrete.
- Adding recycled clay brick aggregate improved the durability of recycled clay brick concrete in some cases. Additionally, recycled clay brick concrete can reduce transportation costs and dead loads and can be used to produce units, beams, and columns.
- It has been shown that completely replacing natural aggregate with recycled aggregate is possible; this can

reduce the consumption of natural resources and encourage the reuse of construction waste. Given that the structural performance of recycled clay brick concrete is important for structural engineering, the application of recycled clay brick concrete in structures can be enhanced.

This study aims to use a natural clay additive derived from oil well drilling waste as a fundamental component in cement mortar to produce homogeneous cement mortar with good properties. It also aims to determine the optimal proportions for partial cement replacement to benefit from the pozzolanic properties of fired clay and to improve the mechanical properties of the mortar, contributing to environmental conservation by utilizing waste. Compression tests were conducted on samples with dimensions of (50x50) mm, and partial replacements of cement and fine aggregate will be done at ratios of (25%, 50%, 75%).

Methodology

The materials used in this study included three cementitious materials (Portland cement, fired clay, fine aggregate), and water.

1. Cement

Ordinary Portland Cement conforming to Libyan (LQS 340-2009) and British (BS12:1996) specifications was used, produced by Zliten Cement Factory.

Table 1: shows the chemical composition of the cement.

Oxides	PC
CaO	**63.24**
SiO_2	**20.13**
AL_2O_3	**4.59**
MgO	**2.42**
Fe_2O_3	**4.26**
SO_3	**1.12**
C_3S	**63.83**
C_2S	**9.55**
C_3A	**4.34**
C_4AF	**14.05**

2. Fine aggregate

The fine aggregate used is natural sand sourced from quarries in the Zliten area, commonly used in our region.

Table 2: shows the particle size distribution of the fine aggregate.

Specification: BS882:1992	Percentage passing (%)	Sieve opening (mm)
100-60	100	2.36
100-30	99.92	1.18
100-15	99.54	0.6
70-5	68.76	0.3
15-0	5.88	0.15

3. Mixing water

Potable water was used in preparing the mortar mix, compliant with Libyan specifications (LQS 249-1988).

Table 3: illustrates the chemical analysis of the water used in the mix.

Chemical Composition	Quantity (mg/L)
Carbonates	57.97
Bicarbonates	104.12
Chloride	216.29
Sodium	120.62
Magnesium	5.43
Calcium	3.32
Potassium	62.18
Calcium Carbonate	30.84
Total Dissolved Solids	698

Conductivity	1.21
pH (Hydrogen ion concentration)	9

4. Clay

Clay is the primary focus of this study, where it was extracted from well drilling operations, chemically tested, and fired in an electric kiln at specific temperatures.

Fig. 1: Main Graphics, Analyze View of the sample

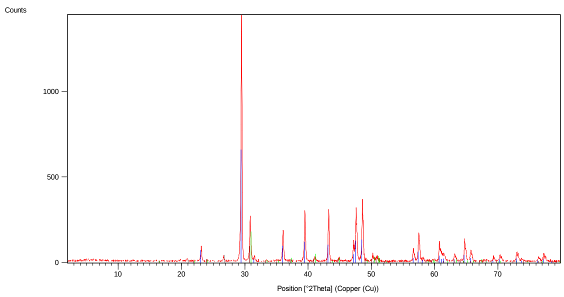


Table 4: Pattern List & Sime Quantitative of the sample

Ref. Code	Compound Name	Mineral Name	Chemical Formula	Semi Quantitative %
01-086-1628	Calcium Carbonate	Calcite	$CaCO_3$	65%
01-082-0511	Silicon Oxide	Quartz	SiO_2	4%
01-075-1656	Calcium Magnesium Carbonate	Dolomite	$CaMg(CO_3)_2$	22 %
01-083-1531	Calcium Magnesium Iron Carbonate	Ankerite	$CaMg_{0.32}Fe_{0.68}(CO_3)_2$	9%

Results and Discussion

The reference samples were tested in two stages: Stage C1, with a curing period of 7 days, where the samples collapsed at a compressive strength of (Map12.4), and Stage C2, with a curing period of 28 days, where the samples collapsed at a compressive strength of (Map18.3).

A total of 54 cubes were tested with clay replacement ratios (25%, 50%, 75%) as cement substitutes at firing temperatures (800, 600, 400) degrees Celsius for 7 and 28 days, with room temperature and mixing temperature measured. The test results for sample group GCA11 showed that the compressive strength decreased by (22.01%, 32.82%, 88.71%) compared to the reference sample at replacement ratios of (25%, 50%, 75%).

Similarly, the test results for sample group GCA12 indicated that the compressive strength decreased by (14.21%, 33.06%, 66.39%) compared to the compressive strength of the reference sample at replacement ratios of (25%, 50%, 75%).

Table 5: shows the compressive test results for alternative cement samples (GCA1):

Samples	Replacement Ratio	Compressive Strength
C1	0%	12.4
C1	0%	18.3
	25%	9.67
CBA11	50%	8.33
	75%	1.4
CBA12	25%	15.7
	50%	12.25
	75%	6.15

Fig. 2: Results of Compressive Strength Test for Cement Replacement Samples at 7 Days Age (GCA11)

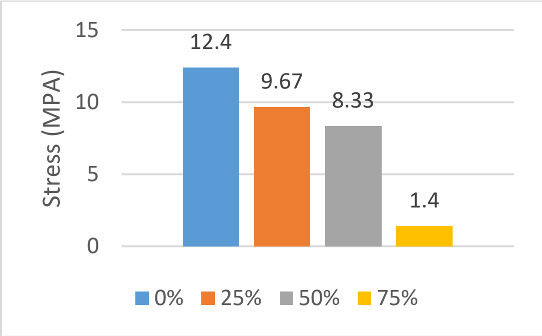
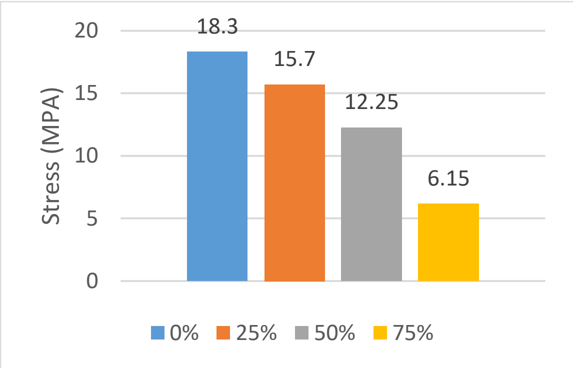


Fig. 3: Results of Compressive Strength Test for Cement Replacement Samples at 28 Days Age (GCA12)



The test results for sample group (GCA21) showed that the compressive strength increased by 59.27% at a replacement ratio of 25% compared to the reference sample. However, at replacement ratios of 50% and 75%, the compressive strength decreased by 1.21% and 67.33% respectively compared to the reference sample. As for sample group GCA22, the test results indicated that the compressive strength decreased by 4.92%, 39.07%, and 88.25% at replacement ratios of 25%, 50%, and 75% respectively compared to the reference samples.

Table 6: displays the compressive test results for alternative cement samples (GCA2):

Samples	Replacement Ratio	Compressive Strength
C1	0%	12.4
C2	0%	18.3
GCA21	25%	19.75
	50%	12.25
	75%	4.05
GCA22	25%	17.4
	50%	11.15
	75%	2.15

Fig. 4: Results of Compressive Strength Test for Cement Replacement Samples at 7 Days Age (GCA21)

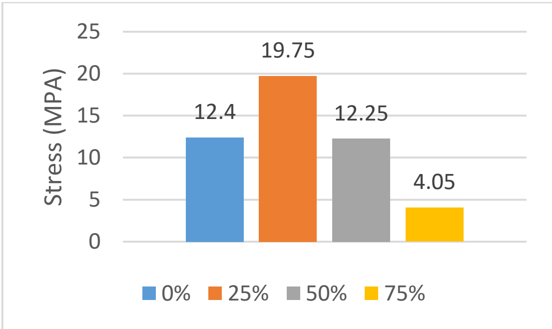
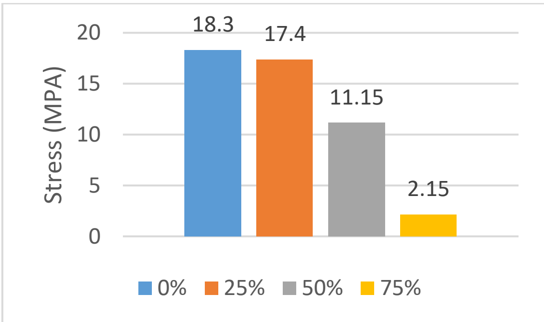


Fig. 5: Results of Compressive Strength Test for Cement Replacement Samples at 28 Days Age (GCA22)



The results of the sample test for group GCA31 showed that the compressive strength of the samples decreased by 16.12% at a substitution rate of 25% compared to the reference sample. As for the remaining samples, their compressive strength was lost, indicating no compressive strength. The same applies to group GCA32, where there is no compressive strength.

Table 7: displays the compressive test results for alternative cement samples (GCA3):

Samples	Replacement Ratio	Compressive Strength
C1	0%	12.4
C2	0%	18.3
GCA31	25%	10.4
	50%	0
	75%	0
GCA32	25%	0
	50%	0
	75%	0

Fig. 6: Results of Compressive Strength Test for Cement Replacement Samples at 7 Days Age (GCA31)

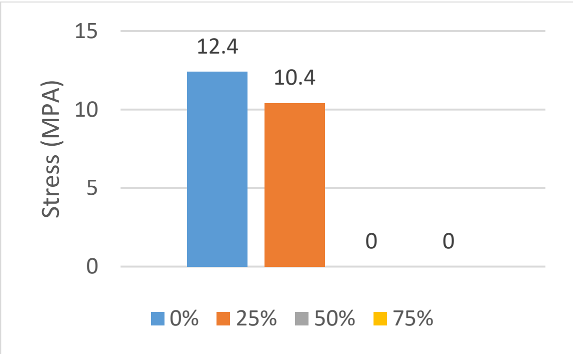
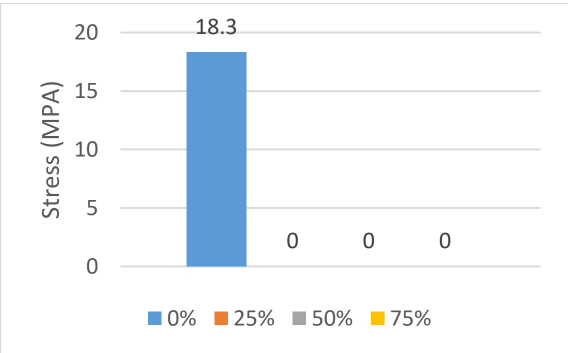


Fig. 7: Results of Compressive Strength Test for Cement Replacement Samples at 28 Days Age (GCA32)



Conclusion

The experimental test results on samples where burnt clay was replaced with cement revealed varying increases in compressive strength at a 25% substitution rate and a firing temperature of 600°C compared to the reference sample. It was noted that most samples experienced collapse.

As previously mentioned, room temperature and mixing temperature were measured for all samples, ranging between (25, 29) degrees Celsius except for samples where burnt clay was substituted at an 800°C firing temperature. In these cases, the mixing temperature increased significantly, reaching up to 34.5°C at a 25% substitution rate, 54.1°C at 50% substitution, and 83.4°C at 75% substitution.

The results of this study, where clay was substituted for cement up to 25% and fired at 600°C, showed the best outcomes with a 63.77% increase in compressive strength compared to the reference sample after 7 days of curing.

This study demonstrated the effectiveness of using clay as a substitute for cement up to 25% to enhance the compressive strength of cement mortar. These experiments also showed that samples where clay was substituted for cement at an 800°C firing temperature had a significant water absorption rate and high temperatures, making them useful for concrete mixing in cold environments and in buildings within maritime facilities.

Arabic section:

العنوان: تأثير نسب الإحلال للطين المستخرج من حفر الآبار الجوفية على خواص الميكانيكية للمونة الإسمنتية

المؤلفون: أيمن الفرجاني، هديل النعاس

الكلمات المفتاحية: (المونة الاسمنتية، الطين البوزلاني، الإضافات، الخرسانة الخضراء).

الملخص: لقد جعلت التأثيرات البيئية السلبية للإسمنت البورتلاندي كمادة رابطة في صناعة البناء دافعاً متزايداً لتطوير مواد رابطة بديلة مستدامة. حيث يمكن استخدام إعادة النفايات الناتجة من الطبيعة كمواد بوزلانية بديلة للإسمنت. تعرض هذه الدراسة تأثير مادة الطين المحروق لإنتاج مونة إسمنتية ذات موصفات جيدة ومتانة عالية، حيث تم تجهيز وصب سلسلة من (60) عينة، منها ستة مكعبات أخذت كعينات مرجعية أما المكعبات المتبقية قسمت إلى (54) مكعب بديلا للإسمنت بنسب (25%، 50%، 75%) على درجات حرق (400،600،800) درجة مئوية. من النتائج لوحظ أن من خلال الاختبارات كان مستوى الاستبدال 25% هو المستوى الأمثل من

حيث مقاومة الانضغاط ثم تنخفض القوة ما بعد نسبة 25% من الاستبدال تم تحقيق مقاومة الانضغاط للعينات البديلة للإسمنت بمقاومة تبلغ 19.75 ميجا باسكال عند نسبة استبدال 25% وعلى درجة الحرق (600) درجة مئوية ولمدة (7) أيام، وتقل القوة كلما زادت نسبة الطين في الخلطة. أظهرت هذه الدراسة أن الطين المستخرج من حفر الآبار لديه قدرة على انتاج مونة إسمنتية جيدة بنسب استبدال معينة.

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