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THE IMPROVEMENT OF THE PROPERTIES OF INTERLOCK TILES BY ADDING DIFFERENT LIME CONTENTS

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ABSTRACT

The tiles industry has developed in recent times, as the different types, shapes, thicknesses, and colors of interlock occupied the first place in their acceptance as a product in the construction industry, with its special features that increase their demand locally. Foreign investment entered this industry previously for its production, which is manufactured in factories that were imported from outside Sudan, using local materials and Sudanese labor. After that, factories spread all over the country to distribute their concrete products, of which interlock is one of them. This paper aims to improve the properties of interlock tiles such as durability, weight, and absorption by adding lime. The methodology used to attain the objectives of the work depends on collecting data from different sources, and production sites, reviewing previous studies, making a mix of interlock tiles without adding lime, and conducting laboratory experiments for mixes with adding lime in different proportions. The effect of different proportions of lime on improving the interlock mix for durability, weight, and absorption properties was studied at the ages of 3, 7, 14, and 28 days. It was found that the greatest result of compressive strength at the age of 28 days was when adding 20% of lime (Sample 5) in comparison with the other proportions of lime. It also found a slight reduction in compressive strength compared to the reference design mix (without adding lime). It was also noticed that the weight gain was at the age of 28 days, by adding lime of 20%. Sample 3 gave the highest increase in the absorption ratio when lime was added by 10%. From regression analysis using proposed equations, it was found a good correlation between lime content (up to 30%) and compressive strength. It was recommended to utilize other types of sand and additives to improve the properties of interlock tiles.

KEYWORDS: Interlock tiles, Samples**,** Lime content, absorption, weight, compressive strength.

INTRODUCTION

Interlock tiles are a kind of tiles in geometric shapes of chemically treated concrete. They are installed by interlocking or overlapping methods, as they are made without the use of cement mortar and are installed directly over the rammed sand. For this reason, the interconnection by the interlock method depends on their weight in balance and immobility. The tiles overlap with each other so that they can be removed and re-installed when needed by digging without being damaged or broken, and they are made in multiple shapes and colors. Previous studies were carried out to improve the interlock properties using different types of sand and additives. In this work, 15 previous studies were presented.

The first work is done by the Scientific Research laboratory of Kuwait Institute. The analysis work was done by finding and processing a group of mixture proportions for modified sulfur concrete that was most promising and supported the check results with the bitumen additive and also the completely different ingredients.[1]

The second study aims to work out the effect of the form, pattern, and joints of concrete interlock in places like squares, automobile parking, and stadiums for water infiltration through the joints. It contains 5 models for various interlock types, joints between the block, and various pattern pavements, with 3 different base courses beneath pavements and 5 situations of rainfall intensity.[2]

Manufacture of interlocking concrete tiles mixed with relative replacement of granite exploitation native pit gravel isn't simply possible. However, it also competes favorably with those made of sole granite in some engineering characteristics such as density and compressive strength. However, because the proportion of pit gravel will increase, workability will increase at the same water/cement ratio. Interlocking concrete tiles producers have encouraged the replacement of granite with original gravel by up to 40% as the compressive resistance strength of concrete remains at the appropriate limit for structural concrete.[3]

The impact of curing technologies on the efficiency of interlock tiles is not clear, and understanding this development can ensure optimum resistance and efficiency for the construction of interlock tiles in the future. The optimum hardening technique was found to be the pond technology because it resulted in the highest compressive resistance.[4]

Interlocking tiles are widely used in many countries to provide paving in areas where typical types of construction are not strong to service and ecological constraints. During this work, a performance test was done on the designed interlocking tile block machine.[5]

Another work describes spent metalwork sand mixtures and new users within the production of concrete blocks for interlocking pavement. Cylindrical and polygon concrete blocks were created with the whole replacement of natural sand with spent metalwork sand mixtures and their mechanical properties were evaluated.[6]

The bedding layer represents a significant role in finding the usefulness of interlock tiles pavement. Therefore, in Japan, geotextiles are usually placed between the sand bedding layer and thus the base track, to prevent run-off of the lining sand. The amount of geotextile used annually has currently reached about one million m^2. However, there are few studies on the useful effects of geotextile to keep the bedding and base courses separated from one another and up the pavement's usefulness.[7]

In another study, wood and soil are utilized as a replacement for cement and fine sand to produce ultra-lightweight green interlocking paving blocks. Interlock paving tiles, treated with water for 90 days with 100% perfect wood content, achieved compressive resistance of 16.6 MPa.[8]

This work concentrates on manufacturing interlock paving units by replacing the normal coarse aggregates in units with recycled concrete aggregates with fly ash as industrial waste. In the present study, a 30% substitution of normal coarse aggregates with recycled concrete aggregates and a 15% substitution of cement with fly ash in the mix was used as it was found to provide the optimum strength.[9]

The multicolor tiles were initially utilized in extremely trafficked pedestrian ways and walkways in industrial areas, particularly within the industrial center of the Capital. The interlocking paving tiles are widely used for aesthetic advantages and their high durability. These tiles are used as a surface layer of asphalt pavements in several signalized intersections to regulate surface rutting.[10]

In the current study, concrete paving blocks could also be made locally on the market cement, aggregates, fly ash, and waste glass powder as mineral admixtures. The study indicated that ash and wasted glass powder would be used effectively as a substitute for cement with no fundamental modification in strength.[11]

A concrete paving interlock unit is often excellent material to recycle bottom ash. During this study, experimental works were performed to analyze the influences of recycling bottom ash in the production of concrete paving units. Three bottom ash obtained from completely different coal-burning plants were used.[12]

Another study enclosed the hypothetical production and consideration of the mechanical characteristics of paving units created from a mixture of laterite, sand, fine-grained bovine bone, and cement. In addition, experimental models of compressive and flexural resistance have been developed and provided here for paving units.[13]

The study discovered that the use of rigid concrete in pedestrian construction is gradually disappearing as most walkways have recently been constructed using interlocking stones.[14]

The final study compares the various types of pavement material to provide info for decision-makers concerning the environmental impacts of each type of material. It’s hoped that this may facilitate the choice of materials that have the minimum environmental impact.[15]

OBJECTIVES

The paper is aimed to study the influence of adding different proportions of lime on the absorption, weight, and compressive strength of interlock tiles. All materials used are available in Sudan's local market.

METHODOLOGY AND CASE STUDY

The methodology relied on collecting information from different sources, a design mix for interlock, performing all laboratory tests for materials, and then measuring the weights, absorption ratio, and compressive strength of the samples in the laboratory.

Interlock tile is one of the construction techniques in the modern era, where concrete was used as a filler and easy to form in the manufacture of interlock. Cement is included as a main component in the interlock product with high weight percentages, small aggregates of 10 mm, fine sand, and mixing water. Lime was chosen as an improver of the special properties of interlock to increase compressive strength, reduce the absorption and increase weight. Lime includes different physical and chemical classifications because of burning and adding water to limestone.

In this study, the reference sample of interlock tiles was used with 0% of lime content, and the remained samples were made by adding lime with different percentages of cement weight (5%, 10%, 15%, and 20%). The study relied on the evaluation of the effect of adding lime on the properties of interlock represented in measuring the absorption rate of different interlock mixtures, measuring the weights and compressive strength in comparison with the reference sample.

The study included conducting the setting time test (initial and final) for Portland cement, sieve analysis for fine sand and aggregates, the specific gravity and absorption for aggregates, and the lime test according to the standard of the British Code.

It was found that the components of the reference sample contain coarse aggregate, fine sand, cement, and water with weights of 1050, 645, 300, and 150 kg, respectively. The amount of lime added to the various samples was taken as a percentage of the cement weight.

MATERIAL TESTS RESULTS

Table 1 illustrates the results of cement tests for setting times, and compressive strength at different ages. Sieve analysis of fine sand and aggregates was also carried out as illustrated in

Tables 2 and 3. It was found that the specific gravity and absorption rate of the aggregate were 2.22 and 3.75, respectively. It was also found that both fine sand and aggregates comply with the British Standard Specifications.

Table 1: Portland cement test results.

Test	Results	Requirements of BS 12-1996
Consistency	29.0%	
Setting Time		
a) Initial	45 min	No less than 60 min (-15 min)
b) Final	2 hrs.	Not more than 10 hrs.
Compressive strength		
a) **2 days**		Equal or Greater than 10 N/mm^2
Sample 1	20.1 N/mm^2	
Sample 2	20.7 N/mm^2	
Sample 3	19.5 N/mm^2	
b) **28 days**		Equal or greater than 42.5 N/mm^2
Sample 1	45.6 N/mm^2	
Sample 2	47.1 N/mm^2	
Sample 3	48.2 N/mm^2	

Table 2: Sieve analysis results for fine sand.

Sieve size (mm)	Retained weight (g)	Passing weight (g)	Percentage of Passing (%)
4.75	0.003	0.997	99.7
2.36	0.001	0.996	99.6
1.18	0.018	0.978	97.8
600	0.379	0.599	59.9
300	0.405	0.194	19.4
150	0.091	0.103	10.3
0.75	0.064	0.039	3.9
Pan	0.039	0.000	0

Table 3: Sieve analysis results for aggregates.

Sieve size (mm)	Retained weight (g)	Passing weight (g)	Percentage of Passing %
12.5	7	1988	99.6
9.5	217	1771	88.77
4.75	1.707	64	3.2
2.36	60	4	0.2
1.18	0	4	0.2
Pan	4	0	000
	1995		

The chemical characteristics of lime tests were also carried out. To check the fineness, all grains of hydrated lime must pass through a 2.36 mm sieve, and the retained amount in the

850-micron sieve should not be more than 5%, and the retained amount should not exceed more than Sieve 300-microns for 10% and the test is achieved according to BS EN 459-2.

The absorption test was conducted on the five Interlock samples containing different percentages of lime as shown in **Table 4**. A comparison was made for the average absorption of the interlock units as illustrated in Figure 1. **Table 5** illustrates the average weights of interlock units at ages 3, 7, 14, and 28 days. **Figure 2** illustrates the comparison of average weights of interlock for different samples and their ages.

Table 4: Absorption ratios for different interlock samples.

Sample ID	Lime Content	Unit No.	Dry weight (kg)	Weight of saturated sample (kg)	Absorption (%)	Average Absorption (%)
Sample 1	0%	1	2.192	2.325	6.07	6.16
		2	2.158	2.305	6.16	
		3	2.255	2.396	6.25	
Sample 2	5%	1	2.325	2.454	5.5	6.23
		2	2.208	2.353	6.5	
		3	2.178	2.325	6.7	
Sample 3	10%	1	2.255	2.3895	5.96	6.97
		2	2.286	2.4545	7.37	
		3	2.293	2.4665	7.57	
Sample 4	15%	1	2.332	2.477	6.22	6.51
		2	2.208	2.353	6.57	
		3	2.178	2.325	6.75	
Sample 5	20%	1	1.862	1.970	5.8	6.30
		2	1.954	2.078	6.3	
		3	2.046	2.186	6.8	

Table 5: Results of average weights of the interlock samples at various ages.

Age	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
3 days	2.203	2.233	2.297	2.313	2.333
7 days	2.233	2.250	2.278	2.293	2.330
14 days	2.273	2.268	2.280	2.293	2.378
28 days	2.330	2.360	2.380	2.391	2.403

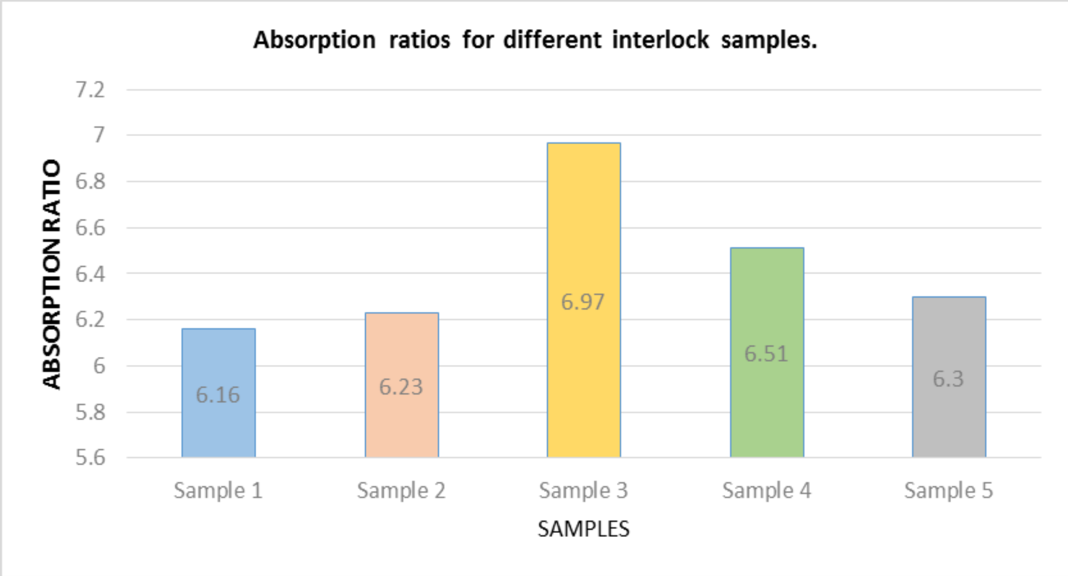

Figure 1: Comparison between the average absorption rates of the interlock samples.

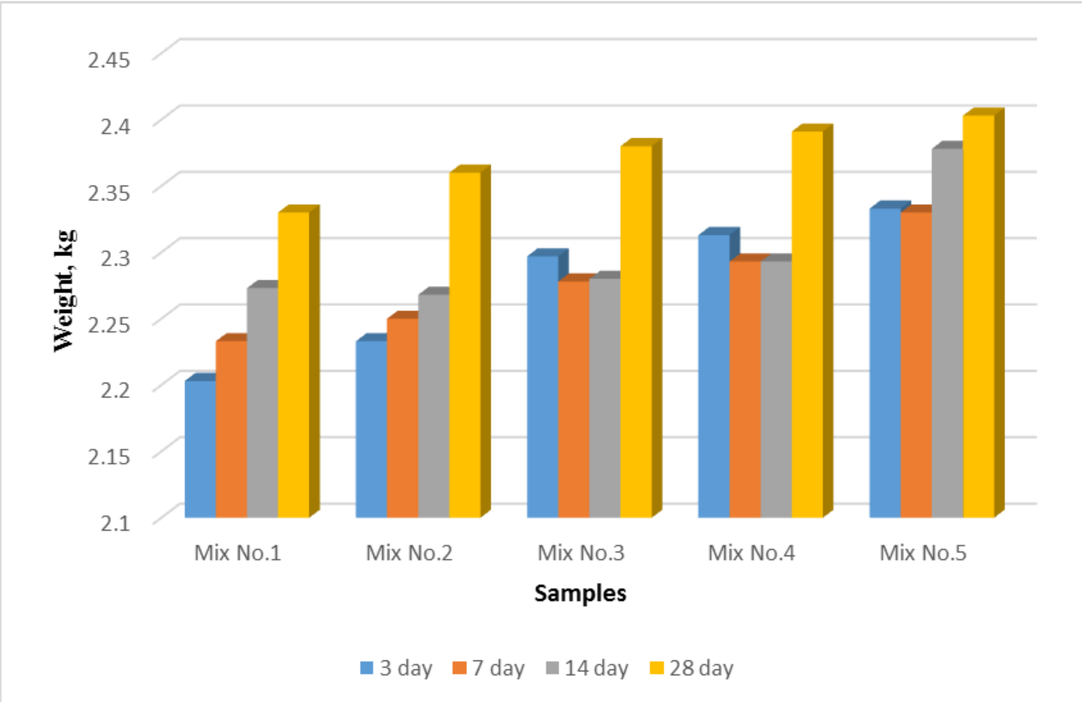

Figure 2: Comparison of average weights of the interlock samples at various ages.

The compression test of interlock units was conducted for the five samples containing different percentages of lime as shown in **Table 6**. The comparison of compressive resistance at various ages was made with interlock samples that give the maximum compressive strength for **Sample 5** at a lime content of 20% as illustrated in Figure 3.

Table 6: Comparison of average compressive strength for different interlock samples at various Ages.

Sample ID	Lime Content %	Age	Average Compressive Load, kN	Average Compressive Strength, MPa
Sample 1	0%	3 days	870	8.7
		7 days	134	13.4
		14 days	226	22.6
		28 days	294	29.4
Sample 2	5%	3 days	90	9.0
		7 days	144	14.4
		14 days	185	18.5
		28 days	207	20.7
Sample 3	10%	3 days	133	13.3
		7 days	153	15.3
		14 days	164	16.4
		28 days	266	26.6
Sample 4	15%	3 days	142	14.2
		7 days	182	18.2
		14 days	209	20.9
		28 days	286	28.6
Sample 5	20%	3 days	166	16.6
		7 days	228	22.8
		14 days	282	28.2
		28 days	322	32.2

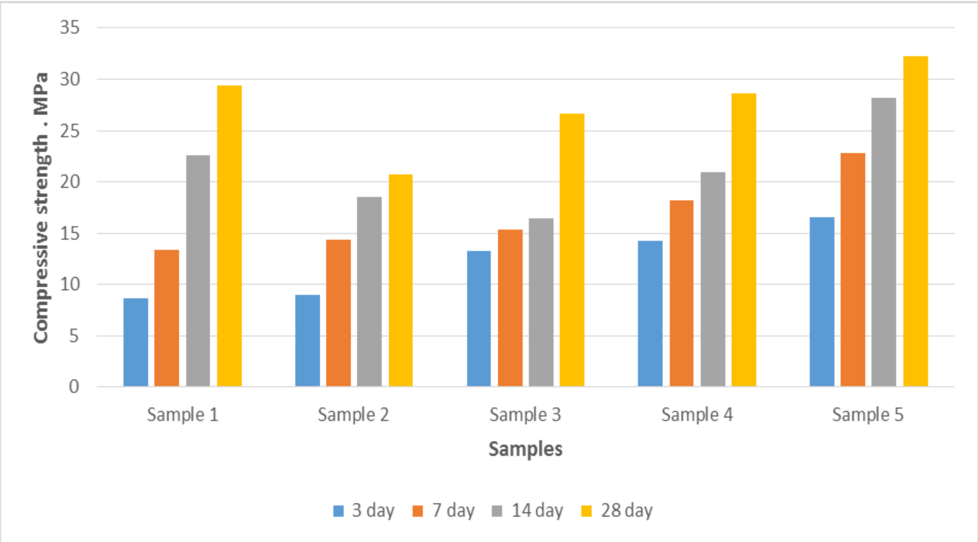

Figure 3: Comparison of average compressive strength of interlock samples at various ages.

Microsoft Office Excel software was used for the regression analysis of the compression resistance of the five mentioned samples of interlock tiles. Different relationships between lime content and compressive strength at ages 3, 7, 14, and 28 days respectively were established as illustrated in Figures 4- 7.

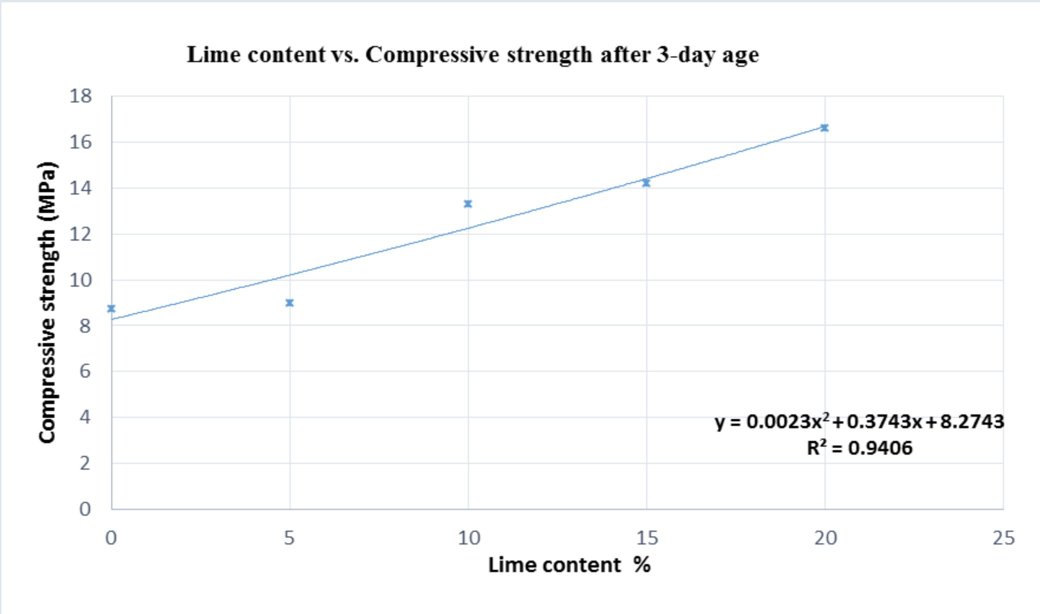

Figure 4: Regression to fit the Best Curve for lime content and compressive strength after 3- day age.

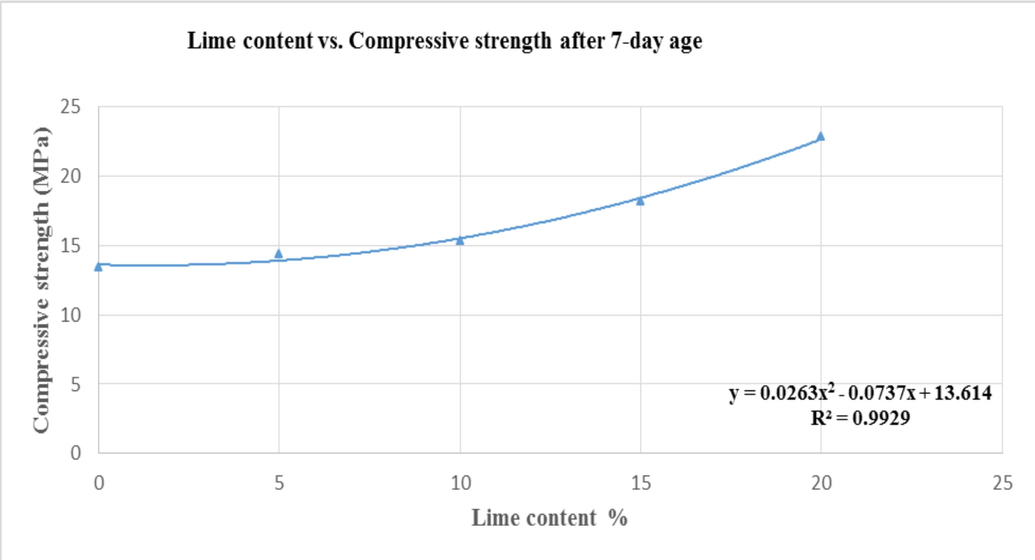

Figure 5: Regression to fit the Best Curve for lime content and compressive strength after 7-day age.

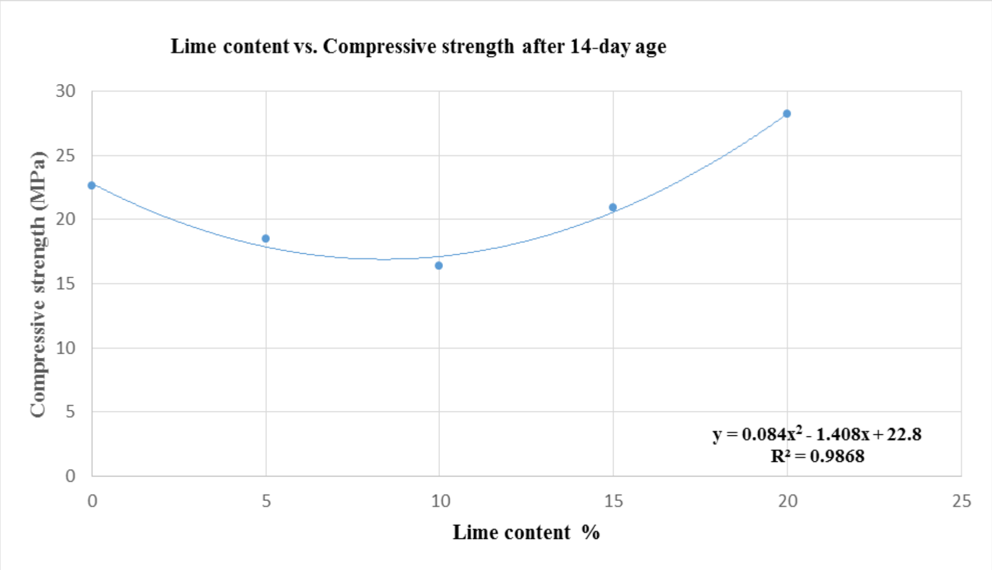

Figure 6: Regression to fit the Best Curve for lime content and compressive strength after 14-day age.

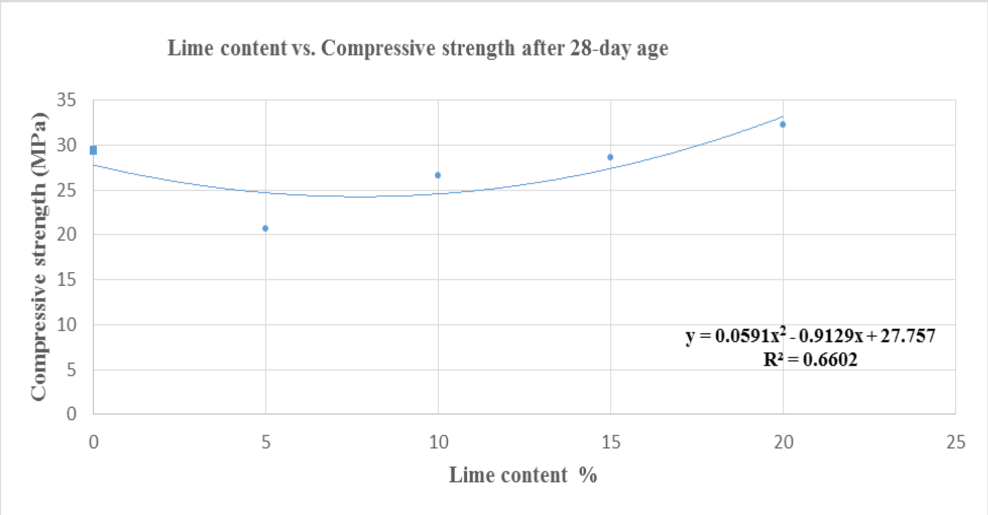

Figure 7: Regression to fit the Best Curve for lime content and compressive strength after 28-day age.

Suggested equations from regression analysis are very useful for determining the concrete resistance strength of the different lime contents. Thus, it is applicable to foretell the concrete compressive resistance of the lime contents that were not taken in the mixes design. The compressive resistance of concrete was calculated again using regression analysis equations at various ages as shown in Figure 8.

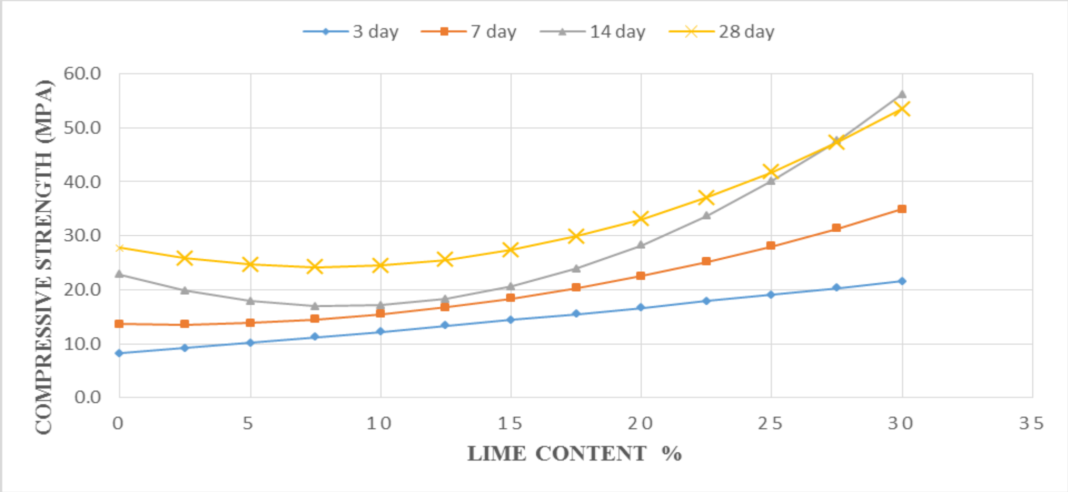

Figure 8: Values of compressive strength after 3, 7, 14, and 28 days vs. lime content using proposed equations by regression analysis.

DISCUSSION

In this section, the results of the experiments will be discussed. The discussion was summarized as follows:

1. From the results of cement tests, it was found that the result of consistency was 29% and the initial and final setting times were 45 minutes and two hours, respectively. It was also found that the compressive resistance of cement during 2 and 28 days was 20 N/mm^2 and 47 N/mm^2 respectively.
2. The lime test results were found to comply with BS-EN 459-2.
3. It was observed that the absorption ratio of the interlock samples increases at 10% of lime content and began to gradually decrease until the lime content reaches 20% as illustrated in **Figure 1**. This means that increasing the lime content reduced water absorption.
4. The different sample weights containing the percentages of lime were compared with reference **sample 1** with 0% of lime content. It was noted that sample weights were increased with increasing lime content as shown in **Figure 2**.
5. The compression test results for samples were made for different lime contents (5%, 10%, 15%, 20%), and it was found that the maximum compressive strength was obtained at 20% of lime content at the 28-day age (**Sample 5**) as shown in **Figure 3**.
6. From the results of regression analysis using the proposed equations, it was not recommended to use lime content of more than 30 % in concrete mixes because the concrete compressive resistance tends to be decreased as illustrated in Figure 8.

CONCLUSION

The conclusion can be drawn as follows:

1. **Sample 5** gave the maximum result of compressive strength at the 28-day age in comparison with the other samples. It was noticed that **Sample 4** compressive strength was decreased compared with the reference **Sample 1** which means the addition of lime does not give a substantial amendment in strength.
2. It was also shown that the maximum weight was obtained at the age of 28 days for **Sample 5** and increased by about 3% in comparison with reference **Sample 1**.
3. It was noticed that **Sample 3** at 10% of lime content gave the highest increase in the absorption rate in comparison with other samples.
4. From the regression analysis, there was an excellent relationship between lime content (up to 30%) and compressive strength.

RECOMMENDATIONS

Suggested recommendations for further research can be listed as follows:

1. Developing calculated design sheets for interlock samples using computer programs to shorten the time.
2. Conducting studies for other additives that can be added to improve the interlock tiles' properties.
3. Conducting studies that include the different types of sand in Sudan to obtain the best compressive strength of interlock.

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CONFLICT OF INTEREST

There is no conflict of interest between the authors of this manuscript.

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