The Properties of Lime/Soil Concrete

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ABSTRACT

The investigation of materials for replacing cement in concrete manufacturing has garnered steady interest from experts in recent years. However, the majority of past researches have only focused on the use of lime as a cement substitute in producing Lime Concrete. The reason for this is that lime concrete can be made easily and cheaply while still providing a durable material that can minimize negative environmental impacts. Even though lime is used as an alternative material the integration of a new material as a replacement for conventional aggregates has been limited. As a result, this study will attempt to examine the various compositions of hydraulic lime as a partial replacement of cement while completely replacing the coarse and fine aggregate with a soil to find the influence on the physical characteristics of Lime/Soil concrete. This will also help in decreasing the ecological imbalance caused due to the excess use of conventional aggregates. Locally available reddish-brown laterite soil was used in this study without any modifications. C30 concrete mixes containing 0%, 10%, 15% of hydraulic lime replaced with OPC and complete replacement of aggregate with laterite soil were casted before subjected to water curing. Workability, compressive strength, splitting tensile strength and water absorption test were conducted in accordance with the existing standard. Based on the results obtained from the study it has shown that even with complete replacement of aggregate with laterite soil it was able to produce workable concrete with satisfactory strength that can be employed for ground improvements in pavement design and to manufacture economical non-load bearing concrete blocks. The targeted strength still can be achieved with replacement of 15% hydraulic lime for a lower cost. With the accomplishment from the composition, future studies will be able to better assess the long-term effects of construction operations on the environment.

KEYWORDS: *Compressive strength, lime concrete, physical properties, hydraulic lime, laterite soil.*

1 INTRODUCTION

1.1 Background

In the recent years the importance of ecological and sustainable design of structures in the development of the construction industry has played a major role. Due to this reason many alternative materials like soil and lime in the production of concrete which contain proportions of various ecological components are expected to be developed rapidly. Generally concrete is an artificially built hardening mixture which includes a binding agent, coarse aggregate, fine aggregate, and water with or without a suitable admixture. Concrete is mainly used in construction of columns, beams and slabs which are components of buildings. Most of the structures which are made are designed to withstand usually more than 50 years. This is half the amount of a life span of a human being. Therefore, these structures should be properly built to withstand any kind of loading which can alter the safety during its life period. Similarly, it is important that the materials used in constructing these structures are eco and man friendly.

This research aims to optimize the compositions of lime as partial replacement of cement to find the influence on the physical characteristics of concrete made by completely replacing the fine and coarse aggregates with a soil. Another purpose of this research is to produce concrete with the express

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objective of reducing the production of greenhouse gas emission. When considering lime, it does not generate as much CO2 in its production as it does in the production of Portland cement. Lime is a durable, abundant, and versatile material which has been used as a binder widely in constructions like lime concrete and lime mortar. Natural hydraulic lime which is the lime type that is intended to be used in this research has hydraulic properties where it sets with the help of water.

When soil-based constructions are considered, they go back centuries. In the recent years, use of soil for construction has attract lots of attention due to the eco-friendly nature of the material. Most of the early research have studied the mechanical properties of soil-based concrete which can be used in modern constructions and buildings. Furthermore, the characteristics of the buildings that were constructed in the early stages using concrete made from soil has shown lower temperatures in the summer and also higher temperature in winter. This has inspired several modern researchers to study the properties of concrete by introducing soil into lightweight conventional concrete. The 28-day compressive strength of laterite and clay-based concrete ranged from 8 to 22 MPa for densities of 1500–2350 kg/m^3. (Ma Cong & Chen Bing, C, 2015)). Compressive strength and thermal conductivity ranged from 0.95–3.85 MPa and 0.201–0.281 W/m K for densities of 843–1038 kg/m^3.

Natural coarse aggregate depletion, pointing out that the natural resource is depleting while the demand for aggregate for concrete manufacturing remains strong. The depletion of this substance may lead to its extinction in the future, resulting in a rise in the cost of concrete. One approach to tackle this problem is to modify the concrete ingredients. This is one way to reduce granite usage. Concrete made from alternative components may reduce the amount of natural aggregate used.

Most of the physical properties of concrete, especially the compressive strength mostly depends on the mix design of the concrete. Although, the mix design plays a major role in the characteristics of concrete it is also affected by the factors like the methods of mixing, placing, curing and quality of the ingredients which are used in the concrete. The compressive strength of concrete is defined as the maximum stress that the solid material can sustain without causing any fracture when a load is applied gradually.

The building materials used in the modern-day constructions are very sensitive to humidity. Therefore, the measure of water absorption plays a major role in the durability of the porous materials. The movement of water in to concrete mainly depends on the diameter of pores, the distribution, and the continuity of the pores.

1.2 Objectives

- To identify the material properties of soil to be used as an aggregate in concrete production.
- To investigate the physical properties of lime/soil concrete.
- To propose the most suitable mix design for the production of lime/soil concrete.

2 LITERATURE REVIEW

The connection between lime and soil was initially reviewed, annotated, and summarized by Herrin and Mitchell in the year 1960 (H. Moreland & M. Henry, 1961). The review has indicated the valuable effects of the use of lime as a stabilization on the factors like workability, plasticity, and strength properties of soil. It has been found that in most of the case the strength has been increased and also the workability characteristic was improved. According to the studies made by Herrin and Mitchell at that time, the work they have published was primarily concerned on the various physical properties due to the effects of different types and various quantities of lime on the soils. With the amount of work done by these two researchers since 1960 it has involved in the nature of lime soil reaction products and the influence of the properties of natural soil properties on the reactions between lime and soil.

Dr. A. Anbuchezian et al. (A. Anbuchezian & Kumar, 2018) has studied the experimental work on Splitting Tensile Strength, Flexural Strength, and the Compressive Strength of concrete. In those experiments the cement has been replaced with lime powder and fine aggregates has been replaced with groundnut shell. In this research they have partially replaced the content of fine aggregate with groundnut shell varying in the range of percentages 5%- 20%. And the lime powder has been replaced instead of cement in general ration of 20%. They have concluded that for the groundnut shell contents of 5% and 10% the concrete has achieved a higher strength. Lime concrete with 20% of lime has achieved more strength than normal concrete.

B. T. Sapna et al. (B. T. Sapna & M. Aravindhraj, 2018) has also discussed the physical properties like Compressive and Splitting Tensile Strength of concrete by replacing the cement content with 0%, 5%, 10%, 15%, 20% of red mud and also with 5% of hydrated lime. Their conclusion has shown that the compressive strength of concrete has increased to a percentage of 17% by replacement of cement with 15% of red mud and for hydrated lime it has been 5% compared to normal concrete. The authors have seen that the compressive strength of the test cubes and the splitting tensile strength of the test cylinders have achieved the highest values for the optimum percentages of red mud and lime with 15% and 5% replacements.

Awodiji Chioma Temitope Gloria et al. (Gloria, Ogbonnaya, & Olujide, 2017) has investigated the Tensile and Flexural strengths of concrete by replacing cement with hydrated lime. In this recent study they have replaced cement with hydraulic lime with the percentages ranging from 5% to 30%. They have concluded that the highest value for Tensile and Flexural strengths have been recorded for the replacement of cement by 13.83% of hydrated lime and the strengths have been achieved after 28 days of casting.

K.Muthusamy et al. (K.Muthusamy & N.W.Kamaruzaman, 2012) integrated a new soil material as a partial replacement for coarse aggregate to reduce the high dependency on conventional aggregate in concrete production. Results of the study have showed with replacement of aggregate to an appropriate content the strength of concrete was achieved up to a considerable extent. The optimum amount of aggregate replacement was identified as 10% to produce a mix with comparable strength to plain concrete. Even with 30% of laterite replacement the target strength could be achieved according to the results from the study.

3 METHODOLOGY

3.1 Materials

Ordinary Portland Cement of strength class 42.5 N was adopted in all the experimental procedures. Hydrated lime was used as the cement replacement in the study. The soil selected for this study was Reddish Brown Laterite with a maximum aggregate size of 20mm which is locally available and easily accessible. The bulk density of this varied from 1500kg/m^3 – 1600kg/m^3. This soil has a past of being used for compressed earth blocks and a subgrade material in road constructions. These Laterites are formed as a result of a long-term tropical weathering process. It is classified as A-2-7 (0) in the AASHTO soil classification system. The soil was used without any modifications.

3.2 Mix Design

The mix design used in the process was the mix design for M30 grade of concrete using 42.5 grades Ordinary Portland cement that is used in the study. This mix design was performed as per BS Standard. The water/cement ratio for the mix was .55 Aggregates was used with a saturated dry condition of the surface, and this was helpful in calculating the water requirement more accurately and adjusting the amount of water according to the moisture content.

3.3 Aggregate Tests for Laterite Soil

Material tests were conducted on the laterite soil to compare the results with conventional aggregates and to determine the reasons for the deviations in soil concrete results with normal concrete. A sieve analysis was conducted on a sample of laterite soil according to BS 882 - 1992 to determine the distribution of particles because this will help in giving an idea to determine the compliance with the concrete design and the strength of concrete. Usually for a soil sample a wet sieve analysis is done to eliminate the fine particles as they contain more fines. But in this case since the soil is used as an aggregate a normal sieve analysis was done. The sieve sizes used for the test ranged from 20mm – 0.075mm. The AIV test was conducted on laterite particles passing the 14mm sieve and retaining on 10mm according to BS 812 – 113: 1990 to measure the resistance to sudden impact or shock. Water absorption test for the laterite soil was conducted according to BS 822 - Part 2 - 1995 to get an idea on the internal structure of the particles in the soil. This will provide the suitability of the material as an aggregate by the porosity of the sample in nature. The specific gravity of the laterite soil was found according to BS 822 - Part 2 – 1995 to measure the indirect density of the material. This parameter is required to identify the strength and quality of the aggregates. The following Table 3.1 shows the results obtained for Laterite Soil properties.

Table 3.1. Physical and mechanical properties of laterite aggregates

Property	Value
Specific Gravity	2.8
Bulk density	1500 - 1600kg/m^3
AIV	29.83%
Water absorption	8.60%

3.4 Fresh Concrete Tests

Slump, Temperature and Wet density was measured according to BS EN 12350 - 2: 2009 and BS 1881- 130: 2013 standards to make sure that the condition of the fresh concrete was maintained in the required standards.

3.5 Test Variables

A cost and strength analysis were done in order to find the most effective range of lime for replacing the cement. The strength analysis was done using the results of the past studies and the cost analysis was done by determining the percentage of cost saved from addition of lime compared to cement. Percentage range 10 – 20% can be selected as the most optimum variation of lime. The below Table 3.2 shows the variable percentage of lime used in the study.

Table 3.2. Test Variables

Concrete designation	Concrete Type	
	Cement	Lime
Soil / LC-0	100%	0%
Soil / LC-10	90%	10%
Soil / LC-15	85%	15%
Soil / LC-20	80%	20%

3.6 Casting

Test cube casting is usually done with two types of specimens either cubes of 15cm x 15cm x 15cm or using 10cm x 10cm x 10cm. This will be mostly dependent on the size of aggregates which are been used in the test. But under this case the cubic moulds of size 15cm x 15cm x 15cm was used.

A hardened soil cement mixture's primary structural criterion are appropriate strength and durability. Mixing proportions for soil cement was according to the BS test standards. Lime was used as a partial replacement for cement, and it was used in different percentages. For this study amount of lime used was 10%, 15% and 20% by the weight of cement. For each percentage at least three cubes were casted and three each for the testing days.

The concrete was poured into the moulds and properly tampered so that it will ensure to not have any voids in the mix. Each cube was marked with a proper identification on the top of the test cubes. After casting the test cube samples were left undisturbed for 24 hours. After 24 hours the moulds were open, and the test cubes were immersed in water for curing until the cubes are taken for testing. Top face of the test cubes should be made even and smooth. This can be done by applying cement paste on top of the face and spreading them smoothly on the whole area of the specimen. The water used for the curing purpose was tested every seven days, this is done to ensure the temperature of the water and it was maintained at 27 +- 2^{o}C.

The specimens for splitting tensile tests were prepared using a cylinder. The length of the cylinder shall not be less than that of the diameter and also should be less than twice the diameter. The dimensions of the cylinder used in this case was 150mm in diameter and 300mm in length. Moulds used for this, and cube casting were coated with mould oil to prevent adhesion of concrete. Figure 3.1 briefly demonstrate the above processes.

Figure 3.1 Concrete Casting and Curing

3.7 Harden Concrete Tests

Compressive strength, splitting tensile strength, Water absorption and Dry density tests were conducted accordance with to BS 1881 - 116: 1983 and BS EN 12390 – 6: 2009 standards to determine the physical properties of soil concrete.

4 RESULTS AND DISCUSSION

4.1 Fresh Concrete Test Results

Table 4.1 Fresh Concrete Test Results

Fresh Concrete Test Results				
Concrete Designation	**Concrete Type**	**Slump (mm)**	**Temp.**	**Wet density (kg/m^3)**
C30 Normal	Cement 100%	143	25.7	2489.0
Soil / LC-0	Cement 100%	45	26.4	2055.3
Soil / LC-10	Cement 90%, lime 10%	40	26.3	2074.1
Soil / LC-15	Cement 85%, lime 15%	30	25.6	2288.9
Soil / LC-20	Cement 80%, lime 20%	30	24.6	2362.9

The above Table 4.1 shows the variation of Slump, Temperature, and the Wet density of the soil concrete with the increase of lime. When the slump value of normal concrete mix is compared with the control mix of soil concrete there can be seen a significant drop in the workability. This shows that the laterite soil aggregate is less workable than the normal concrete even with the equal amount of water cement ratio. This implies that the soil aggregate requires more amount of water to gain the required workability probably due to high rate of water absorption than the conventional aggregates. The water absorption results obtained for the soil supports to the consistency of the concrete. Number of voids in the aggregate or the higher porosity may have result in the decrease of slump.

Similar results can be seen when the slump of different percentages of lime is compared. When the amount of lime increases the slump decreases. This is because lime is produced from limestones which has the property of hydration and high-water absorption, and this means that to gain the binding property of lime it requires more water in the reaction thus decreasing the workability of concrete.

When the temperature of normal concrete mix and the soil mix in the Table 4.1 is compared a rise in temperature can be observed. The rise in temperature might have been since when the laterite is mixed with cement it releases more amount of heat than the normal aggregates. Usually, the temperature is expected to increase with the addition of lime as the reaction is exothermic and more heat is generated due to the reaction of lime with water. But in this case the change might have occurred due to the properties of soil affecting in the lime mixture. High temperature values in the mix can cause to loss in workability and can severely affect the durability of the concrete by increasing the number of voids. This will also results in the decrease in slump. With addition of 15% of lime the results have shown a similar temperature value to the normal concrete. This is an advantage in the process of lime addition to decrease the negative impacts from temperature rise in the soil concrete mix. Ambient temperature may also have affected in these results.

When the results of wet density of the soil concrete in the above Table 4.1 is compared with the C30 normal concrete the values have decreased. A sudden drop can be seen in 0% lime mix but gradually increased with the lime percent increasing. This shows that lime has positively affected the soil and cement mix in the initial stage of concrete. The addition of lime has increased the wet density of concrete therefore that will also affect the durability and the water absorption of the harden concrete. But this cannot make any conclusion on the strength of the soil concrete but with these results it can be concluded that when soil is used for concrete less voids are formed in the concrete mix making the wet density low.

4.2 Compressive Strength

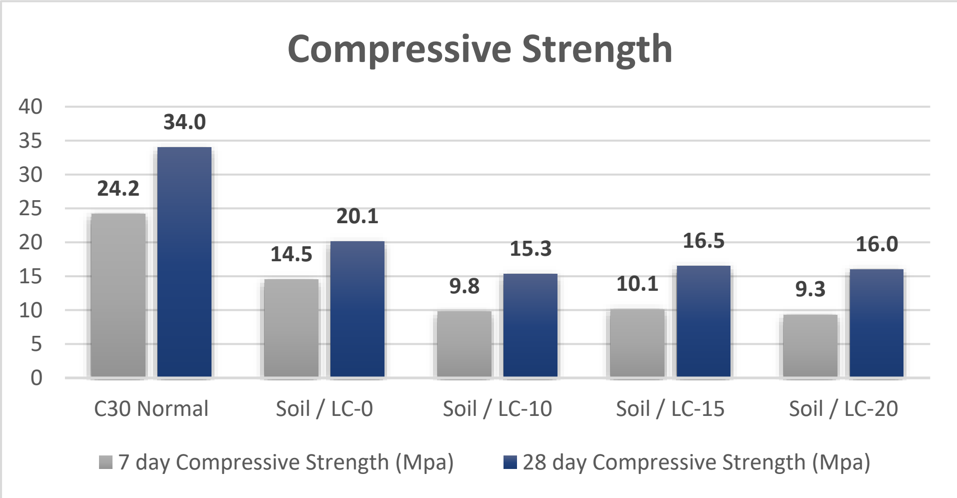

Figure 4.1 Compressive Strength Test Results

As shown in the Figure 4.1 from the results obtained a clear trend can be seen for the different values of lime. All the samples have shown a continues development in the strength as the curing age increases. Similar results can be seen from both 7 and 28 days. The maximum strength for the soil concrete is seen in the mix with 0% lime and the optimum lime content can be observed as 15%. The replacement of lime beyond 15% has caused strength reduction in the concrete. Addition of too much lime has resulted in losing the bonding ability of the mix. The continuous water supply has not affected the soil by enhancing any clay properties thus decreasing the strength. Initially in the strength gain a 50% strength from the final expected value was gained in 7 days and only 15% was gained in the next 14 days. This shows that soil concrete has a high initial strength gaining capability. According to the standard the 7-day strength is within the range of 70 – 75%. Therefore, this value is considerably satisfied for a soil concrete. A maximum value of 20.1MPa was obtained for the lime replacement of 0% in 28 days and the least was obtained for 10% replacement of lime with a value of 15.3MPa. The main reason for these values is due to the physical properties of the laterite aggregate compared to the traditional aggregate in denseness, surface texture, hardness, and shape. With further improvements or modifications of the laterite aggregate better results could be obtained compared to normal concrete.

4.3 Splitting Tensile Strength

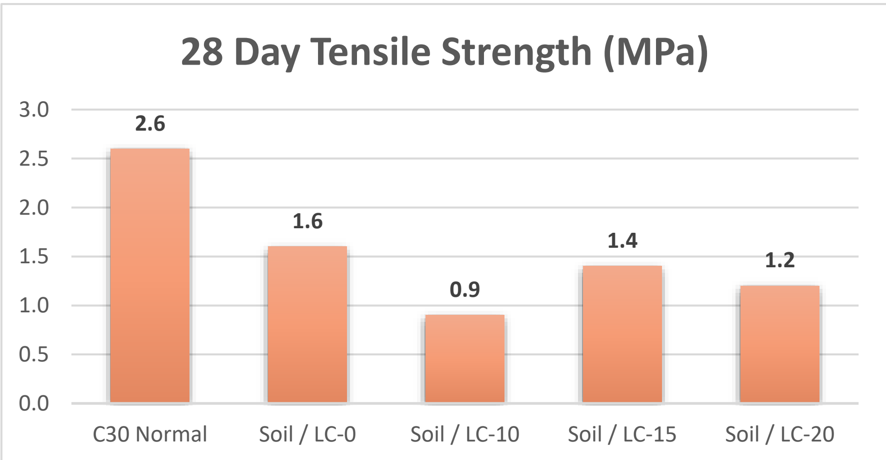

Figure 4.2 Splitting Tensile Strength Test Results

According to Figure 4.2, obtained results for tensile strength shows a similar variation to the compressive strength. The results are comparatively low when compared with the C30 normal concrete mix. But as the rule of thumb for tensile strength of concrete is 5% to 10% of its compressive strength, the obtained tensile strength values for all the mixes are in the acceptable range. When the lime replacements are compared with each other the results show that for 0% replacement of which has produced the maximum results of 1.6MPa even for the optimum lime percentage the strength is almost similar with a value of 1.4MPa. this shows that addition of lime has not affected the tensile strength as for the compressive strength. Also, the strength decrease percentage is lower than that of compressive strength for the comparison between normal concrete mix and soil concrete mix. The results may have slightly varied due to the preloading micro cracks that could have developed in cylinders.

4.4 Water Absorption

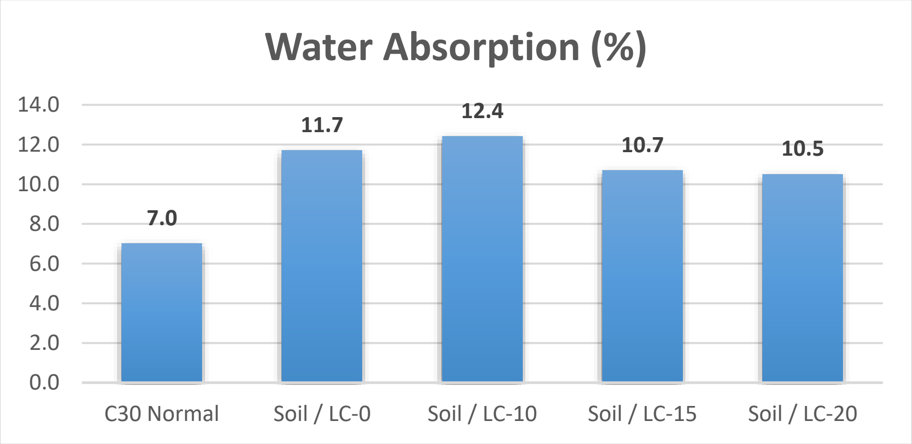

Figure 4.3 Water Absorption Test Results

As shown from the above results in Figure 4.3 the C30 normal concrete mix has the lowest water absorption percentage which depicts the fact that lower the water absorption better the results. When the soil concrete results are compared with each other addition of more lime decrease the water absorption and therefore increase the durability of concrete. Mix with 0% lime has a higher water absorption and the lowest can be seen in 20% lime replacement. This shows that soil only will not give overall results for the durability of concrete, but lime have the ability to stabilize the soil cement mix thus increasing the durability. When considering the tensile and compressive strength results the most suitable lime content can be identified as 15% which has given the optimum results in this study

4.5 Dry Density

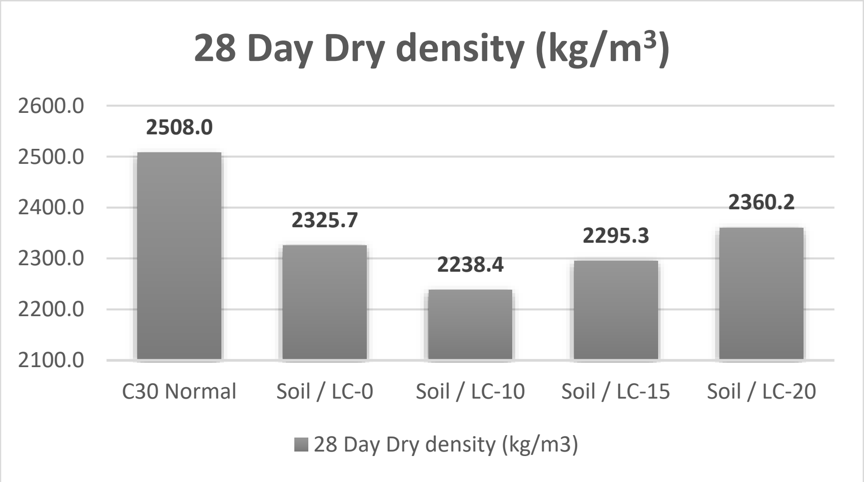

Figure 4.4 Dry Density Test Results

According to the results shown in the Figure 4.4 the density of C30 normal concrete was more than the average value. When the soil concrete values are compared with the control mix value a significant drop can be observed. This is due to the unit weight of the aggregate used. Soil contains more finer particles than sand and metal which can lead to lesser weight in concrete. Among the results of the varying lime percentages, initially 10% lime has decreased the density more than just soil concrete. But with the increase of lime percentage the dry density values have increased. This shows that lime contributes more on the weight than cement when mixed with soil. Lime has the ability to positively influence the density of soil concrete which can result in providing higher strength and decreasing the number of voids and porosity. When the number of voids in concrete decreases, it becomes less permeable to water and other soluble elements. This property in Lime/Soil concrete can contribute to increasing the durability where its lower in than normal concrete. The water absorption property also gets reduced due to this reason. In conclusion it can be understood that even though soil can decrease the unit weight of concrete, lime can maintain an acceptable weight in soil concrete.

5 CONCLUSIONS

This aim of this research was to optimize the compositions of lime as partial replacement of cement while completely replacing the coarse and fine aggregates with a soil to find the influence on the physical characteristics of concrete. Production of concrete can be done using different types of alternative materials specially for cement. The aggregate type and the bonding material are the most important concerns in physical characteristic of concrete. Lime has become a cheap and ecofriendly material from the early stages. Even though lime is used as an alternative material the integration of a new material as a replacement for conventional coarse and fine aggregate has been limited. The cost for concrete production and the ecological imbalance due to the high dependency of the conventional aggregates has been the leading factor in conducting this type of a research.

According to the results of this study it was able to produce concrete with a soil aggregate that could provide a Compressive strength 20MPa and a tensile strength of 1.6MPa. Material testing of the laterite soil aggregate has shown satisfactory results compared to the conventional aggregates. But the acceptable workability was not obtained from soil aggregate therefore the water cement ratio is required to be increased in order to maintain a proper workable concrete. The optimum lime content was found as 15% as it gave the maximum mechanical properties among the lime replacements. Even though addition of lime slightly decreased the strength results, from some of the test it was concluded that the lime was able to enhance the properties of concrete which was reduced due to the soil aggregate. The rate of increase of compressive strength was higher at early ages as the lime content is increased.

Concrete produced in this study has shown satisfied properties which can be used in application like ground improvements in pavement design and producing an economical Non-Load Bearing Concrete block which would increase the ecological value and the sustainability of future constructions. With the initial investigation of the soil aggregate and the results obtained from this research the future studies will be able to better assess the long-term effects of construction operations on the environment.

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