

# Developing Suitable Proportions for the Production of Pineapple Leaf Fibers Reinforced Normal Strength Concrete

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## Abstract

The present work tried to develop suitable proportions for the production of Pineapple Leaf Fibers (PALF) reinforced Normal Strength Concrete (NSC), an experimental analysis with a mix ratio of 1:1.84:3.27 for cement: fine aggregates: coarse aggregates with constant water to cement ratio of 0.54. The total volume per mixing batch was calculated of 9 cubes + 9 cylinders + 3 beams in order to know the number of materials to be used in casting per batch, and the PALF percentage was taken based on cement weight whereby it starts from the lowest to the maximum as follow 0%, 0.2%, 0.4%, 0.6%, 0.8%, and 1%. The tests that were done on fresh concrete were compacting factors and workability using the slump test which was carried out on each fresh mix of concrete. The results showed that PALF can be used to improve the Tensile and Flexural properties of Normal Strength Concrete.

## Keywords

Pineapple Leaf Fibers, Tensile Strength, Compressive Strength, Flexural Strength, and Water Absorption

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## 1. Introduction

The construction industry is one of rapidly growing industries across the world. In this industry, concrete plays an inherent role and is the most widely used manmade construction material. Concrete will continue to be the leading construction material all over the world due to its versatile advantageous properties

such as good compressive strength, and high mould ability, plastic and malleable when fresh and durable, impermeable and fire resistant when hardened [1] [2]. Concrete is therefore used for advanced applications, design and construction techniques such as building houses, bridges, dams, pavements, stadiums, retaining structures, airports and skyscrapers. However, NSC has some undesirable properties like being weak in tension, brittleness, less resistance to cracking, low impact resistance and heavy weight, hence there is a need to improve the concrete properties [3] [4]. Pineapple Leaf Fibers (PALF) are more compatible natural fiber resource and constitutes a good chemical composition [5]. PALF are a vital natural fiber, which have a high specific strength, rigidity, flexural and torsional rigidity than other fibers; seen all these advantages of PALF and since no one has developed suitable proportion of production of PALF reinforced on NSC it is time to try such fiber. Natural fibers have the advantages of low density, low cost, and biodegradability. When concrete cracks, the randomly oriented fibers start functioning, arrest crack formation and propagation, and thus improve strength and ductility. Natural fibres from pineapple leaves are a good option to study because of their high tensile strength and high cellulose content [6]. The use of PALF reinforcement in construction materials can enhance structural strength and toughness, and this can reduce cracking and shrinkage [7]. Hence this study was made to develop a suitable proportion of production of PALF on properties of NSC.

## 2. Materials and Methods

The methods adopted and followed for this study are discussed in the subsequent section. The most important test methods and standards are summarized in **Table 1**, The materials used in this study were coarse aggregates, fine aggregates, Ordinary Portland Cement (OPC) grade of (42.5 N) East African Standard KS EAS 18.1 was used in the study and water, all of them were collected from Kenya. The PALF materials were obtained from Hand Conifer Company Ltd, Mumbai, India. The fibres were extracted from the leaves by using a mechanical extractor machine [8]. Coarse aggregates were obtained locally and those conforming to BS EN 109-1 specification and limited to a maximum size of 25 mm

**Table 1.** Test methods adopted.

Test on Constituent materials of NSC		Test on fresh and hardened NSC with PALF	
Test Performed	Standard Used	Test Performed	Standard Used
Sieve Analysis	BS EN 109-1	Slump	BS EN 12350-2
Aggregate specific gravity	BS EN 1097-6	Compacting Factor	BS 1881-103
Fineness modulus	ASTM C136	Water absorption	BS EN 12350-3
Cement Specific Gravity	BS EN 197-1	Compressive strength	BS EN 12390-3
Aggregate water absorption	BS EN 1097-6	Split tensile strength	BS EN 12390-6
Consistency & Setting Time of Cement	BS EN 197-1	Flexural strength	BS EN 12390-7

were used. They were first washed to remove the dust and dirt, and then dried to surface dry condition before use in the mix. The fine aggregates used was river sand obtained locally from Meru, in Kenya and was then sieved through a 10 mm sieve to remove any coarse particle before use. The materials were batched by weight at a ratio of 1:1.84:3.27 with respect to OPC: fine aggregates: coarse aggregates with a constant water/cement ratio of 0.54, they were then mixed and after PALF were added to the mix at percentages of 0%, 0.2%, 0.4%, 0.6%, 0.8%, and 1% of cement weight and finally water added to form a paste. On each fresh mix of concrete both workability was determined using the slump test and compacting factor was determined using two conical hoppers having a hinged trap door attached to the lower end of each hopper, allowing the concrete sample to flow freely into the cylindrical mould in accordance with BS EN 12390-6. The mixture was then cast into greased cubes of  $150 \times 150 \times 150$  mm, cylinders of 150 mm diameter and 300 mm height and beams of and then compacted using a poker vibrator after which was left to set for 24 hours and then demoulded and placed in curing tanks for 7 days, 14 days and 28 days of curing period [9] [10]. The concrete cubes, the cylinders and beams were tested for compressive strength, splitting tensile strength and flexural strength using the universal testing machine at 7 days, 14 days and 28 days in accordance with European Standards of BS EN 12390-3 and Water absorption at 28 days accordance to BS EN 12350-3.

### 3. Material Characterization

#### 3.1. Coarse and Fine Aggregates

The fine aggregates used was river sand sieved on a 10 mm BS sieve to remove any coarse particles and the fine aggregates were ranging from 0.15 mm (150  $\mu$ m) to 10 mm. The coarse aggregates used were crushed angular shaped rocks ranging from 2.36 mm to 25 mm. **Table 2** shows the physical properties of both the coarse aggregates and the fine aggregates that were carried out. From these results, the conclusion was made that both aggregates satisfied the standards and therefore could be used in the production of Normal weight concrete reinforced with PALF.

**Table 2.** Physical properties of coarse and fine aggregates.

Properties	Fine aggregates	Coarse aggregates
Particle size	0.15 mm - 5 mm	2.36 mm - 25 mm
Specific gravity	2.67 g/cm <sup>3</sup>	2.78 g/cm <sup>3</sup>
Water absorption	5.78%	2.25%
shape	-	Angular
Surface texture	-	Rough
Moisture content	2.21%	2.06%
Fineness modulus	2.41%	-

Source: BS EN 109-1.

### 3.2. Ordinary Portland Cement (OPC) I 42.5 N

**Table 3** shows the physical properties of the cement used in the study as compared to the requirement as per BS EN 197-1 Methods of physical tests for hydraulic cement (Determination of consistency of standard cement paste).

### 3.3. Pineapple Leaf Fibers

PALF were treated in 4% of Sodium Hydroxide Before chemical properties analysis and tensile strength of PALF (NaOH) solution over various duration NaOH is one of the best treatment of natural fibers, in increasing fibers roughness by chemically modifying and cleaning the fibre surface [11] [12]. **Table 4** shows the chemical properties that were determined. In this way, three containers (dishes) were put in oven dry for 10 minutes to be cool. The three samples were ready for the experiment, after that, they were weighted. The samples of PALF were added on the three dishes and weighted. To calculate the moisture content it was necessary to put them in oven dry for 3 hours, and then after weighing them to see the weight after drying our 3 samples. In accordance with ASTM D854-9 the PALF were cut in equal length of 30 mm and 0.052 mm of diameter.

Wt. A = weight after 12 h of even dry 40°C using C<sub>2</sub>H<sub>5</sub>OH

Wt. B = weight after 12 h of even dry 80°C using KOH

Wt. C = weight after 12 h of even dry 80°C using H<sub>2</sub>SO<sub>4</sub>

**Table 3.** Physical properties of ordinary Portland cement.

Properties	Description	Requirement as per EN197-1
Standard consistency	31.5%	26% to 33%
Specific gravity	3.14	3.1 to 3.16 g/cm <sup>3</sup>
Initial Setting Time	138 min	Not less than 60 min
Final Setting Time	229 min	Not more than 600 min
Soundness	0.8 mm	Not more than 10 mm
Color	Grey	-
Specific gravity	3.14	3.1 to 3.16 g/cm <sup>3</sup>

Source: BS EN 197-1.

**Table 4.** Chemical properties of PALF.

sample	smp wt	glass wt	glass + smp	wt. A	wt. B	wt. C	cellulose	hemicellulose	lignin
A	1.007	31.7241	32.7311	32.8743	32.5838	32.2444	33.704	28.848	32.2444
B	1.009	31.9622	32.9712	33.1588	32.8394	32.4612	37.483	31.655	32.4612
C	1.004	31.3027	32.3067	32.5025	32.2354	31.9047	32.898	26.643	31.9047
						mean	34.695	30.252	32.353
						stdev	2.672	2.512	0.281

Source: The chemical properties (*i.e.*, proportions of cellulose, hemicellulose and lignin) of the treated four (4) fibers samples were determined based the procedure described by Direct method of cellulose, hemicelluloses and lignin [6] [13].

### 3.4. Water

Water Ordinary portable water conforming to BS 1348-2 (1980) available in the laboratory with a pH of 8.1 was used in the study for mixing and curing of concrete mixes.

## 4. Results and Discussion

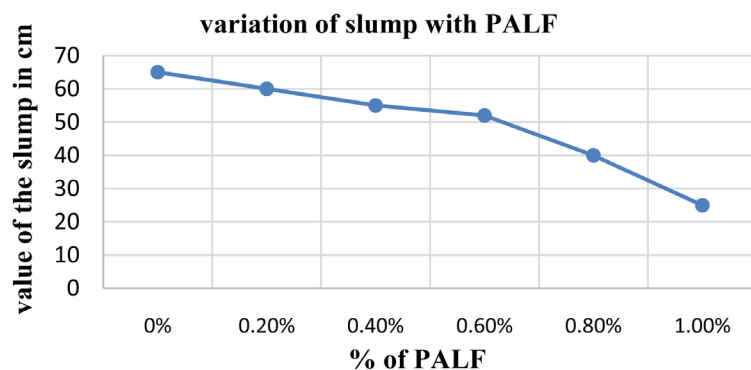
### 4.1. Workability of Normal Strength Concrete with PALF

Determination of workability in this study was done by the slump test which was carried out in triplicate on every mix that was made and an average value obtained. Results of the slump test are presented in **Figure 1** showing the average slump for each mix versus the percentage addition of PALF in the mix [14].

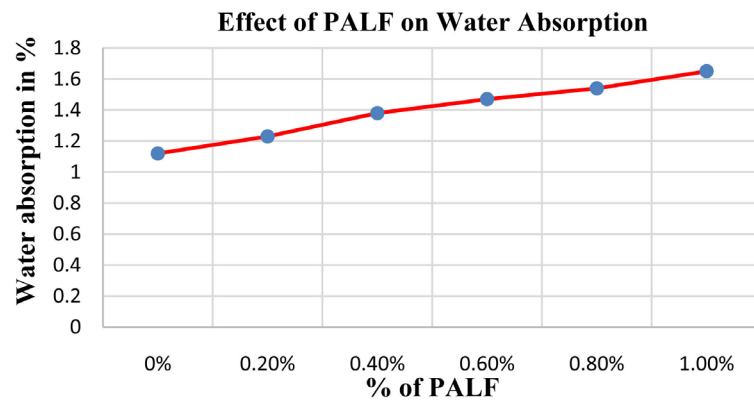
Considering a constant water/cement ratio of 0.54 which was used in the mix design, as seen from **Figure 1**, as the content of PALF was increased in the mix, there was a reduction in the workability levels as reported by a reduction in the slump values from 65 cm for normal concrete at percentage reductions of 7.69%, 15.38%, 20%, 38.46%, and 61.53% for 0.2%, 0.4%, 0.6%, 0.8% and 1% PALF addition respectively as compared to the control. As there was a reduction in the slump with the addition of PALF in the mix, the concrete remained workable in nature. This reduction in a slump of concrete was attributed to the presence of fibers in the mix as they lump on each other reducing the slump while the mixture is still workable. Also, a reduction in the workability of fresh concrete may be caused by an adhesion within the concrete and holding the other ingredients of concrete together impeding easy flow. Therefore the mix required more compacting effort to achieve proper compaction as this would directly affect the density, strength, water absorption and hence the durability of the hardened concrete.

### 4.2. Water Absorption of Normal Strength Concrete with PALF

As portrayed in **Figure 2**, PALF incorporation in the concrete mix increased the water absorption of the mixes as the control had the least water absorption whereas there was a subsequent increment as the PALF were increased in the mix.



**Figure 1.** Variation of a slump with PALF.



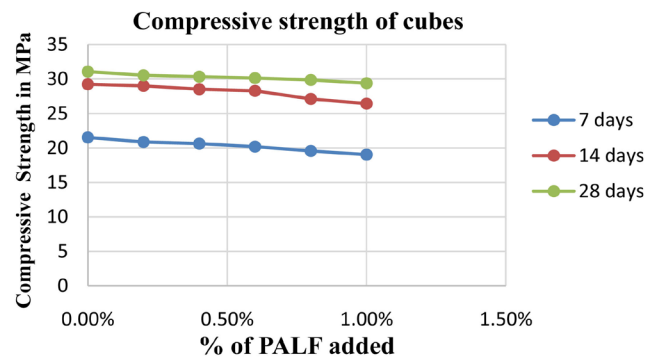
**Figure 2.** Effect of PALF on water absorption.

PALF added at percentages of 0.2%, 0.4%, 0.6%, 0.8% and 1% had a percentage increase in the water absorption of 9.82%, 23.21%, 31.25%, 37.50% and 47.32% respectively as compared to the control mix (0% PALF). The increment in water absorption as the PALF are increased could be as a result of the poor compaction leading to poor bonding as a result of the smooth texture of the fibers and this increased the number of pores in the concrete specimen causing it to absorb more water.

#### 4.3. Compressive Strength of Normal Strength Concrete with PALF

Compressive Strength of concrete with PALF [15] a reduction in compressive strength was recorded for both the 7 days, 14 days and 28 days though there was an increase in compressive strength with curing time as 28 days compressive strength values were greater than those at 7 days and 14 days curing. Percentage reductions of 3.07%, 4.21%, 6.19%, 9.14%, and 11.60% at 0.2%, 0.4%, 0.6%, 0.8% and 1% PALF additions respectively were obtained as compared to the control mix at 7 days testing, where as 1.81%, 2.47%, 3.24%, 3.87%, and 9.59% at 0.2%, 0.4%, 0.6%, 0.8% and 1% PALF additions respectively as compared to the control mix were obtained at 14 days testing, where as 1.72%, 2.37%, 3.01%, 3.82% and 5.48% percentage reductions at 0.2%, 0.4%, 0.6%, 0.8% and 1% PALF additions respectively were obtained as compared to the control mix at 28 days curing time. From these results (**Figure 3**) it can be seen that PALF addition had the less percentage reduction in compressive strength compared to normal strength concrete and therefore it offers better compressive strength properties as compared to other percentages of 0.8% and 1% PALF.

From these results, the conclusion can be made that the addition of PALF in normal strength concrete reduces its compressive strength. This could be attributed to the adhesion properties due to the smooth texture of the PALF in the mix which reduces the bonding properties of the concrete mix and hence more compacting energy is required to achieve the desired compressive strength of the concrete. Therefore PALF cannot be used to enhance the compressive strength properties of normal weight concrete.



**Figure 3.** Effect of PALF on the compressive strength of concrete.

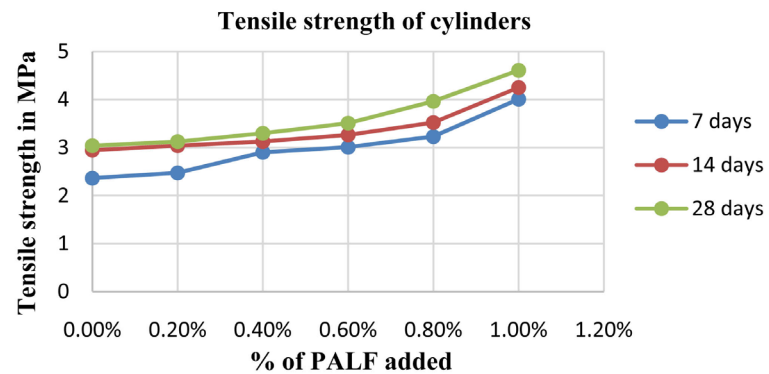
#### 4.4. Splitting Tensile Strength of Normal Strength Concrete with PALF

The Splitting Tensile Strength at all percentages of PALF addition increased with curing time as 28 days at each percentage had a larger Splitting Tensile Strength value than those at 7 days and 14 days curing. There was a significant increment in the tensile splitting values at 1% PALF for 7 days, 14 days and 28 days curing times. There were percentage increment of 4.61%, 22.76%, 27.29%, 36.60% and 69.61% for 0.2%, 0.4%, 0.6%, 0.8% and 1% PALF additions respectively were obtained as compared to the control mix at 7 days curing time, where 3.15%, 16.07%, 23.76%, 39.45%, and 54.19% for 0.2%, 0.4%, 0.6%, 0.8% and 1% PALF additions respectively were obtained as compared to the control mix at 14 days testing, where 2.73%, 8.45%, 15.43%, 30.37%, and 51.62% for 0.2%, 0.4%, 0.6%, 0.8% and 1% PALF additions respectively were obtained as compared to the control mix at 28 days of curing time. **Figure 4** shows graphically an improvement in the splitting tensile strength as the percentage of PALF were added therefore incorporating PALF as reinforced fibers on the Normal Strength Concrete can also improve first crack strength and ultimate ductility index.

#### 4.5. Flexural Strength Test on Normal Strength Concrete with PALF

It was also observed that the flexural properties were improved comparing to the control mix of normal strength concrete as the percentage of PALF increased there was an increment of flexural strength value with curing time of 28 days. Results in **Table 1** show that there was an improvement in the flexural values at 1% PALF. There were percentage increment of 0.98%, 3.54%, 10.84%, 15.06% and 42.58% for 0.2%, 0.4%, 0.6%, 0.8% and 1% PALF additions respectively were obtained as compared to the control mix at 28 days curing time, but it was observed as shown in **Table 5** that the compaction factor was reduced as the percentage of PALF increased.

The PALF have increased the strength of the normal strength in tensile and flexure more than in compressive, this is showing that the PALF acted more in traction than in compression within the composite.



**Figure 4.** Effect of PALF on the splitting tensile strength of concrete.

**Table 5.** Effect of PALF on the flexural strength of concrete.

Batch	% of PALF	Slump	Compacting factor	Flexural at 28 days
1	0.0%	65 cm	0.930	4.142 Mpa
2	0.2%	60 cm	0.927	4.183 MPa
3	0.4%	55 cm	0.920	4.289 MPa
4	0.6%	52 cm	0.880	4.591 MPa
5	0.8%	40 cm	0.850	4.766 MPa
6	1.0%	25 cm	0.780	5.096 MPa

## 5. Conclusions

From this experimental investigation, the following conclusions can be made:

- 1) PALF have shown that they can contribute to the construction field on Normal strength Concrete, they can reduce cracks in the structure and improve the tensile and flexure properties of NSC.
- 2) According to the experimental work, PALF reinforced NSC have a limitation when their percentages increase more than 1% of cement weight, the Normal Strength Concrete will not be workable.
- 3) The best percentage to be used is from 0.2% to 0.8% because it is where the slump was in range, it was found that PALF cannot be used to enhance compressive strength and water absorption.

## 6. Recommendations

From this experimental study, the following recommendations were made: For Possible Applications:

1) **PALF** can be utilized in Normal Strength Concrete to improve the split tensile strength and flexural strength in the production of structural of NSC especially where crack control is a concern especially in water retaining structures.

2) **Further studies:**

- a) Investigations should be made on how to improve the bonding properties



of the PALF reinforced Normal Strength Concrete.

b) The study at the durability aspect of PALF reinforced Normal Strength Concrete should also be studied.

### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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