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Research Paper

Physical Characteristics and Compressive Strength of Raffia Fibre Reinforced Sandcrete Blocks

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This study investigated the effect of raffia palm fibres on the compressive strength of solid sandcrete blocks. The (120 x 120 x 100) mm sandcrete blocks were reinforced with 1%, 2%, and 3% raffia palm fibre, and cured with irrigation method. At each testing day (7, 14, 21 and 28 days after moulding), the physical characteristics (density, water absorption and swelling rate) and compressive strength of the blocks were tested. The test results obtained showed that fibre size had no significant effect on the compressive strength, water absorption and swelling rate of the blocks. But fibre volume had significant ($P \leq 0.05$) on the compressive strength, water absorption and swelling rate of the blocks. The compressive strength generally decreased with an increase in the fibre volume, while the water absorption and swelling rate of the blocks increased with an increase in fibre content. At day 28, the compressive strength of the blocks was 3.15 N/mm², 2.49 N/mm², 2.065 N/mm², and 1.921 N/mm², for 0%, 1%, 2% and 3% raffia fibre content respectively. The water absorption rate was 7.82%, 8.53%, 10.85%, and 11.41% for 0%, 1%, 2% and 3% raffia fibre content, while the average density decreased from 1954.20 kg/m³ at 0% to 1522.35kg at 3% fibre content.

Keywords: Sandcrete block; raffia palm fibre; compressive strength, density, absorption

INTRODUCTION

Sandcrete block is made up of cement, fine aggregate (sand) and water, and can be moulded into different shapes and sizes. Freestanding walls and building structures with load bearing and non-load bearing sandcrete blocks are common in Nigeria because of their ease of construction and their affordability (Odeyemi *et al*., 2018). Sandcrete skin panels and blocks are sometimes used to provide aesthetics to buildings and serve as control to moisture infiltration and wind action (Alohan, 2012). This usefulness of sandcrete block in comparison to its cost and adaptability to climatic conditions makes it widely acceptable in many building constructions; especially in the countries within tropical rainforests, which experiences high precipitation and temperature (Odeyemi *et al*., 2015; Odeyemi *et al*., 2018). According to Anosike and Oyebade, (2012), two types of sandcrete blocks are specified by NIS, type A (load bearing blocks), and Type B (non-load bearing blocks). There are 4 main families of blocks; are solid blocks, hollow blocks, perforated blocks, interlocking blocks (Rigassi, 1995). About 90% of buildings constructed in West Africa are constructed with sandcrete blocks, making them important building material (Baiden and Tuuli, 2004; Anosike and Oyebade, 2012). After curing, sandcrete block has a relative high compressive strength; range of minimum strength specified in NIS 87:2007 is between 2.5N/mm^2 to 3.45N/mm^2, which increased with increase in density (Anosike and Oyebade, 2012). Sandcrete blocks are produced in many parts of Nigeria without reference to any international or national specifications (Anosike and Oyebade, 2012). According to Odeyemi (2012), sandcrete blocks are relatively cheap when compared to other construction materials. In addition, they have higher resistance to rusting, insect and pest attack, crumbling, and are non-hazardous when compared with other building materials (Odeyemi, 2012; Odeyemi *et al*., 2015).

Low cost construction materials are essential for the building of low cost housing estate for Nigeria growing population. Earth construction is cost effective, energy efficient, environmentally friendly and safe (Rigassi, 1995). The above-mentioned qualities are relevant and important with the ever growing need for increased awareness to reduce energy consumption worldwide (Adam and Agidi, 2001). Application of natural fibres as reinforcement materials in blocks, bricks and other cement composites used in building construction had been widely used for centuries. During the historic times, the Egyptians mud bricks were usually reinforced with horsehairs and straws, while Chinese and Japanese housing were reinforced with straw mats (Li, 2002). Raffia palm fibre is a long thin membrane obtained from the underside of raffia palm frond. Raffia fibre has many uses, especially in the textiles industries, it is also used in twine production, roof coverings and shoes production (Tucker *et al*, 2010; Uguru and Umurhurhu, 2018). Some unique properties of natural fibres are: biodegradability, recyclability, low density, good thermal properties, reduced tool wear, and enhanced energy recovery (Thakur *et al*., 2014). The US Department of Agriculture and the US Department of Energy had set goals of having at least 10% of all basic chemical building blocks be created from renewable and plant-based sources in 2020, increasing to 50% by 2050 (Mohanty *et al*., 2005; Yan, 2014).

Several researchers had worked on compressive properties of fibre reinforced sandcrete and stabilized earth blocks. Ugwuishiwu *et al*. (2013) investigated the influence of fibre reinforcement on water absorption of compressed stabilized earth blocks for its suitability in block production. Their findings showed that water absorption increased with percentage fibre content, ranging between 5.68% and 12.53%; as against the 5.65% value obtained in the control experiment. According to Adebakin *et al*. (2012), the percentage replacement of sand in sandcrete blocks should not exceed 10 % to achieve better results. The addition of fibres to concrete and sandcrete blocks influenced their mechanical properties, and significantly depend on the type and percentage of fibre reinforcement (ACI Committee 544, 1978; ACE Committee 544, 1982; Naaman, 1985). The use of fibres in reinforced concrete flexure members increases ductility, tensile strength, moment capacity, and stiffness. The fibers improve crack control and preserve post cracking structural integrity of members (Wafa, 1990). Yalley and Kwan, (2009) worked on the effect of coconut fibres on the compressive properties of concrete blocks. The possibility of using rice husk ash (RHA) in the production of sandcrete blocks was studied by Oyekan and Kamiyo, (2011) and Oyetola and Abdullahi, (2006). They reported that the optimum water/cement + RHA ratio increases with rice husk ash contents and that up to 40% RHA could be added as partial replacement for cement without any significant change in compressive strength at 60 days and 28 days respectively.

Although many studies have been conducted on the use of natural materials as main reinforcement in the sandcrete blocks, there is little information about the use of raffia palm fibre as reinforcement material in sandcrete blocks. Therefore, the main objective of this study was to investigate the influence of raffia palm fibre reinforcement on some physical characteristics (density, water absorption rate and swelling rate) and compressive strength of sandcrete blocks, to evaluate their suitability in building constructions.

MATERIALS AND METHODS

Materials

Cement

Dangote Portland cement was used for the study. The cement is of grade 42.5, in compliance with CEM II of NIS-444 Part 1 (NIS, 2003; Musa and Abubakar, 2018).

Water

The water used for the sandcrete blocks production was free of aquatic plants, foreign materials, inorganic salts, oil contamination, and was able meet the NIS 554:2007 standard recommendation (British Standard-3148; NIS 554:2007). Hydration occurs when water reacts with cement.

Fine aggregate (sand)

The fine aggregate used in this study was collected from the river Niger bed. The sand was sieved with 4.75 mm British Standard test sieves.

Fibre

The raffia palm fibres used for this were obtained from local market in Ozoro, Delta State, Nigeria. They were manually inspected to remove damage fibre before they were cut into different sizes (10 mm, 20 mm, 30 mm, 40 mm, and 50 mm). The fibre with average thickness ranged 0.027– 0.032 mm.

Methods

Mixing

A mix ratio of 1:7 (one part of cement to seven parts fine aggregate) was used for the sandcrete block moulding, while the water cement ratio was 0.5 as specified by (BS 6073). There was partial replacement of the fine aggregate

Table 1. Proportions of sand: raffia palm fibre mixing ratio.

Sand volume (%)	Fibre size (mm)	Fibre volume (%)
100 (control)	-	-
99	2	1
99	4	1
98	2	2
98	4	2
97	2	3
97	4	3

with raffia palm fibre, in the proportion shown in (Table 1). Cement to water ratio determines the workability and mechanical properties of sandcrete blocks.

Sandcrete block production

The solid sandcrete blocks with dimension (120 x 120 x 100) mm were produced with Portland cement, fine aggregate, and raffia palm fibre. During the sandcrete molding; cement, fine aggregate, and the raffia palm fibre (reinforcement material) were mixed thoroughly, before the required water quantity was added to the mixture to obtain a workable mortar. The mortar was then transferred to the standard mould and rammed seven times, before it was de-molded.

Curing

The blocks were cured by irrigation method twice daily (morning and evening), for 28 days. Curing was important to the sandcrete blocks because it facilitates proper hydration and hardening of the blocks.

Fine aggregate physical characteristics determination

Specific gravity

A specific gravity bottle was weighed and the value recorded, before it was filled to 75% volume with the fine aggregate, and weighed again. Distilled water was added to the bottle and its content up to the upper mark, before it was weighed again. The Specific gravity of the fine aggregate was calculated using equation 1.

$$SG = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)} \quad (1)$$

W_1 = Weight of the empty bottle
W_2 = Weight of the bottle filled with 75% of the total volume.
W_3 = Weight of the bottle and its content filled with distilled water up to the meniscus.
W_4 = Weight of the bottle filled with distilled water to the meniscus.

Fine aggregate sieve analysis

The sieve analysis of the fine aggregate was done to determine its particle size distribution. Before the test, the fine aggregate was air-dried for two week in the laboratory at ambient temperature of 28±4 °C. During the analysis, a set of British standard (BS) sieves, a pan and a weighing scale (XY Series, manufactured in China) were used. The sieves were arranged in descending order; the largest aperture sieve was placed at the top, followed by the smaller one, until the smallest aperture sieve was placed at the bottom. One kilogram of the fine aggregate was weighed with electronic weighing scale, poured into the sieves set from the top, before the sieves set was inserted into the mechanical sieve shaker. The machine was operated for twenty minutes, and the fine aggregate retained in each of the sieve was weighed and recorded. The cumulative weight passing through each sieve was calculated as a percentage of the total sample weight (Odeyemi *et al.*, 2018).

Sandcrete block physical characteristics determination

Water absorption capacity and swelling rate test

Water absorption is the ability of a sandcrete block to absorb moisture for the environment. The test was carried out as recommended by BS EN 771-1:2011 (Yan, 2104). Four sandcrete dried blocks were selected at random, weighed and measured with digital vernier caliper before they were completely immersed in water at ambient temperature for 24 h. At the end of the 24 h, they were brought out of the water, wrapped dry with trowel, measured and weighed again to calculate their water absorption and swelling rate. The water absorption capacity of the sandcrete blocks was calculated using equation 2, while the swelling rate was calculated using equation 3.

$$\text{water absorption} = \frac{M_a - M_b}{M_b} \times 100 \quad (2)$$

$$Swelling\ rate = \frac{V_a - V_b}{V_b} \times 100 \quad (3)$$

M_a = weight of block after soaking in water
M_b = weight of block before soaking in water
V_a = volume of block after soaking in water
V_b = volume of block before soaking in water

Sandcrete density determination

The sandcrete blocks were weighed at each test day (7, 14, 21 and 28 days), with electronic weighing scale (XY Series, manufactured in China), having accuracy of 0.01

Kg. The three principal dimensions (length, width and height) of the block were measured with a digital vernier caliper, having accuracy of 0.01 mm. Then the density of each block was calculated as the ratio of the weight to the volume (L x W x H) of the block, as shown in equation 4.

$$Density = \frac{Mass}{Volume} \quad (4)$$

Sandcrete block compressive properties determination

Compressive strength test

The compressive strength of the sandcrete block was done in accordance with (NIS-87, 2004), with the aid of Concrete Compression Testing Machine (STYE 2000), manufactured in China. The tests were carried out at 7, 14, 21, and 28 days of moulding. During the testing process, each block was clamped to the compression cell of the machine, and compressed gradually until failure occurred (Figure 1). At the end of each test, the compressive force was read from the machine, and the compressive strength of the block calculated. The compressive strength of the sandcrete blocks was calculated by dividing the crushing load divided by the effective surface area of the block, as shown in equation 5.

Figure 1. Sandcrete block undergoing compressive test.

$$Compressive\ strength = \frac{Crushing\ load}{Effective\ surface\ area\ of\ block} \quad (5)$$

All the tests were carried out at the concrete laboratory of the Department of Civil Engineering Technology, Delta State Polytechnic, Ozoro, Nigeria. Four blocks of each sample were tested and the average value was recorded.

Statistical analysis

The results obtained from this study were subjected to Analysis of variance using SPSS statistical software (version 20.0, SPSS Inc, Chicago, IL). Then the mean were separated using Duncan's Multiple Range Tests at 95% confidence level.

RESULTS AND DISCUSSION

Fine aggregate grading and specific gravity

The result of the particle size distribution of the fine aggregates is shown in (Figure 2). As shown in (Figure 2) the fine aggregate was well graded and met the NIS 87:2000 requirement, recommended for sandcrete blocks production. Results obtained from specific gravity test of the fine aggregate are presented in (Table 2). From the result (Table 2), the specific gravity of the fine aggregate was a little bit lower than the minimum value of 2.6 specified for natural aggregates (Neville, 2011).

Analysis of variance

The Analysis of Variance (ANOVA) results of physical characteristics and compressive strength of the fibre reinforced sandcrete blocks are in (Table 3). From the ANOVA results (Table 3), raffia fibre size did not significantly ($P \leq 0.05$) influenced the water absorption, swelling rate, density and compressive strength of the sandcrete blocks. However, fibre loading rate (volume) and curing period had significant effect ($P \leq 0.05$) on the water absorption, swelling rate, density and compressive strength of the sandcrete blocks. According to (Table 3), the interaction of fibre size by loading rate and curing period by fibre size did not significantly ($P \leq 0.05$) influenced the physical characteristics and compressive strength of the sandcrete blocks. Furthermore, the results showed that smaller fibre size (2mm) produced a little bit higher compressive strength and physical characteristics than the larger fibre size. This could be attributed to the better adhesion force smaller particles had in a matrix (mortar), to produce a homogenous entity than larger particles.

Compressive strength

The compressive strength results of the sandcrete blocks as influenced by fibre reinforcement are presented in (Figure 3). As seen in the results, the compressive

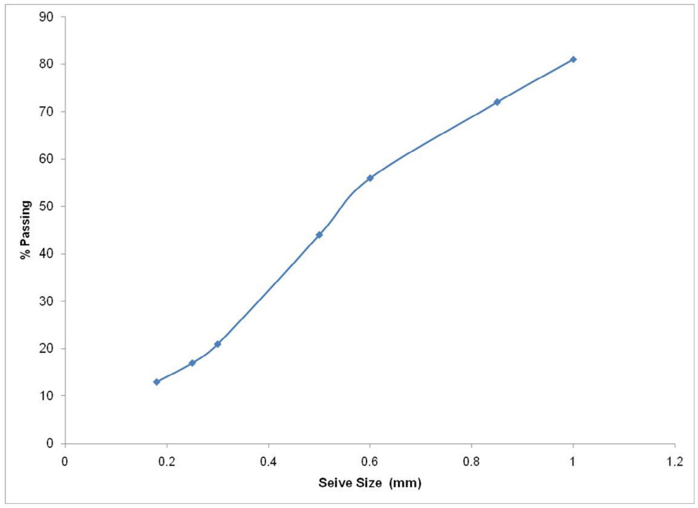

Figure 2. Particle size distribution of the fine aggregate.

Table 2. Specific Gravity of Soil Samples

W_1	W_2	W_3	W_4	Specific gravity
19	83.8	112.7	73.5	2.53

Table 3. ANOVA for response of physical characteristics and compressive strength of raffia fibre reinforced sandcrete blocks.

Source of variation	Compressive strength	Water absorption	Swelling rate	Density
Size	0.0644^{ns}	0.0553^{ns}	0.0891^{ns}	0.0563^{ns}
Loading	3.07E-25*	3.00E-73*	1.12E-62*	2.24E-22*
Curing	3.59E-41*	2.97E-73*	1.79E-54*	1.24E-38*
Size x Loading	0.3001^{ns}	0.2544^{ns}	0.7272^{ns}	0.4525^{ns}
Size x Curing	0.9691^{ns}	0.1696^{ns}	0.8256^{ns}	0.4327ns
Loading x Curing	5.28E-03*	6.27E-37*	2.62E-07*	4.07E-09*
Size x Curing x Loading	0.9109^{ns}	0.8042^{ns}	0.9987^{ns}	0.7834^{ns}

* =Significant (P ≤ 0.05); ns = non-significant (P ≤ 0.05).

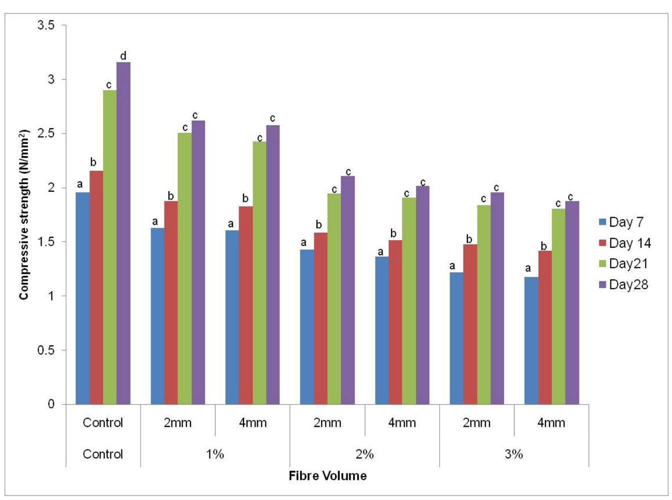

Figure 3. Effect of fibre volume and size on the compressive strength of sandcrete block. Columns with the same common letters means that they are not significant different at (P ≤0.05).

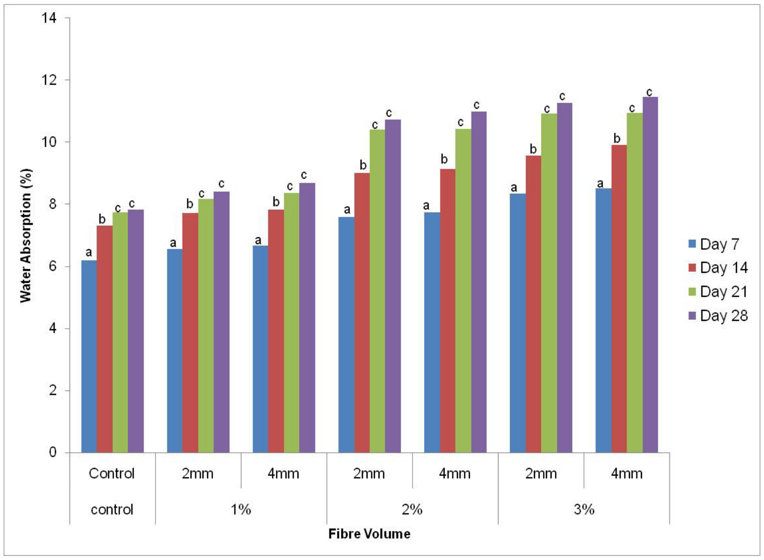

Figure 4. Effect of fibre volume and size on the water absorption of sandcrete block. Columns with the same common letters means that they are not significant different at (P ≤0.05)

Table 4. Effect of fibre volume and size on the density of sandcrete blocks.

Proportion		**Density (Kg/m^3)**			
Fibre volume	**Fibre size mm**	**Day 7**	**Day 14**	**Day 21**	**Day 28**
Control (0%)	-	2001.2^a	1979.3^a	1954.2^a	1954.2^a
1%	2	1912.3^b	1879.2^b	1804.5^b	1714.6^b
	4	1903.5^b	1857.7^b	1800.3^b	1702.9^b
2%	2	1901.9^c	1826.7^c	1773.8^c	1624.5^c
	4	1897.3^c	1811.9^c	1761.5^c	1618.6^c
3%	2	1883.5^d	1767.4^d	1687.1^d	1527.8^d
	4	1873.7^d	1756.2^d	1672.3^d	1516.9^d

Means having the same superscripts in the same column are not significantly different (P ≤0.05), using Duncan's Multiple Range Test.

strength of the blocks decreased significantly (P ≤ 0.05) with increase in fibre volume. From the results, sandcrete blocks reinforced with low fibre volume fall within the allowable compressive strength limit, for non-load bearing walls. According to NIS 87 (2000), the minimum compressive strength of non-load bearing blocks is 2.5N/mm^2 (Odeyemi *et al.*, 2018). The declining in the compressive strength of the blocks with increased in fibre volume could be attributed to the poor bonding of the raffia fibre, caused by low percentage of the mortar in the mixture, creating maximum void contents and weak interfacial adhesion in the process (Oghenerukevwe and Uguru, 2018). Similar results were obtained by Adebakin *et al.* (2012). Adebakin *et al.* reported that after 28 curing days, the control (100% sand) sandcrete blocks had compressive strength of 4.26 N/mm^2, while compressive strength of 1.80 N/mm^2 was for sandcrete block made with 40% sawdust content. According to Abdullahi (2005) and Afolayan *et al.* 2008, compressive properties of sandcrete blocks are inconsistent due to the different production methods employed (manual moulding, machine moulding, mixing ratio), the properties of constituent materials, and the level of quality control employed.

Water absorption

The effect of fibre volume and fibre size on the water absorption of sandcrete blocks are presented in (Figure 4). As shown in (Figure 4), for higher percent of fibre volume, the water absorption rate of the blocks increased

Table 5. Effect of fibre volume and size on the swelling rate of sandcrete blocks.

Proportion		Swelling rate (%)			
Fibre volume	**Fibre size mm**	**Day 7**	**Day 14**	**Day 21**	**Day 28**
Control (0%)	-	0.028^a	0.033a	0.043^a	0.045^a
1%	2	0.45^b	0.55^b	0.85^b	0.93^b
	4	0.51^b	0.60^b	0.89^b	0.97^b
2%	2	0.79^c	0.97^c	1.38^c	1.46^c
	4	0.84^c	1.02^c	1.41^c	1.50^c
3%	2	1.09^d	1.29^d	1.64^d	1.74^d
	4	1.15^d	1.37^d	1.70^d	1.78^d

Means having the same superscripts in the same column are not significantly different (P ≤0.05), using Duncan's Multiple Range Test.

significantly, but fibre size did not played any significant role in the water absorption of the blocks. The maximum water absorption value (11.57%) obtained for the reinforced sandcrete blocks (at day 28 of curing), is within the allowable limit, as the maximum standard limit for sandcrete blocks is 12% (NIS-87, 2004; Musa and Abubakar, 2018). The higher water absorption rate of the reinforced blocks could be attributed to the cellular structure of the raffia fibre, and the high void ratio within the block, leading to higher water permeability. According to Ugwuishiwu *et al*. (2013), fibres are responsible for the high absorption of water in fibre reinforced blocks, while the blocks densities decreased with the increase in fibre volume. Water absorption is appreciable to an extent, but excessive of it causes various defects in the block, such as, shrinkage of block after drying, cracking of blocks, opening of the joints, etc. (Boob, 2014).

Sandcrete block density

Presented in (Table 4) is the influence of raffia palm fibre volume and fibre size on the densities of sandcrete blocks. From the results (Table 4), it can be seen that the density of the sandcrete block was highly dependent on the fibre volume, and independent on the fibre size. The density decreased with increase in the fibre volume (Table 4), across the 28 curing days. It can be observed from the results that fibre size played no significant role in the density of the blocks. Boob, (2014) reported similar trend for sawdust reinforced sandcrete blocks, where the density decreased from 2400 Kg/m^3 to 1800 Kg/m^3, as the sawdust reinforcement increase from 0% to 20%. On the contrary, Musa and Abubakar (2018), reported an increased in the density of sandcrete block in increased in volume tyre steel fibre reinforcement, which they attributed to the higher density of tyre steel fibres that the sandcrete block were made of. The low density of the fibre reinforced blocks couple with their relative high compressive strength makes them suitable building material for non-load bearing walls, and where high density block is a problem.

Sandcrete block swelling rate

The results of the sandcrete blocks swelling test are presented in (Table 5). As shown in (Table 5), the swelling rate of the blocks increased with increase in the fibre volume. From the results, maximum swelling occurred in blocks with 3% fibre volume (at day 28 of curing), which is a serious setback in the utilization of the blocks in area exposed to dampness.

Conclusion

This study assessed the influence of raffia palm fibre size and volume on the physical characteristics and compressive strength of sandcrete blocks. The results obtained from this study showed that fibre volume had significant effect on the above mentioned parameters. From the results, low fibre volume reinforced sandcrete blocks complied with the minimum standard compressive strength limit of 2.5N/mm^2 for non-load bearing walls. The water absorption and swelling rate of the sandcrete blocks increased with increase in the fibre volume. In addition, the low densities of the reinforced blocks made them good building materials for partition walls provided the wall is not exposed to high moisture.

Authors` Declaration

We declare that this study is an original research by our research team and we agree to publish it in the journal.

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