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SOME MECHANICAL CHARACTERISTICS OF CONCRETE REINFORCED WITH DRIED WATER HYACINTH AND QUARRY DUST AS FINE AGGREGATES

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Abstract — This paper presents some mechanical properties of concrete reinforced with dry water hyacinth stem and quarry dust as fine aggregates. Fresh water hyacinth stems were collected from Lake Victoria; sun dried for a week and chopped into 3 cm long pieces. Sieve analysis was done for fine and coarse aggregates. Concrete mix designs were done according to Department of Environment (United Kingdom) method. A total of 32 cubes of concrete were cast (16 horizontal orientations of fiber, and 16 vertical orientations of fibers). Dry water hyacinth stems were incorporated during casting of cubes in terms of 0%, 0.1%, 0.2% and 0.3% of the volume of cube. Average compressive and split tensile strength tests were performed after 28 days. The results showed concrete composed of horizontal orientation of dry water hyacinth stem fibers had an average optimum tensile strength of 1.5 N/mm^2 corresponding to 0.1% replacement. In vertical orientation, there was uniform decrease in tensile strength as the percentage replacement increased. Compressive strengths decreased slightly as the composition of water hyacinth fibers increased for both vertical and horizontal orientations.

Keywords: Aggregates, Compressive strength, Hyacinth, Quarry dust, Tensile strength

1.0 INTRODUCTION

Housing demand has been increasing in Kenya. To cope with this problem, the government came up with the 'Big Four Agenda' in 2018 to help in solving this problem [1]. The 'Big Four' includes; Manufacturing, Affordable Housing, Universal Healthcare and Food and Nutrition Security [2]. Provision of affordable houses to people requires use of cheap and environmental friendly materials. Concrete is one such material used in the construction of houses in Kenya. Concrete is a composite material that constitutes natural sand, coarse aggregates, cement, water and in some cases admixtures [3]. Conventional concrete is weak in tensile strength. In addition to this, sand harvesting not only leads to depletion of natural resource but causes environmental degradation. These problems can be minimized by use of quarry dust as fine aggregates and reinforcing concrete with dry water hyacinth stem. Quarry dust is a by -product from quarry during production of coarse aggregates. Uniformly graded quarry sand has been used as a partial replacement of river sand [4]. Quarry dust is cheap, environmental friendly, readily available and is known to improve both tensile and compressive strengths of concrete. Water hyacinth is plant that grows on water bodies. It invaded Lake Victoria (Figure 1); the largest fresh water lake in Africa and second largest in the world [5]. It causes problems such as fish reduction, navigation hindrance, breeding for mosquitoes and affects quality of water [6]. In the past, water hyacinth has been used in production of biomass which used as fuel; making baskets; as manure and also in paper and pulp industries [7]. Previous studies show that water hyacinth has been used as partial replacement of cement in concrete [8], and pozzolanic material for use in blended cement [9]. This study focused on use of dry water hyacinth stem and quarry dust in the production of concrete. Laboratory tests such as compressive strengths, tensile strengths and slump tests were conducted to help in the investigation of properties of concrete reinforced with dry water hyacinth stem and finding the optimum point that yields highest tensile strength.

Figure 1 Water Hyacinth in Lake Victoria

2.0 MATERIAL AND METHODS

2.1 MATERIAL

In this research, quarry dust and coarse aggregates were sourced from Sirikwa Quarry in Eldoret. The two ingredients conformed to BS ISO 812.103:2003. Ordinary Portland cement (Bamburi cement) grade 32.5 that conformed to BS EN 197-1:2000 [10] was also used. Fresh water hyacinth stems were collected from Lake Victoria in Kenya and chopped into 3 cm long pieces as shown in Figure 2a (fresh) and 2b (dry).

(a) (b)

Figure 2 preparation of water hyacinth (a) Fresh Water Hyacinth (b) Dry Water Hyacinth

2.2 METHODS

Collection and cleaning of water hyacinth stems from Lake Victoria was done manually. Air drying of the water hyacinth in sunlight was done for one week. Sorting of dry water hyacinth stems was done and chopped into pieces of 3 cm long was done. Sieve analysis tests were performed based on BS 812-103.1:2000 [11] for both the fine and coarse aggregates. Design of concrete mixes was based on the approach proposed by the Department of Environment, Building Research Establishment of United Kingdom, (DOE) [12]. The mix design ratios were 1:2.7:5 for cement, quarry dust and coarse aggregates, respectively. The batching was done by weight and mixing was continuous to ensure that all materials formed a homogeneous mix. The mixes were used to cast cubes (150 mm by 150 mm by 150 mm) for testing in two replicates and done according to BS EN 12390-2:2009 [13]. Thirty-two cubes were cast (16 for horizontal orientation of fibers and 16 for vertical orientation of fibers). Dry water hyacinth stem was added in the cubes at time of casting with the following percentages (0.0%, 0.1%, 0.2% and 0. 3%) volume of a cube, based on orientations of fibers. Horizontal orientation involved placing the dry water hyacinth stems horizontally in the mould during casting at depths of 25 mm, 75 mm and 125 mm from the base of the mould. Similarly, for vertical orientation dry water hyacinth stems were placed vertically in the mould during casting. During compaction, care was taken so that the final concrete was monolithic and uniform. Slump tests were done based on BS EN 12350-2:2009 [14]. The specimens were labeled as follows: N for normal (0.0%), E for 0.1%, L for 0.2% and J for 0.3%. The cubes were cured in a water tank for 28 days. Laboratory tests for compressive strength and split tensile tests based on BS EN 12390-3:2009 [15] and BS EN 12390-6:2009 [16], respectively were done. The means of weight of cubes at 0.1% and 0.0% were compared to find the percent reduction in weight. The split tensile test equation according to Fanlu and Jiang [17] was used:

$$\text{Tensile strength} = 2PL/BD^2 \quad (1)$$

Where
B = width of the sample (mm)
L = length of the sample (mm)
P = maximum applied load in Newton
D = diagonal length (mm)

The compressive strength equation was:

$$\text{Compressive strength} = P/A \quad (2)$$

Where
P = maximum applied load in Newton
A = cross sectional area in mm^2

3.0 RESULT AND DISCUSSION

3.1 SIEVE ANALYSIS RESULTS

3.1.1 COARSE AGGREGATES

The results from sieve analysis for coarse aggregates weighing 4455 g are tabulated in Table 1.

Table 1: Sieve analysis for coarse aggregates.

Bs sieve mm	Weight retained in g	Cumulative weight Retained	% cumulative weight retained	% weight retained	% weight passing	% passing SPEC Lower	Upper
28	0	0.0	30.2	0	100	100	100
20	1346	1346	82.0	30.2	69.8	65	80
10	2309	3655	100	51.8	18.0	15	40
5.0	800	4455	100	18.0	0.0	0	10
2.4	0	4455	100	0	0.0	0	10
2.36	0	4455	100	0	0		
1.18	0	4455	100	0	0		
0.6	0	4455	100	0	0		
0.3	0	4455	100	0	0		
0.15	0	4455	100	0	0		

Fineness modulus = [Total cumulative % weight retained] /100 (3)
7122/100=7.122

A value of 7.122 meant that the average size of particle of the coarse aggregate sample was between 5 mm and 10 mm. From the table, it can be observed that, coarse aggregates particle distribution was reasonably uniform and it was in agreement with BS grading requirement [11].

3.1.2 FINE AGGREGATES

The results from the sieve analysis of fine aggregates weighing 1987 g are tabulated as shown in Table 2.

Table 2: sieve analysis for fine aggregates

Bs sieve mm	Weight retained g	% retained	Cumulative % weight retained	% passing
6.3	0	0	0	100
5.0	197	9.9	9.9	90.1
2.36	256	12.9	22.8	77.2
1.18	407	20.5	43.3	56.7
0.6	236	11.9	55.2	44.8
0.3	324	16.3	71.5	28.5
0.154	567	28.5	100	0.0
Pan	0.9			

Fineness modulus = [Total cumulative % weight retained] /100 (4)
302.7/100 = 3.027

A value of fineness modulus of 3.027 meant that the average size of particle of the fine aggregate sample is between 2.36 mm and 5.0 mm. From the table, it can be observed that, fine aggregates (quarry dust) particles distribution is reasonably uniform and it is in agreement with BS grading requirement [11]. This meant that the aggregates were approximately of the same size. The fine aggregate was regarded as coarse sand whose fineness modulus falls between 2.9 and 3.2 [18].

3.2 INDIRECT TENSILE STRENGTH TEST RESULT

3.2.1 ORIENTATION OF FIBERS

The tensile strengths for horizontal orientation for the fibres are shown in Table 3 while the tensile strengths for vertical orientation for the fibres are shown in Table 4.

The average tensile strengths increased as percentage of dry water hyacinth stem fibers increased up to 1.5 N/mm^2 corresponding to 0.1% replacement for horizontal orientation of fibers. The average compressive strength reduced from 1.5 N/mm^2 as the percentage of dry water hyacinth stem increased. It can also be seen that horizontal orientation of fibers yielded higher compressive strengths than vertical orientation of fibers. The reason behind this was attributed horizontal orientation of fibers being acting against the applied load. Therefore, fibers offered resistance to the applied loads.

Table 3 Tensile Strength Test Result for Horizontal Orientation of Fibers

Samples designations	% of dry water hyacinth stem	Weight of each cube in kgs	Load in N ($*10^3$)	Tensile strength in N/mm^2	Average tensile strength in N/mm^2
N	0	7.60	30.5	1.36	1.37
		7.55	31	1.38	
E	0.1	7.50	34	1.52	1.50
		7.50	33	1.47	
L	0.2	7.40	31	1.38	1.37
		7.38	30.5	1.36	
J	0.3	7.35	26	1.16	1.21
		7.32	28	1.25	

Table 4 Tensile Strength Results for Vertical Orientation of fibers

Samples designations	% of dry water hyacinth stem	Weight of each cube in kgs	Load in N ($*10^3$)	Tensile strength in N/mm^2	Average tensile strength in N/mm^2
N	0	7.60	28.4	1.26	1.25
		7.55	28.0	1.24	
E	0.1	7.15	24.1	1.07	1.08
		7.10	24.5	1.09	
L	0.2	6.90	18.5	0.82	0.79
		6.95	17.0	0.76	
J	0.3	6.80	15.6	0.69	0.64
		6.75	13.2	0.59	

3.3 COMPRESSIVE STRENGTH TEST RESULTS

3.3.1 ORIENTATION OF FIBERS

The compressive strengths of horizontal orientation of the fibers are shown in Table 5 while the compressive strengths for vertical orientation of fibers are shown in Table 6.

Table 5 Compressive Strength Result for Horizontal Orientation of Fibers

Samples designations	% of dry water hyacinth stem	Weight of each cube in kgs	Load in N ($*10^3$)	Area in mm^2	Compressive strength in N/mm^2	Average compressive strength in N/mm^2
N	0	7.66	640	22500	28.12	28.06
		7.5	632	22500	28.00	
E	0.1	7.45	610	22500	27.10	27.05
		7.50	608	22500	27.00	
L	0.2	7.40	560	22500	24.90	24.8
		7.45	556	22500	24.70	
J	0.3	7.35	546	22500	24.30	23.95
		7.35	530	22500	23.60	

Table 6 Compressive Strength Results for Vertical Orientation of Fibers

Samples designations	% of dry water hyacinth stem	Weight of each cube in kgs	Load in N (*10^3)	Area in mm^2	Compressive strength in N/mm^2	Average compressive strength in N/mm^2
N	0	7.66	592	22500	26.31	26.18
		7.5	586	22500	26.04	
E	0.1	7.10	420	22500	18.67	18.94
		7.20	432	22500	19.20	
L	0.2	7.10	480	22500	18.22	18.12
		7.15	494	22500	18.13	
J	0.3	7.20	386	22500	17.16	16.32
		7.10	348	22500	15.47	

Dry water hyacinth stems had an impact on the compressive strength of concrete. It reduced the average compressive strength of concrete, as the percentage of dry water hyacinth stem increased. It reduced compressive strength by 1.01 N/mm^2 for horizontal orientation at the optimum point of 0.1% hyacinth incorporation. Compressive strength for Normal concrete in Table 5 and 6 should be the same. However, in this research, they are not the same because the samples were cast at two different days. This partly contributed to the variance. Normal concrete has a density range of 2240 kg/m^3 to 2400 kg/m^3 [19]. When the density of concrete is below that of normal concrete, it may be considered as lightweight concrete. The average density of concrete at optimum point was found to be 2215 kg/m^3 and 2119 kg/m^3 for horizontal and vertical orientations, respectively. From table 5 and 6, there was reduction in weight as the percentage of water hyacinth increased. For horizontal orientation of fibers, the percentage reduction of weight at optimum point was 1.4% while for vertical orientation the reduction of weight was 5.7%. Therefore, this concrete was considered as a lightweight concrete [19].

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

It can be concluded that 0.1% hyacinth incorporation was the optimum point that yielded the average highest tensile of 1.5 N/mm^2. It was also noted that vertical orientation resulted in tensile strength reduction as amount of dry water hyacinth increased. Compressive strength in both orientations decreased as the amount of dry water hyacinth fiber increased. It is worth noting that concrete reinforced with the fibers was light and thus can be suitable in construction industry where lightweight concrete is desirable.

4.2 RECOMMENDATIONS

This study was limited to horizontal and vertical orientation of fibers and therefore there is need for further research to investigate properties of concrete reinforced with dry water hyacinth stem fibers with random and inclined orientation of fibers. The study used dried stems and not ash from stems and this could be a possible research area in future

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