Comparative Study of the Compressive Strength of Cement Laterite Brick Produced with Rice Husk Ash and Wood Ash as Partial Replacement Of Cement

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Abstract

The paper presents an outcome of experimental comparative study on the compressive strength of laterite brick made with rice husk ash and wood ash as partial replacement of cement. First, Rice Husk Ash (RHA) and Wood Ash (WA) were prepared and subjected to the following tests: specific gravity, density and bulk density. This was followed by the production of three types of bricks viz cement laterite-bricks(control), cement-laterite bricks produced using RHA as partial replacement of cement and another brick made with WA as partial replacement of cement. Replacement levels range from 0 - 30% at 10% intervals. The samples were cured by water sprinkling, before testing them for compressive strength at 7, 14, 21 and 28 curing days. Result of the tests showed that the specific gravity of RHA and WA are 2.20 and 2.13 respectively. The Absorption capacity of all the samples is in the range of 4.5 – 9.1%which is within the allowable value of 25% set by the Nigerian Industrial Standard. Compressive strength for10 % replacements range from 0.75N/mm^2 for 7days to 3.7N/mm^2 for 28 days for RHA, as against 2.6 N/mm^2 for 7days to 5.3N/mm^2 for 28days curing for WA. This shows that bricks produced using WA are relatively higher in strength than those made with RHA. Though it is concluded that RHA and WA, can be used as partial replacements of cement in the production of laterite brick. Also, laterite brick produced with 20% and 30% partial replacements of cement with RHA and WA, respectively,, have, satisfied the minimum requirement as contained in BS 6073, and are recommendable.

Keywords: Cement, compressive strength, rice husk ash, laterite brick, partial replacement levels, wood ash.

Introduction

Sandcrete block which consists of natural sand, water, and binder is the most widely used walling material in Nigeria. However, the use of cement as a binder is the most expensive input in the production of sandcrete blocks. This brings the need to produce blocks with low cement content that will minimize cost so that buildings can be affordable to people. This is particularly truebecause of the poverty level in the developing countries. Yet, one major disadvantage associated with sandcrete blocks made with low cement content, is that it leads to micro-cracks on the wall after construction.

The high cost of cement as a binder in the production of sandcrete block has led to various research efforts on the use of cheaper alternative materials as stabilizer that will greatly enhance the production of walling materials with desired properties at low cost. For example Felix and Philibus (2002) undertook a research on sawdust as a concrete material. Also, Elinwa and Ejeh (2004) studied the effect of the incorporation of sawdust incineration fly ash in cement paste and mortar. Rahman (2006) evaluated the effect of rice husk ash on properties of bricks made from fired laterite; Corotis *et al* (2007) studied the effect of rice husk ash on mechanical properties of concrete under elevated temperature. Dahiru and Zubairu (2008) assessed the suitability of RHA in concrete production; Emmanuel (2009) investigated the effect of wood ash admixtures on the engineering properties of burnt laterite clay brick. While Dahiru *et al* (2011) studied the use of rice husk as a partial replacement of cement in sandcrete block. According to Oluremi (1999) in Olowe(2009), a survey by Raw Materials Research and DevelopmentCouncil of Nigeria, revealed that certain building materials deserve serious consideration as substitutes for imported ones. It was also, noted that some of the materials include cement/lime stabilized bricks, sundried soil bricks, burnt clay bricks, cast in-situ walls and Rice husk ash (RHA).Results of the aforementioned studies showed that RHA and WA are good natural pozzolanic material that can be used as partial replacement of cement. The optimal replacement levels are 10% and/or 15% cement replacement by RHA as an optimal level for achieving maximum strength. It is also observed that RHA concrete improves the durability of concrete. Besides that concrete made with up to 20% replacement of cement with RHA is suitable for low cost housing development (Abalaka 2012). According to Ramasamy and Biswas (2008), RHA is highly reactive pozzolanic material. However most of these researches were confined to investigating the suitability of these natural pozzolanic materials in concrete production.

Another important material that deserves attention is laterite. This is because it has been used in construction of shelter and approximately 30% of world's present population still lives in laterite structures (Lawal, 2015). It has been used extensively for wall construction around the world. Laterite is cheap, environmentally friendly and abundantly available building materialin the tropical region of West Africa. Laterite has other advantages which make it potentially a very good material for construction, especially of rural structures in the less developed countries. The advantages include less specialized labour requirement for production of laterized concrete or actual construction. Laterized concrete structures have sufficient strength compared with that of normal concrete (Wild, 1993 & Warner, 2007). With abundant supply of laterite in Nigeria, this potential is not being utilised maximally. This is particularly important considering the fact that it is more economical to use laterite for brick production as it requires affordable amounts of cement and energy because it does not require (fuel demanding) firing process. Besides that, laterite bricks are fire resistant and bulletproof. Laterite bricks of 330x150x150 mm are reported to be economical and easy to lay; apparently an improvement on the fired clay bricks of 250 x 150 x 100 mm because 22 bricks are required of laterite bricks per meter square of wall as against the 33 required for fired clay bricks. Consequently, the mortar for jointing per square meter of wall is reduced significantly. Good laterite bricks were produced from different sites in Kano when laterite was stabilized with 3 to 7 % cement. The study showed that particle size distribution, cement content, compactive effort and method of curing are factors which affect the strength of the bricks (Olubenga *et al.,*2007, Emmanuel 2008, Ojambati & Aderiyej, 2009).

Laterite bricks were made by Nigerian Building and Road Research Institute (NBRRI) and used for the construction of bungalow. From the study, NBRRI proposed the following minimum specification as requirements for laterite bricks: bulk density of 1810 kg/m^3, water absorption of 12.5%, compressive strength of 1.65N/mm^2 and durability of 6.9% with maximum cement content fixed at 5%. Laterite stabilized with cement was used successfully to produce bricks in Sudan. The pressure ranges: 2 to 4 N/mm^2, 8 to 14 N/mm^2 and 6 to 20N/mm^2, designated low, high and hyper respectively were used in the production of bricks, with cement content of 5 to 8 % and a brick size of 290x140x90 mm. Compressive strength ranging from 3 to 3.5 N/mm^2 was achieved using a pressure range of 8 to 14 N/mm^2. The study showed that the strength of bricks was dependent on the pressure applied during production, percentage of cement used and the particle size distribution of laterite (Olugbenga *et al,* 2007; Ojambati & Aderiyej, 2009).

Rice husk and waste from wood are among the major waste materials found in Nigeria constitute nuisance, as they are considered as degrading the environment, without economic values (Halliday, 2004). Worse still, there are no adequate equipment for effective evacuation of waste; no known engineered landfill and other disposal sites (Ibrahim, 2006). The paper presents a comparative study of the properties of laterite brick produced using rice husk ash and wood ash as partial replacements of cement.

Methodology

Materials

Materials used in carrying out the study are as follows:

Rice Husk Ash: RHA was obtained from rice processing mill at Mai'Adduwa, Funtua Local government, Katsina state - Nigeria. It was prepared by pre-heating the rice husk, in order to reduce the carbon content. The rice husk was then put in electric furnace and heated at 650^{0}C for two hours thirty minutes. The time and temperature used were based on the approach adopted by Abalaka (2012) and Ettu*et al,* (2013) .On completion of the calcinations, the sample was allowed to cool down in the furnace. The RHA was then grounded with a ball mill in the department of chemical engineering Ahmadu Bello University Zaria, so as to achieve 80µm fineness. It was then sieved in the concrete laboratory of the Department of Building, Ahmadu Bello University Zaria. The RHA was grey to ash colour.The photograph of Rice husk and RHA are shown in plates I and II.

PLATE I

PLATE II

PLATE I: Mai 'Adduwa Rice Husk (Raw). PLATE II: Mai' Adduwa Rice Husk(heated/sieved)

Wood Ash: The WA, which is in form of powder, amorphous solid, was sourced from Watson bakery, at Ahmadu Bello University, A.B.U; Zaria. The wood waste was a bye product of four basic woods namely: Doka, Shea tree (*kade*), tamarind (*tsamiya*), chewstick tree (*marke*) in which Doka constitute up to 50-70% of the wood. It was sieved with a 300um sieve to remove impurities and larger particles. WA was, afterwards taken to the department of chemical engineering where it was grounded using a ball mill. The WA was then sieved in the laboratory of the Department of Building, Ahmadu Bello University Zaria. The picture of WA is shown in Plate III.

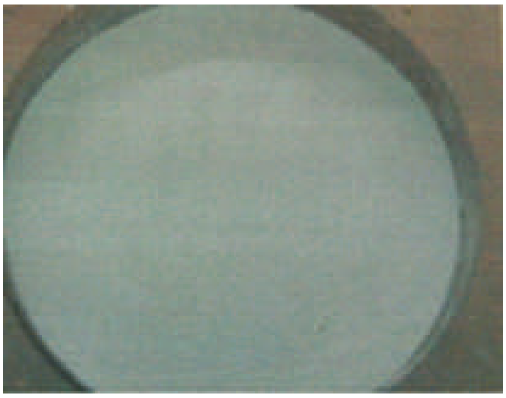

PLATE III: Wood Ash after sieving.

Cement: The cement used was Ordinary Portland Cement, (OPC) manufactured and recently supplied by the Ashaka cement company. [The cement satisfied the minimum requirement as provided BS – EN 196 - 3 (1995)]

Water: Pipe borne water pumped from A.B.U water treatment plant was used for mixing the material. The water was safe for drinking and satisfied the requirement for water to be used for block production as contained in BS – EN 1008(2002).

Methods

The experimental study was achieved following these steps:

i. determined their physical properties of RHA and WA,
ii. determined the properties of laterite bricks stabilized with RHA and WA;
iii. compared the properties of the above bricks with the standard
iv. identified and proposed areas of application of laterite bricks produced with RHA and WA.

The prepared samples of laterite, RHA and WA used in the experiment, were subjected to specific gravity and Bulk density tests, in accordance with the provisions of BS 812 – 109 (1995) and BS 812 – 2 (1995).

Production of Bricks

Three trial mixes were prepared to determine the most suitable water/cement (W/C) ratio to be used for the production of brick sample. An absolute volume method of batching was used to produce 75mm x 75mm x 75 mm mortar cubes, using, 0.65, 0.70 and 0.80 W/C ratios. Based on the results of the trial mixes, 0.80 W/C ratio was chosen. Using an absolute volume mix and a W/C of 0.80, a total of eighty four, 230mm x 110mm x100mm bricks were produced. Three sets of bricks were used in the study – as follows:
These bricks are as follows:

a. Laterite – Cement (alone) bricks: a ratio of 1:15 of cement to laterite was used to produce this type of brick which served as a **control sample** (Lyons, 1995).
b. Laterite - Cement brick having RHA as partial replacement (**LCR**).
c. Laterite - Cement brick having WA as partial replacement (**LCW**).

PLATE IV: Brick samples: Laterite/Cement, Laterite-RHA and Laterite-WA as partial replacements

In each of the two cement/laterite brick samples, which were produced using as partial replacements of cements, RHA and WA, the replacement levels ranges from 0 – 30% at intervals of 10%. Thus, there are four sets of bricks – for the percentage replacements used. These are: 0% = R_0 (control), 10% = R_1, 20% = R_2 and 30% = R_3. Types and number of laterite bricks is shown in table 1. While detail of the quantities of materials used for the production of bricks per $1m^3$ is presented in table 2 and the photograph of the three sets of bricks is shown in plate IV

Table 1: Total Number and Types of Laterite Bricks Used for the Experiment

Curing Days	**Sets of Laterite Bricks Used**						
	Control	LCR			LCW		
	R_0	R_1	R_2	R_3	R_1	R_2	R_3
	Number of Bricks for Each Day of Curing						
7	3	3	3	3	3	3	3
14	3	3	3	3	3	3	3
21	3	3	3	3	3	3	3
28	3	3	3	3	3	3	3
TOTAL	**12**	**12**	**12**	**12**	**12**	**12**	**12**

Table 2: Quantities of materials/$1m^3$

Mix	**Cement (kg)**	**Laterite (kg)**	**RHA/WA (kg)**	**Water (kg)**
R_0	4.50	63.50	-	3.60
R_1	4.05	63.50	0.45	3.60
R_2	3.60	63.50	0.90	3.60
R_3	3.15	63.50	1.35	3.60

Testing of hardened laterite bricks

The three sets of bricks produced were subjected to tests at the various curing of 7,14,21,28 days in order to determine their properties these tests are:

1. Compressive Strength Test: the bricks were subjected to the compressive strength test in accordance with the British Standard, BS – EN 12390 - 3 (2002), at 7,14,21,28 days of curing. The test was carried out at Department of Building Ahmadu Bello University, Zaria.

2. Absorption capacity test

The absorption capacity test was also carried out in accordance with the provision of British Standard - EN1881: 122. (1983).

Results

Results of the various tests carried out are as follows

Physical properties

As it was noted earlier, some the physical properties of materials were determined. Details of the results are presented in Tables 2, 3 and 4.

Table 3: Specific gravity and Bulk density of RHA

S/No.	Property	Condition of Sample	Unit	Value
1.	Specific gravity	Dry	-	2.2
2.	Bulk Density	Uncompacted	Kg/m3	600
		Compacted	Kg/m3	740

Table 4: Specific gravity and Bulk density of WA

S/No.	Property	Condition of Sample	Unit	Value
1.	Specific gravity	Dry	-	2.13
2.	Bulk Density	Uncompacted	Kg/m3	680
		Compacted	Kg/m3	760

Table 5: Silt content test

Description	Height (ml)	% Silt Content
Silt	31	34
Laterite with silt	92	

Absorption capacity

Result of Absorption Capacity test is presented as follows

Table 6: Absorption capacity of cement laterite brick with RHA

Mix	Oven Dry Weight (kg)	Wet Weight (kg)	Absorption Capacity (%)
R_0	4.4	4.8	9.1
R_1	4.4	4.8	9.1
R_2	4.4	4.8	9.1
R_3	4.4	4.6	4.5

Table 7: Absorption capacity of cement laterite brick with WA

Mix	Oven Dry Weight (kg)	Wet Weight (kg)	Absorption Capacity (%)
R_0	4.4	4.8	9.1
R_1	4.5	4.9	8.9
R_2	4.4	4.8	9.1
R_3	4.4	4.7	6.8

The Absorption capacity of the brick sample produced with WA as partial replacement of cement is also within the same range except for 30% replacement; which is relatively higher than the cement laterite brick produced with a partial replacement of RHA because it has 6.8% absorption capacity

Density of Laterite brick sample

Details of the density of density of cement laterite brick sample are presented in the tables 8 and 9.

Table 8: Density of RHA

Mix		Density (kg/m^3)		
Curing Days	**7**	**14**	**21**	**28**
R_0	1818	1779	1739	1739
R_1	1770	1700	1700	1660
R_2	1739	1660	1700	1660
R_3	1700	1700	1700	1581

Table 9: Density of WA

Mix		Density (kg/m^3)		
Curing Days	**7**	**14**	**21**	**28**
R_0	1818	1779	1739	1739
R_1	1687	1756	1739	1752
R_2	1607	1700	1700	1687
R_3	1608	1660	1607	1621

Compressive strength test result

Result of the compressive strength test on the three types of cement laterite bricks is presented in Tables 10 and 11

Table 10: *Result of compressive strength test of RHA*

Mix	Compressive Strength (N/mm^2)			
Curing Days	**7**	**14**	**21**	**28**
R_0	2.70	4.75	4.90	5.61
R_1	0.75	1.30	2.50	3.80
R_2	0.71	1.02	2.13	3.50
R_3	0.61	0.71	1.40	2.53

Table 11: *Result of compressive strength test of WA*

Mix	Compressive Strength (N/mm^2)			
Curing Days	**7**	**14**	**21**	**28**
R_0	2.70	4.75	4.90	5.61
R_1	2.60	4.00	4.70	5.30
R_2	2.30	3.30	4.00	4.34
R_3	1.90	2.90	3.52	3.68

Results and Discussion

Density of bricks

Looking at the average density of the three sets of brick samples, as presented in Tables 7 and 8, it can be observed that the density of Laterite – cement bricks (control) sample is slightly higher than the density of RHA laterite brick and WA laterite brick. For example, at 28 days of curing, the density of control sample is 1739kg/m^3 while that of RHA laterite brick and WA laterite brick, are 1660 kg/m^3 and 1752 kg/m^3 respectively. Thus RHA laterite brick is slightly less than the control sample by 4.74%. According to Opoola (2015) "5 per cent (.05) is the border between small and not small", that is, if the difference between two values is not more than 5%, then, it can be regarded as insignificant. On the other hand the WA laterite brick has density that is even higher than the density of cement laterite bricks (control). Thus there is no much difference between the control samples and RHA laterite brick and WA laterite brick.It is interesting to note that the difference in density of the bricks prepared with WA and RHA is also reflected in the compressive strength of the two samples. The density of brick made with WA is higher than the brick made with RHA, likewise the compressive strengthof brick produced with WA is relatively higher than the compressive strength of bricks made with RHA.

Absorption capacity

Tables 6and 7 show the result of Absorption capacity test. It can be observed that the Absorption Capacity of the sample specimens produced with RHA as partial replacement of cement, $R_{1,}$ R2and R_3 are 9.1%, 9.1% and 4.5% respectively. While that of bricksamples made of WA as partial replacement of cement, $R_{1,}$ R2and R_3 are 8.9%, 9.1% and 6.8% respectively. Thus the result of the test on the absorption capacity of the three set of samples showed that the absorption capacity is within the range of 4.5 to 9.1%.According to TTTI (2005) water absorption of common building bricks should not be more than 20% by weight. However, the Nigerian Industrial Standard, NIS,(1976), noted that the absorption capacity for bricks should not be more than 25% by weight after immersion in water for 24hours.

Komar (1987) noted that absorption capacity is the ability of material to absorb and retain water. It was noted that absorption capacity depends on the volume of pores, their shape and size, nature of materials and water retaining properties. This means that the RHA laterite brick and WA laterite brick, would be able to satisfy two of the important functional requirements when they are used as walling material; that is, water exclusion and prevention of dampness.

Compressive strength

The result of compressive strength test, in Table 8 and 9,revealed that the compressive strength varies with change in percentage replacements levels. This also applies to change in curing period. In the case of change in replacement levels, result shows that the higher the percentage of RHA/WA, the less the increase in the compressive strength of brick samples. For example, the compressive strength of R_0, R_1, $R_{2,}$ and R_3 for bricks produced with RHA after 28 days of curing, are:5.61 N/mm^2, 3.80 N/mm^2 3.50 N/mm^2 and 2.53 N/mm^2 respectively. While the compressive strength of bricks made with WA as partial replacement of cement, have the following values: 5.61 N/mm^2, 5.30 N/mm^2, 4.34 N/mm^2 and 3.68N/mm^2 at 28 curing days, for R_0,R_1,$R_{2,}$ and $R_{3,}$ respectively. That means there is inverse relationship between the compressive strength and the increase in RHA/WA replacement levels. The higher the replacement levels, the less the compressive strength.This clearly indicates that RHA and WA have negative effect on the compressive strength of bricks. Increase in the content of RHA and WA as partial replacement of cement in laterite brick production leads to decrease in the compressive strength of the brick. Thus there is a limit to the use of RHA/WA as partial replacement of cement in the production of brick. This is particularly important taking the observation of Lyons (1997) into consideration – that compressive strength is an important property of brick that gives a good indication of the quality of brick.Although partial replacement of, up to 10% has not considerably affected the compressive strength of the brick.

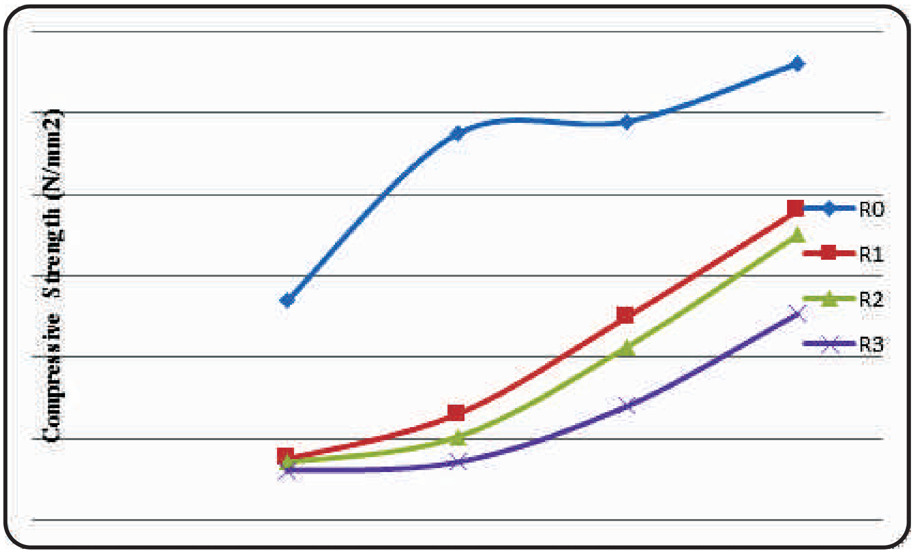

***Figure 1:** Compressive strength of brick sample made with various % partial replacements of cement with RHA*

Figures 1 and 2 show that the rate of increase in the compressive strength is not uniform. For instance, the average compressive strength of the control samples ranges between 0.9N/mm^2 at 7 days of curing, to 4.7N/mm^2 at 28 curing days for brick sample made of RHA.. On the other hand, the compressive strength ranges between 2.7N/mm^{2}at 7 days to 5.61N/mm^2 at 28 days of curing for bricks made of WA as partial replacement of cement. Figure 1, shows that there is a wide difference between the graph of control sample R_0 and other graphs (R_1, R_2 and R_3)

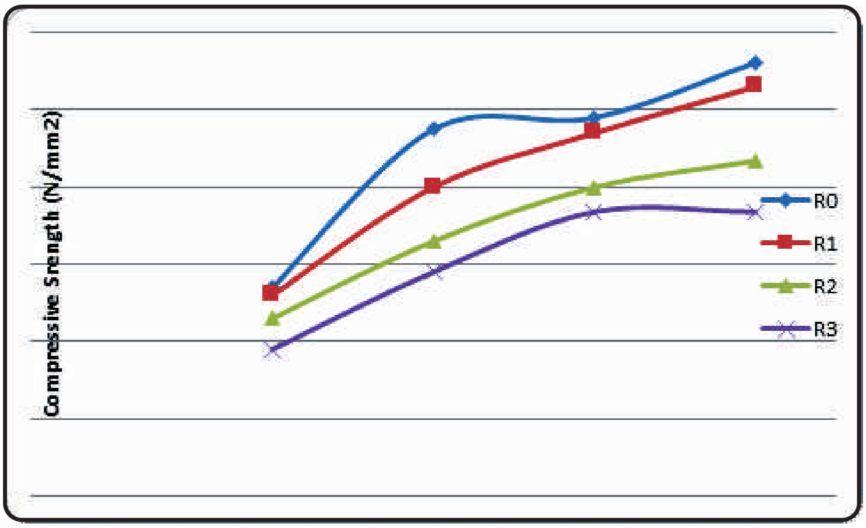

Figure 2: Compressive strength of Brick Sample Made with Various % Partial Replacements of Cement with WA

For the brick sample made with WA as partial replacement of cement, there is slight difference, compared to brick sample made of RHA. When the test result is compared with standard 20% RHA laterite brick (R_2) and 30% WA laterite bricks (R_2), meet the minimum strength requirement of 2.8N/mm^2 for sandcrete blocks as provided in BS 6073 Part1and, can therefore be used for non- load bearing walls.

Conclusion and Recommendations

Conclusion

Comparative study of the compressive strength of cement laterite brick with bricks produced with RHA and WA as partial replacements of cement was undertaken. Results of the study showed that the compressive strength of bricks for all mixes increase with age and decrease as RHA and WA content increases. However, the compressive strength of sample specimen produced with WA as partial replacement of cement have higher values when compared with the samples produced with RHA as partial replacement of cement. Also, the compressive strength of bricks produced with replacement levels of 20% and 30% of RHA and WA respectively, are within the acceptable limit as provided by NIS (1976). Arising from the results of the study, it is thus concluded that RHA and WA can be used as partial replacement of cement in the production of Cement laterite brick. In addition, the replacement levels should not exceed 20% and 30% partial replacement of cement with RHA and WA, respectively.

Recommendations

Based on the result of the study, it is recommended that 20% partial replacement of cement with RHA and 30% replacement with WA canbe used in the production of cement laterite brick. In view of the fact that the built structures are normal in open harsh and hostile environment condition, durability properties of bricks made with RHA and WA as partial replacement of OPC should be carried out. Also further studies should be undertaken on the quality of sandcrete block and cement laterite brick made with WA as partial replacement of cement using higher percentage replacements such as 40% upwards.

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