

# INVESTIGATION OF POSSIBILITY PRODUCTION OF POZZOLANA FOR MARKETING CAPACITY IN ADAMAWA STATE; FOCUSING ON SOURCE AND AVAILABILITY OF RAW MATERIALS

Zaria, C. and Danboyi, G.

Department of Civil Engineering Technology Adamawa State Polytechnic, Yola

Corresponding email: [chindachagwa@gmail.com](mailto:chindachagwa@gmail.com)

## ABSTRACT

*The increasing cost and scarcity of Portland cement and its cost has impacted negatively on the delivery of affordable housing and infrastructural development in developing countries like Nigeria. This study aimed at investigation of possibility production of pozzolana to marketing capacity in Nigeria, Adamawa State Yola North local government using RH as raw materials. Reconnaissance survey was conducted across the research areas, Yola-North LG to validate availability of RH. Some dumping sites was found capable of producing the required quantity for even medium scale. 10 bags of Polythene bags weighing about 5kgs with RH were collected for processing. A brick oven to resist high temperature was constructed for burning process of the materials. Concrete cubes measuring 150x150x150mm were made from six different concrete mixes prepared using pozzolana replacement of Portland cement by mass. The workabilities of the fresh concrete mixes were evaluated using the slump test and compacting factor test while compressive strengths of concrete cubes were evaluated at 7, 14, 21 and 28 days. The maximum compressive strength at all ages of testing was obtained at 30% replacement, corresponding to an increase of 3%,12%,24% and 19% compared to the 7-day, 14-day, 21-day and 28-day compressive strengths. Workability decreased with an increase in replacement percentage. Pozzolana therefore is recommended to be used to partially replace ordinary Portland cement in the production of concrete without compromising strength. From this study it was ascertained that the production of pozzolana to marketing capacity in Nigerian is possible.*

**Keywords:** Portland cement, Housing, Infrastructure, Possibility, Workabilities, Adamawa State

## 1 INTRODUCTION

Concrete is a crucial material for infrastructural development. Its versatility and flexibility in usage and application make it superior to other building materials such as wood and steel [1]. Concrete is considered the most widely used construction material in the world. Portland cement (PC) is one of the major inputs in concrete. [2] identified major brands of cement used in Nigeria for concreting, which includes Dangote, Eagle, Ibeto and Elephant. Cost of cement production and its environmental concerns have led researchers to develop other binders for construction works. According to [1] concrete production contributes 5% of the annual global CO<sub>2</sub> emissions of which the bulk is from the production of cement. Some of the binders used before the emergence of PC are clay, lime bitumen, pozzolans [1] The global trend is researching into the reduction of the Portland cement contents in the concrete mixtures with cheaper Supplementary Cementitious Materials (SCM) to improve certain properties of concrete. “Pozzolanas which are the supplementary cementitious materials (SCMs) are added to concrete mixtures for various reasons including improving durability, decreasing permeability, aiding in pumpability and finishability; mitigating alkali reactivity and improving the overall hardened properties of concrete” [3]. Types of

pozzolans used in cement mortar and concrete are categorised into two thus; which are natural and artificial pozzolans [4]. Blended Cements are more common in Europe and South America and are generally less expensive than cement. [5]. Pozzolans which can partially replace PC were defined by [6,7] as broadly classified materials that are either siliceous or both siliceous and aluminous. By themselves, they have little or no cementitious value. However, in the presence of water, they react with calcium hydroxide at ordinary temperatures (e.g., room temperature) to form compounds (e.g., calcium silicate hydrate and calcium aluminate hydrate) with cementitious properties". And by [8] as siliceous or siliceous and aluminous materials in which in themselves have little or no cementitious property but which will in finely divided form and in the presence of water react chemically with calcium hydroxide at room temperature to form compounds having cementitious properties. The measure of capacity of a pozzolana to react with calcium hydroxide and water is given by measuring its pozzolanic activity [9]. Pozzolans have historical evidence dating back as 500-400 BC. The Greeks followed by the Romans in the pre-400 BC were the first civilizations to use pozzolana in lime mortars. The ancient Greeks deliberately used volcanic materials, such as, volcanic ashes or tuffs. [10] This was uncovered at the ancient city of Kameiros, Rhodes, Greece. Pozzolana was used in Rome which made their concrete structure to withstand weathering [11] In Europe, Asia and America, the application of Pozzolanic cements has been established. According to [2], developed countries have started wide production of these alternative binders and have developed standards for their applications. In recent times, more than 100,000 tons of pozzolana was used to construct the Los Angeles aqueduct. Particularly in Europe, North America and Japan, many mass concrete and marine structure, such as, dams and harbors have been constructed using pozzolana. In developing countries, commercial exploitation of pozzolana is at a slower pace. In Africa, Ghana has acknowledged the use of Pozzolanic cements where the Building and Road Research Institute, BRRI in Ghana established a Pilot Plant in Ashanti City of Kumasi, likewise in Rwanda and the United Republic of Tanzania. In Nigeria, the use of pozzolana in commercial scale have not been acknowledged in spite of the great potentials, though, research works have been carried out extensively on the use of pozzolana. In view of this, the search for the production of the product to market capacity became necessary [12].

## **2 TYPES OF NATURAL POZZOLANIC MATERIALS AND PRODUCTION**

According to [13] eight (8) pozzolanic materials from agricultural by-products was identified. These are; rice husk ash (RHA), Saw Dust Ash (SDA), Oil Palm Bunch Ash (OPBA), Cassava Waste Ash (CWA), Coconut Husk Ash (CHA), Corn Cob Ash (CCA), Plantain leaf Ash (PLA), and Pawpaw Leaf Ash (PPLA). Among these RHA stands as the most common artificial pozzolana material. The specific surface area of silica formed is about 200000 cm<sup>2</sup>/gram as against 2300 to 3000 cm<sup>2</sup>/gram that of cement. Therefore, according to [14] "Using 20 % RHA with 5 % olive waste ash (OWA) increases compressive strength by approximately 58.7 %". The use of rice husk ash (RHA %) in concrete was patented in the year 1924 and upto 1972, researches were concentrated to utilize ash derived from uncontrolled combustion. Pozzolana production from calcinated RH can be divided into three major stages. Each of these stages has more than one operation. The first stage is raw material preparation which consists of collection of rice from the dumping sites and drying for complete burning. The second stage is burning of the raw materials. The optimum calcinating temperature is normally taken between 700 and 800-degree Celsius. After calcination, it is ground in a using piston and mortar as in the case of work. The third stage is metering and bagging. Figure 1 shows the flow chart for the process. Pozzolans are used beneficially with either lime or/and OPC. Blending with OPC only allows for replacement of up to 50 percent. With lime, (lime: pozzolana) of 1:1 to 1:4 is possible depending on the quality of lime and pozzolana, and the end use of the mortar. James and Rao indicated that isothermal heating at a minimum of 675 K (402°C) is required for complete destruction of organic matter from rice husk and to liberate silica. On combustion, the cellulose–lignin matrix burns away, leaving a porous silica skeleton, this on grinding will give very fine particles having large surface area. Parameters influencing the surface area of ash samples are temperature, duration of combustion and the treatment of rice husk before burning. [15] conducted a research on ashes produced from three different types of field ovens, analyzed for their reactivity and pozzolanic properties to identify the most feasible method to produce a reactive pozzolana as an alternative to cement for construction

applications like masonry and plastering. In this research work, a rectangular enclosure (30×3.0×1.8 m) incinerator was built using clay bricks for the burning of rice husk (RH). Consequently, large pozzolanic materials dispersed throughout the country, a pilot plant to meet a demand of 2 tons per day was built and test run by the Nigerian Building and road research institute (NBRI). The essence is to demonstrate the technology on a pilot scale hence, medium and large-scale production plants can be built. The aim of this paper is to investigate possibilities of pozzolana Production to marketing capacity using rice husk (RH) in Nigeria, Yola-North local government of Adamawa state as case study. pozzolana production on a mini scale (15,000 ton per year) could be viable. Production of cement or cementitious binders/admixtures on a medium scale according to [16] is one with a total installed capacity not exceeding 200 tons/day which utilizes one or more kilns for its operations. The case of setting up mini scale is to utilize deposits of raw materials in dispersed areas. Such production facility allows participation of small local investors and thus help in building the local economy. Mini scale production also offers the following advantages: (i) 1. Less capital intensive; (ii) 2. Short gestation period; (iii) 3. Quick return of investment; (iv) 4. Utilization of small deposits of raw materials; (v) 5. Attractive to entrepreneurs with limited financial resources.

### **3 MATERIALS AND METHOD**

The research work of “investigation into possibility of production of pozzolana to marketing capacity” was conducted in Yola-North local government of Adamawa state. Raw materials were sourced from across Yola-North Local government areas. An ordinary labor force was used in the sourcing of the raw materials from across Yola-North Local government areas. Laborers were employed and trucks hired for collection for the raw materials from the dumping sites to processing center. The production site was located in Adamawa state Polytechnic main campus along the western fence. A field brick oven was constructed for burning of the raw materials which was later transported to workshop for laboratory work.

#### **3.1 Materials**

The raw materials used for the pozzolana was rice husk (RH) sourced from Yola-North local government areas. Polythene bags were used for collection of the rice husk from dumping site. Rubber basin for fetching it into the bags. Clay bricks for the construction of the incinerator. Trowel 5. Shovel 6. Digger 7. Wheel barrow 8. Line cord 9. Plumb

##### *3.1.1 Building/Civil Work/Electrical and Furniture*

The building is meant to be the processing area. It consists of provision for offices, conference room and welfare facilities for the factory workers. Other spaces allocated include; canteen, changing and locker room. An estimated working area for the purpose of setting up a mini scale of 15,000 ton annual pozzolana production scale is 45 m × 75 m. Other inputs required for production of pozzolana are as, Land for industry building, Availability of rice farms and rice mills, Industrial Blower. Ball Mill (grinding machine). Metering and Bagging Facility.

##### *3.1.2 Organizational and Operational Requirement*

The manpower required in a pozzolana plant is the entire employee. It is important that all employees have defined roles and are qualified to take their respective responsibilities. The equipment used are easy to operate and operators need not to have too high educational background to handle the tools. The basic requirement for the unskilled labor is fitness (physically and mentally). In a mini scale production (45 ton per day) the breakdown of the manpower is presented in Table 1.

##### *3.1.3 Legal and Professional Fees*

In Nigeria, the cooperate affairs commission is in charge of registering any business. Certain charges are involved in the process to guarantee any firm to operate.

### 3.1.4 Financing Options

Finance is a very important resource for any business. Sources of funds could be personal savings, grants, issuance of shares or loans from financial institutions. Some of these institutions are commercial banks, cooperative societies and Bank of Industries.

Table 1. Manpower required for mini scale operation

S/N	Description	Number
1	Plant manager	1
2	Secretary	1
3	Clerk	1
4	Cashier	1
5	Salesperson	1
6	General Service	4
7	Security	8
8	Foreman	1
9	Electrician/mechanic	2
10	Machine operator	3
11	Laborer	16
12	Quality assurance personnel	1
13	Prerequisites @10% salary	
	Total	40

## 3.2 Method

### 3.2.1 Survey

Reconnaissance survey was carried out across Yola-North Local government areas to identify the dumping sites of the raw materials. Two dumping sites was located behind timber shade along Numan – Gombe Road each capable giving five tons/day. Two also by Lake Gerio in Jambutu capable of giving three tons/day each. One in Sangere Numan –Gombe road and also in Kofare (Wuro -Jabbe) both with the same capacity of 1.5tons/day.

### 3.2.2 Material Collection

Workers were employed and truck hired to move from one dumping site to another for collection of the raw materials to production ground. Ten only bags were collected for this work and transported to the production ground stated above.

### 3.2.3 Brick oven (incinerator)

An oven incinerator was be designed and constructed by the researcher capable of burning the raw material of about five (5) tons and at high temperature of 5000c -7000c as required for this study only. The bricks were laid along stretcher bond with the dimension 2.0 x 2.0 x 1.5m not as stated earlier above. The burning was from bottom to the top. In order to set fire at the bottom, a manhole was made at the bottom of one of the four walls. Then, for free flow of air within the incinerator during the burning, holes of 10cm diameter were made on the four walls in rows from one end to another and from top to bottom.

### 3.2.4 Burning of the RH

A Brick oven and temperature probing instrument was used. Brick oven was filled with the RH and burning of sample started from the bottom by setting fire through the manhole. The burning process was slow compared to the annular enclosure and it took almost five days for complete burning. Temperature was measured during the burning at different points of the samples and it ranges from 500 to 600°C. The oven took the ten bags brought to the center at once. Figure 1 shows the Summary of the production procedure.

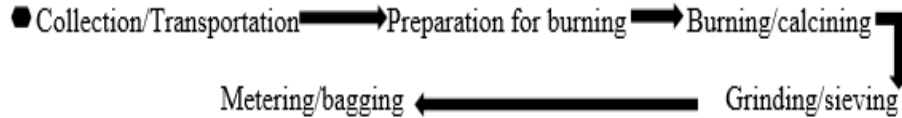


Figure 1. Summary of the production procedure

3.2.5 Grinding, bagging and storage of the ashes

The ashes were scooped into polythene bags after the burning and was transported to civil engineering workshop for laboratory process. The grinding of the material was done with the use of piston and mortar due to lack of grinding machine for that purpose. After the pounding the silica skeleton ash, it was sieved using sieve 90µm to have a fine powder with very surface area.

3.2.6 Testing the cementious properties of the product and efficiency of the method

A laboratory compressive test was conducted on the product to determine the strength. Concrete cubes were made, three for each specimen and were cured for three different period. The concrete cubes with 10%, 20%, 30%, 40% and 50% partial replacement of cement were made and cured for 7, 14, 21 and 28 days respectively. The cement used was ordinary Portland cement of strength class 32.5R. Table 2 shows the chemical compositions of binders used in the study. Crushed granite of nominal size 20mm used in producing concrete. The water used in mixing looked clean and free from any visible impurities. Natural river sand with a specific gravity of 2.53 and a bulk density of 1550kgm-3 was used. Six different mixes were used for the study. A control mix of ratio 1:2:4 batched by mass using a water-binder ratio of 0.55. The control mix was produced using OPC only as binder while in other mixes, pozzolana was used to replace 10%, 20%, 30%, 40% and 50% of the mass of ordinary cement in the control mix. The details of mix proportions are shown in Table 2, while Table 3 shows the concrete mix details.

Table 2. Chemical composition of OPC and pozzolana

Component	Ordinary Portland cement % (by mass)	ASTM Type N Pozzolana% (by mass)
LOI	2.04	1.18
SiO2	18.24	78.71
CaO	60.82	>0.01
Al2O3	4.8	8.72
Fe2O3	3.47	4.49
MgO	3.2	0.33
SO3	3.25	>0.01
Na2O	0.02	0.31
K2O	0.44	0.91

Table 3. Concrete mix details

Percentage replacement (%)	Mass of constituents (kg)			
	Cement	Pozzolana	Sand	Crushed Granite
X				
0	7	0	14	28
10	6.3	0.7	14	28
20	5.6	1.4	14	28
30	4.9	2.1	14	28
40	4.2	2.8	14	28
50	3.5	3.5	14	28

The slump test and compacting factor test [were used in assessing the workabilities of the fresh concrete mixes. No test measures workability directly, but there are tests that measure properties related to workability. Workability is related to the compatibility, mobility and stability of fresh concrete. Casting of concrete was done in cast iron molds measuring 150mm × 150mm × 150mm internally. A total of seventy-two cubes were made. After casting, the molds were covered with plastic sheet to prevent water loss through evaporation. De-molding was done after 24 hours and the specimens immersed in a curing tank to cure for strength gain. Curing improves both the physical and mechanical properties of concrete. The compressive

strengths were determined by crushing concrete cubes at 7, 14, 21 and 28 days of curing using a 1,500kN Matest compression testing machine.

## 4 RESULTS AND DISCUSSION

### 4.1 Workability

The results of workability tests are presented in Table 4. From the results it can be seen that as the percentage replacement of OPC with pozzolana increases, the workability of concrete decreases. Replacing cement by an equal mass of pozzolana causes an increase in volume since the density of cement is higher than that of pozzolana. This therefore increases the water demand and as the pozzolana content increases the workability reduces since the quantity of water remains the same for all mixes. The results also showed the interrelationship between the results of the compacting factor test and the slump test.

Table 4. Results of workability tests

Workability	Cement replacement %					
	0	10	20	30	40	50
Slump (mm)	20	18	16	14	10	8
Compacting Factor (%)	0.88	0.8	0.74	0.76	0.69	0.62

### 4.2 Compressive strength

The results of the compressive strength tests are presented in Table 5.

Table 5. Compressive Strength (Nmm-2)

Pozzolana Replacement (%)	0	10	20	30	40	50
	7	16.4	16.1	15.6	16.9	13.1
14	18.1	17.8	17.3	20.2	13.8	
21	19.1	18.3	17.5	23.7	15.8	
28	21.7	19.6	17.9	25.9	16.1	

According to [15] the variation of compressive strength of concrete is presented in Figure 2. It is seen that the variation of strength shows similar trends with respect to pozzolana replacement. In general, the compressive strength reduced from the control concrete (0% replacement) to 20% replacement. A further rise in replacement increased the compressive strength until a maximum strength was reached at 30% replacement of OPC with pozzolana. On further increase, the strength reduced as percentage replacement increased. This trend is similar at all ages of testing. It is also seen that the strength of concrete increases with age.

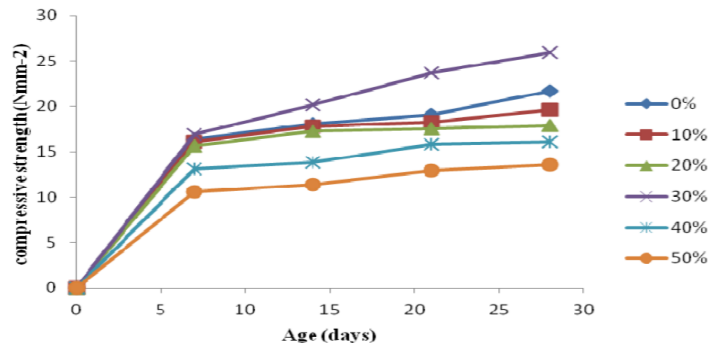


Figure 2. Variation of compressive strength with age

Pozzolanic reaction begins immediately after hydration of cement and continues for a long time thereby increasing strength. Concrete attained its maximum strength at a pozzolana replacement of 30%;

corresponding to an increase of 19% in the 28day strength compared to the control concrete. Similarly, the 7day, 14day, and 21day compressive strengths respectively show increases of 3%, 11% and 24% compared to the compressive strength of the control concrete (Figure 3). Concrete derives its strength from the pozzolanic reaction between silica in pozzolana and the calcium hydroxide liberated during the hydration of OPC. At low percentages of replacement, the quantity of silica is low, therefore, only a limited quantity of C-S-H can be formed, though a large quantity of calcium hydroxide is liberated due to the relatively large quantity of Portland cement. However, at high percentage replacement, the quantity of pozzolana in the mix increases. C-S-H formed reduces due to liberation of a small quantity of calcium hydroxide from the hydration of the relatively small quantity of Portland cement available. The strength of concrete at both low and high percentage replacement is therefore low. An optimum level of replacement exists at which compressive strength is the highest. It can also be concluded that the strength of concrete depends on the relative proportions of silica in pozzolana and ordinary Portland cement available. From Figure 2, it is seen that the average rate of strength growth is constant for the first seven days, after which, the average rate of growth reduces to a constant, but relatively lower rate. The rate of strength gain with respect to time is highest for concrete with 30% replacement of OPC by pozzolana. This is due to optimum reactions which take place at 30% replacement of OPC by pozzolana. The variation of the relative compressive strength of concrete with is presented in Figure 3. It can be seen that, with the exception of concrete with 30% pozzolana replacement, as the age increases the strength ratio decreases even though the strength of concrete increases with age. This is due to the rate of increase of the compressive strength of control concrete, which is higher than concrete at all pozzolana replacement levels with the exception of 30% replacement.

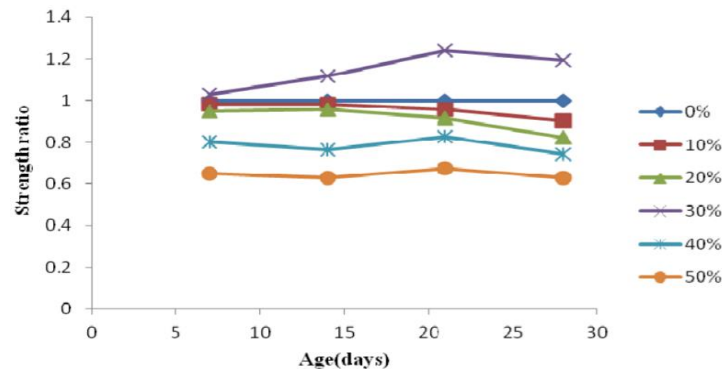


Figure 3. Relative compressive strength of concrete

### 4.3 Marketing strategy

Advertisement of the product in media houses (Radio Gotel, Fombina, and ATV Yola). Production and distribution of hand bills to cement vendors, contractors and some building industries in the state. Organize workshops for rural dwellers and local government works.

## 5 CONCLUSIONS

At the end of the study, the following conclusions are drawn: i) Replacement of cement with pozzolana significantly increased the strength of concrete ii) Replacement of 30% of the mass of cement with pozzolana achieved the maximum value of compressive strength. Iii) The 7-day, 14-day, 21-day and 28-day compressive strengths at 30% replacement respectively showed increases of 3%, 11%, 24% and 19% compared to the compressive strength of the control concrete at those ages iv) Increase in pozzolana replacement decreased the workability of concrete. Therefore, on the subject matter, the investigating into the possibility of pozzolana production to marketing capacity in Nigeria, Yola LGA North Adamawa state. It was observed that it is viable, because of the availability of raw materials spread across the areas littering everywhere. The mini scale production which have numerous advantages is possible as a result of the daily disposal of the materials.

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