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Design and Construction of NBRRI Pozzolana Cement Pilot Plant Access Road

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Abstract
Nigerian Building and Road Research Institute (NBRRI), in trying to solve the menace of housing deficit ravaging the country, established a Pozzolana Cement Pilot Plant at its Laboratory Complex, Ota, Ogun State. When the plant is fully in operation, it would bring respite/succour to the low-medium class citizenry as the cost of pozzolana cement will be affordable to build a light weight/bungalow structures. This gave rise to the birth of this access road, as it became imperative to design and construct an access road to the Pozzolana Cement Plant using a ''stage construction'' approach. The ''stage construction'' approach/method was adopted to construct a 300m long by 7m wide roadway, where the subgrade (poorly graded sand and clay) was stabilized by proportioning technique of mechanical stabilization with well graded lateritic sub-base and base layers of 100mm thickness each. With the development of the bitumen sprayer by the Engineering Material Research Department, the pozzolana access road was used to test the effectiveness and efficiency of the innovation. The combined lateritic road surfacing of 200mm thickness was overlaid with 80mm thick stone-dust (8mm; Ø) interface which was smeared with a thin layer of bitumen MC1. The bitumen surface was then covered with a 100mm thick granite (10mm; Ø) layer. All the layers were well compacted using a 730kg pedestrian roller to an average of 20 passes on each layer. However, when the plant is fully operational, the road would facilitate the movement of goods/ NBRRI Pozzolana cements in and out of the Institute (NBRRI) as this would contribute greatly to the economy of the nation after being adopted/accepted by the larger masses as an affordable alternative to conventional Ordinary Portland Cement (OPC) to erect their light weight concrete structures.
Keywords: Pozzolana cement, Subgrade, Subbase, Base, Pedestrian roller, Light weight, Stabilization, Ordinary Portland Cement (OPC), Bitumen MC1.

1. Introduction

Road pavement serves to sustain and transfer wheel loads of vehicular traffic from the road surface to the underlying natural soil stratum or subgrade (Asphalt Institute, 2001; NBRRI, 2004; Olowosulu, 2005; Ameri and Kharandi, 2009; Abdulfatai and Adekunle, 2012). In the case of a good stable subgrade soil, the loading transferred directly from the surface layer can be supported and sustained by the subgrade soil stratum. But when the subgrade soil is of poor quality and of low bearing capacity, it may not be able to sustain the loading without excessive deformation. In such conditions, it is necessary to introduce layers of good quality soil of appropriate thickness between the surface layer and the subgrade stratum without causing unacceptable levels of deformation in any of the layers (NBRRI, 2004). Also, a sub-grade soil of low quality, that is, uniformly graded, could be improved by stabilizing or blending with aggregate to achieve a more stable well graded sub-grade soil.

In the use of stabilization technique in the design and construction of low volume roads, the emphasis is placed on the effective utilization of local materials with a view towards decreased construction costs. In some areas, the natural soils are of an unfavorable nature and require modification through the use of suitable mineral constituents such as gravel or crushed stone or clay binder. In still other areas, admixtures such as bituminous materials, Portland cement, pozzolanas, salt, or lime are used for effective stabilization. The type and degree of stabilization required in any given instance are largely a function of the availability and cost of the required stabilizing materials as well as the intended application of the stabilized soil mixture (Wright, 1994). A stabilized soil base or subbase may provide the support for a relatively thin wearing surface that will be subjected to light or moderate amount of traffic, or it may function as a base for a high-type pavement that will be subjected to very heavy volumes of traffic. Certain stabilized soil mixtures, including granular soil stabilized mixtures, serve as wearing surfaces in light-traffic roads (Wright, 1994; Kadi Yali and Lar, 2005).

Stabilized soil mixtures also lend themselves readily to the process of ''stage construction'' which involves the gradual improvement of the individual units of a highway system as the demands of traffic increase. Thus a properly designed stabilized soil mixture might function briefly as a wearing surface, receive a thin bituminous surface treatment as traffic increases and eventually serve as a support for a high-type bituminous pavement that will serve a very heavy volume of traffic (Wright, 1994; Kadi Yali and Lar, 2005).

The design and construction of 300m long by 7m wide roadway linking the main access road to Engineering

Materials Research Department with the Pozzolana site within the premises of NBRRI, Ota, Ogun State, was based on a ''stage construction'' approach where the stabilized subgrade is overlaid with lateritic subbase, lateritic base course blended/reinforced with stone dust of 8mm diameter and a 10mm sized granite aggregate materials to serve as wearing course pending when the road would be redesigned and reconstructed to accommodate more load as traffic increases when the Pilot Pozzolana Plant becomes operational.

2. Design

The pozzolana access road design was premised on Bearing capacity, California Bearing Ratio (CBR) values and Flexural pavement thickness relationship adopted from the labour-based light equipment method of road design and construction (NBRRI, 2004). This method of design was necessitated by the urgent need to provide immediate access to the pozzolana plant site for supplies of construction materials. As a result of the expediency of the project, laboratory tests were not carried out. However, simple field test was used to provide an indication of the properties of the soils at the site. The field test carried out at the pozzolana access road was the Jar test according to ASTM D653-85 and D2488. In the jar test, 10% of clay and silt was confirmed and 90 % of sand and gravel was also confirmed in the soil sample. However, the sample was gritty and a little soapy in the test. On the strength of this simple site test, the samples were classified to be sand and poorly graded clay on the Soil Texture Triangle as according to The U.S. Department of Agriculture (USDA) Textural Classification Scheme. Hence, the corresponding CBR values were determined to be 10-20% as shown in table 1. This classification then enabled the design of the pavement using table 2. Using number of vehicles per day exceeding 3 tonnes laden weight of 0-15, since it is a new road. The pavement thickness was designed not to be less than 150mm to give support to the under laying foundation.

2.1 Design Standards

The pozzolana plant access road construction and design were based on the following design standards;

1. Length of the road - 300m
2. Right of way - 10m
3. Width of carriageway - 7m
4. Camber - 5%
5. Top width of side drain (on each side) - 1m
6. Bottom width of side drain (on each side) - 0.50m
7. Thickness of combined lateritic surface - 0.20m
8. Thickness of stone dust(8mm; Ø) - 0.08m
9. Thickness of granite(10mm; Ø) - 0.10m

3. Materials and Methodology

3.1. Inventory of Materials on at site

Light Equipment/Materials
- Pedestrian roller
- Lateritic materials (8 tipper loads)
- Water 3500 litre capacity (8 Nos)

Hand Tools
- Spade (6 Nos)
- Matchet (6 Nos)
- Pick axe (4 Nos)
- Shovel (4Nos)
- Geepee tank 1500 L Cap (2 Nos)
- Geepee tank 500L Cap (2 Nos)
- Wheel-barrow (5 Nos)
- Rakes (6 Nos)
- Linen tape, 50m long (1 Nos)
- Pocket tape, 3.5m long (1 Nos)
- Empty drums (4 Nos)
- Watering can (4 Nos)
- Bucket (plastic) (1 Nos)

3.2. Pavement

Pavement is a road structure consisting of super-imposed layers of selected and processed materials whose primary function is to distribute the vehicle loads to the subgrade. The ultimate aim is that the stresses transmitted to the subgrade are within its bearing capacity. There are basically three types of pavement namely flexible, rigid and composite pavements. The pozzolana access road which is categorized under flexible pavement has a weak subgrade soil comprising of sand and clay which is poorly graded with low bearing capacity to sustain the loading without excessive deformation. The material had to be made stable by means of stabilization with lateritic soil of fairly high plasticity to increase the cohesive strength of the in-situ material. The sub-base, base and surfacing are then constructed on stable subgrade. However, ''stage construction'' in this context which involves stabilization of weak subgrade with lateritic sub base, lateritic base reinforced with stone dust and granite (wearing course) being compacted into a monolithic entity serving as the pavement structure which could actually be improved upon or redesigned and constructed into a standard bituminous flexible or rigid pavement as traffic increases or builds up in the near future when pozzolana plant is fully operational.

The activities involved in the construction therefore include;

1. Bush clearance
2. Tree felling, Grubbing and Stumping
3. Topsoil removal
4. Ditching
5. Cross sections (cut and fill to achieve formation level)
6. Haulage and spreading materials
7. Compaction of the lateritic materials
8. Surfacing

The details of the activities are presented in the following sections:

3.2.1 Bush Clearance

The entire site comprising the access road area and the pozzolana workshop bay area was manually cleared before a pay-loader was used to clear the right of way (r.o.w) of all bush and vegetation having girth 0.5m; and cart away cleared bush to a minimum distance of 7m from road centre line.

3.2.2 Tree Felling, Grubbing and Stumping

Tree felling was done by the pay-loader during the bush clearance operation. Trees having girth in excess of 0.5m were felled and grubbing of the right of way (r.o.w) of all roots, removal and disposal of all stumps to a minimum distance of 7m from centre line of road was done. Manual labour was used in stumping and grubbing, as the site is a virgin land with shrubs and trees with an overwhelming dense root network.

3.2.3 Topsoil Removal

The grader was used to excavate, haul topsoil from the right of way and deposit/spread them in adjacent agricultural farmland. The equipment was also used to make the initial drainage channels and for the cut and fill operations at the site.

3.2.4 Earthworks

The cut and fill operation at the NBRRI Pozzolana plant Access road was achieved with the aid of a grader. It was used in the preparation of the soil (subgrade) to bring it to the correct levels, gradient, profiles and strength. The finished level of the earthwork gave a well-shaped formation level ready for the laying of the different layers of materials.

3.2.4.1 Shape and Level

A template aid camber board may be used to check the cross-section but grader coupled manual labour were used to shape and level the road section.

3.2.5 Construction

Generally, road pavement construction can be divided into two phases; the earthwork and pavement. Pavements are constructed to certain stipulated geometric norms and standards which serve to ensure smooth and safe driving conditions, effective drainage and stable side slopes. The construction of the pozzolana access road commenced with the contractor mobilizing manual labour to cut shrubs, herbs, vegetation on site. A pay-loader was later used for bush clearance after which grader was used for topsoil removal and earthwork.

3.2.6 Ditching
Ditching was achieved at dimension 25m x 1m x 0.4m on both side of chainages throughout the road length**,** since the terrain of the access road had adequate slant or longitudinal slope for storm water to flow naturally without impediments. Scour checks were also constructed along the channels in the longitudinal axis to reduce drastically the effect of erosion.

3.2.7 Cross-Section
For most access roads with low volumes of traffic (< 100 ADT), single lane operation is adequate as there is low probability of traffic congestion on such roads. However, as a result of the peculiarity of the pozzolana plant project which will necessitate movement of heavy trucks supplying raw materials into and conveying finished product out of the pozzolana plant, the road way had to be increased to a two lane roadway. A camber of 5% was used to ensure quick run-off of surface water and prevent the development of ruts and ponding.

3.2.8 Compaction
Compaction was achieved by the use of the pedestrian roller compactor at optimum moisture content (OMC) to achieve the maximum dry density (MDD) at site. 20 passes by the hand roller compactor of 730kg was made to achieve optimal strength on the road. Advantage was also taken of the rainy season to compact at OMC. Rolling was continued until subsequent roller passes were made without making any impression on the surface. This is often referred to as 'compact until refusal'.

3.2.9. Surfacing
Gravel-surfacing work includes spreading, shaping, watering and compacting lateritic materials (subbase and base layers) to a combined thickness of 200mm to lines, levels and camber. Subsequently, a stone-dust material was spread and compacted to 80mm thickness, followed by another layer of granite which was also spread and compacted to 100mm thickness to give it the required strength, stability and durability. It must be mentioned that the concept of labour-based technology was employed in the construction of the pozzolana access road except for payloader/grader brought to create pathway through the thick bush and to grade the road owing the urgency of delivering the project. However, with the development of a bitumen sprayer by the institute (NBRRI), the pozzolana access road was used for testing of the new innovation. The operation involved the spreading of a pre-heated thin layer of bitumen MC1 on stonedust to give adhesion to the granite surfacing.

3.2.10. Maintenance
The importance of maintenance on the life span of earth and gravel roads can not be over-emphasized. Normal, periodic and routine maintenance activities are essential on the roadway, ditches, scour checks, turnouts etc to ensure that they are often in good condition and performing its functions adequately.

4. Conclusion
NBRRI Pozzolana plant site has been opened to several activities such as haulage of construction materials, installation of plant machines/equipment, moulding/laying of NBRRI interlocking bricks for walling, visitation of distinguished House of Representative and Senate members on oversight duties, external media personnel amongst others following the provision of an access road to link the plant site. The access road construction was conceived to allow for the aforementioned activities to take place owing to the urgency of the project (pozzolana plant) which the Institute has realized that pozzolanic materials dotting the nooks and crannies of the nation if well harnessed would help reduce the problem of housing deficit which is linked to exorbitant prices/costs of construction materials which cement happens to be the most important. So if NBRRI could come up with pozzolana cement, a larger percentage of masses would be able to build a light weight (bungalow) structures of their own as it has been substantiated by numerous researchers/literature that pozzolana cement is cheaper to OPC.
However, due to the urgency of the project, a stage construction type of road was preferred to the conventional bituminous or concrete surfacing which would actually be suitable for a project of this nature as heavy trucks would constantly be visiting when plant is fully operational. A stage construction allows for temporary construction of road using majorly local available materials (gravel and laterite) blended together to serve as wearing course in order to stabilize the subgrade. The preference for this kind of construction approach could be due to the urgency of delivering a project, paucity of funds; estimated/expected traffic etc with the intent of building on or improving on it into a well designed and constructed bituminous or concrete surfacing.

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Table 1: Bearing Capacity and CBR values of different soils (subgrades)

Description of Soil	**Classification of Soil**	**Bearing Capacity kg/sq.cm.**	**Approx. CBR (%)**
Soft and plastic clays-poor drainage	Very poor	0.70	3
Black cotton soils	Very poor	0.90	4
Silty clays or heavy clays-uncertain drainage	Poor	1.05 – 1.20	5 – 7
Sand and clay-poorly graded	Fairly hard	1.40 – 1.75	10 – 20
Sand, sandy clay, gravel-fairly graded	Hard-good	2.10	25
Compact clays	Hard-good	2.45	30
Gravel with fines- well graded	Very-hard	2.80-3.50	40-80

Source: NBRRI Training Modules on Labour-based methods for Road Construction (2004).

Bearing capacity is measured as the pressure which is applied to the subgrade uniformly over a circular area of 900mm diameter which causes a settlement of 2.5mm.

Table 2: Thickness of Flexible Pavements (in cm) based on given CBR values

No. of vehicles per day exceeding 3 tonnes laden weight		**Approx. CBR (per cent)**											
		3	4	5	6	8	10	15	20	30	40	50	60
0 – 15		30	26	23	20	18	15	12	10	8	7	6	5
15– 45		37	32	28	25	22	19	15	12	10	8	7	6
45-150		43	37	32	30	25	22	17	14	11	9	8	7

Source: NBRRI Training Modules on Labour-based methods for Road Construction (NBRRI, 2004).

The procedure for determining the pavement thickness by this method is as follows:

1. Identify the type of soil and determine the corresponding value of CBR from table 1

2. Identify the type of loading for the road. Use table 2 to determine the pavement thickness for the loading type and CBR value.

Figure 1: Compaction Operation of stonedust layer