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Morphing the Rules: Advanced Adaptations of Mud in Nigerian Buildings

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Abstract: Mud is a ubiquitous building material in Nigeria, perhaps this is the reason why it is hardly seen as the outright building material that it is. The most popular contribution of mud to Nigerian architecture can only be seen in the ancient traditional huts all over the country. Although still a building material in the suburbs of the country, mud is seen as a relic of the past, a symbol of a primitive tale of Nigerian building construction. The primary effort here is to redefine mud as a "skin" with infinite possibilities of imagery and texture, rather than its typical application as a wall in Nigerian architecture. Mud is attempted to be expressed via a new geometric vocabulary by re-evaluating its surreptitious properties including its ability to behave like a formally defined NURBS (non-uniform rational basis spline) surface. The properties of mud and clay are unconventionally simulated in computer modelling and analysis software to understand the ways in which it can be optimized for advanced building applications. Streamlined calculations and algorithmic calculations serve as tools to discover the NURBS-propensity of mud. This provides a whole new low-cost construction opportunity for the building of irregularly flowing structures.

Key words: Comganisms, generate, morph, mud, skin, spline, texture.

1. Introduction

Over the past three decades (especially in the last ten years), there has been a significantly increasing curiosity to the studies of the nature and behaviour of mud [1], these studies have spawned a gargantuan amount of new information that is practically intriguing and thought provoking. A noticeable number of architects, engineers, scientists and artists have fully researched the characteristics of mud, both collectively and individually [2]. Research has ranged from the analysis of its physical characteristics, mechanical and chemical properties, to even its trado-medical therapeutic values. Especially in the past decade, there have been numerous instances where the prospects of applying mud in a vast array of functions have been dogmatically exploited. Looking closely at Nigeria for example, states of the middle belt like Benue and Kogi have engaged mud in a variety of ways, from molding them into benches to building entire estates out of them. In Benue state, even in the small but developed city of Makurdi, it is not uncommon to find mud benches and huts of varying undulations in clusters of social gatherings. The growth of flowers in their beds and the spread of shrubs are also guided by interlocking modules of iterated clay bricks that are almost unique to each neighbourhood. These "clay shells" shield the plants from the intrusion of ruminant animals like goats and sheep. Mud[1] has been applied as different types of building materials, ceramic furniture, and art forms. However, typically in Nigeria, mud on the other hand has enjoyed a more variegated approach from the contemporary designers and artists than it has from the mainstream architects and planners. Over the past few years, Nigerian artists like Ato arinze (a well-known Nigerian sculptor) and Peju Alatise (an architect and an

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[1] Clay, mud and adobe will often be used in lieu of each other since the character under consideration is common to the three types of earth forms.

artist) amongst others have really demonstrated that an oeuvre of applications of mud is possible in terms of form and its relationship with other materials. The most outstanding user and engager of mud/clay in Nigeria however, can arguably be said to be Yakubu Levi, a master ceramist whose work transcends beyond conventional pottery to high grade technologically influenced[2] in-grain systems of ceramic "coating". Levi has exhibited in almost every international ceramic exhibition; his work also earned him the 2011 Grand Prix Prize for Ceramics, the highest possible award in the field. This kind of dogmatic motive of research, giving rise to multifaceted uses of clay and mud seems to be weak within the circles of design. Currently in design, the primary motive for researching into the prospects of mud has been the aim to reduce the cost of buildings and constructions, and to gear towards a more sustainable and eco-friendly approach of the practise of environmental science. In the midst of all the scientific frenzy generated by the sudden green motive for research into the nature and applications of bamboo and mud, relatively little effort has been made to research certain adaptations of mud. With the world of design already tilted towards being aided by the computer, it is only curious for one to ask if mud possesses certain physical mimetic propensities with the new primitives for design and drafting. It is already obvious that the league of avant-garde architecture and design is consistently and vigorously exploring the X, Y and Z axes, new primitives of design have evolved over the years; design is now aided by what in this study will be called Comganisms[3]. Comganisms like the Spline, the B-spline and the NURBS (non uniform rational basis spline) now seem to hold centre stage in contemporary design. The motive of this study effort is not to go through the already busy intellectual and highly experimental super-highway of the chemical and mechanical properties of mud, but to pave a new but definite street into how mud can be mutated and adapted to behave like a membrane, a skin, and a medium of functioning textural capabilities. Mud can also be redefined to adapt to and mimic the new primitives in computer aided design. This brand of information can allow simulation of material behaviour and conceptual design to be carried out simultaneously. It also gives architects in developing countries like Nigeria a valid, realistic and cost effective chance of further exploring the welter of functionalities in more free-form design generated via non-uniform rational basis splines, an approach that currently seems extremely expensive and unrealistic in Nigeria and other developing countries.

2. Method of Approach

2.1 Adaptation to the Spline

The main aim of this study is to determine how well mud in Nigeria can behave like a NURBS surface with a realistic propensity for construction. To understand the approach, it must be stated that the spline is seen as a major comganism in free form computer aided design; certain properties of NURBS surfaces are reviewed with a view to finding overlapping prospects of superimposing the behaviour of the spline on mud. The currently known effects and challenges of such mechanomimicry[4] are simultaneously noted alongside with researched responses to them. The presentation of the idea is then concluded with a testing scenario of its application in a real-life design project. Projected consequences and effects of the idea in Nigerian architecture are also discussed and briefly analyzed.

[2] This advanced system of coating clay actually goes beyond "coating" but engages a high class chemical and mechanical system that allows the colours or "coat" to be grafted on the clay at an almost molecular level making fading and scratching impossible on the finished work.

[3] A blend of the words "computer" and "organisms" to mean computer organisms, this can be described as a single functioning entity capable of independent existence within the interface of a computer, especially in computer aided design. Comganisms are capable of articulated grouping and regrouping, to form autopoietic and (or) semi-autopoietic generated systems and models.

[4] Mechanomimicry can be explained as the imitation of the mechanical and physical properties of a particular entity by another.

2.2 Functional Texture Propensities

In this study, mud is not only adapted but redefined; mud is taken from its traditional stereotypical nature into advanced geometric realms of infinite textural propensities. A number of methods and techniques are employed for the mutation of mud into "states" and morphologies driven by motives such as sustainability, green effort, programmatic function and an unconventional approach to aesthetics.

3. The Rules

For an unbridled and pragmatic attempt to be made on the adaptations of mud, especially for building, a stage must be set for the adaptation to take place. The adaptations of bamboo and mud under consideration are totally in contradiction to some existing dogmas of architecture in Nigeria. The prospects of the results from this study will imply the start of what is likely to become a chain reaction of more sophisticated freeform design, which is capable of solving advanced design and environmental problems. Considering the nature of this approach of mud application, these so-called rules need to be morphed and not just bent; the rules themselves exist in contradictory parameters to the resulting prospects of what the advanced application of the material under consideration is all about. The following are the most notable dogmas that have for long slowed down the existence and development of avant-garde architecture in Nigeria.

3.1 The Dogma of Rectilinearity

It is a norm in most Nigerian buildings that they must follow certain consequences of classical rectilinearity; these make Nigerian buildings extremely predictable even to the problems they are attempting to solve [3].

3.2 The Dogma of Context

There is this unsung rule of context that has silently gripped the Nigerian building motive. Buildings are seen as a context of what they "should" represent rather than what they "must" represent. This happens at the expense of leaving a noticeable number of environmental and design problems unsolved. The contexts of the problems have changed, it is only imperative that the context of the solutions should as well [3].

3.3 The Concept of Membrane

In Nigeria, the reigning notion of the membrane of a building remains the wall. As a matter of fact, the wall is rarely seen as a membrane [3]. This is a deep contrast to new and effective architectural principles at the tip of avant-garde architecture today, which tackle design and environmental problems from a more effective and efficient angle. In avant-garde architecture, the notion of the wall has since evolved into "skin" and skin has now evolved into "hide"[5]; an advanced hybrid of the skin [4], these notions of membrane are more flexible in delineating the equally advancing methods of spatial form creation.

3.4 Ghosts of the Primitive

In avant-garde architecture, primitive primitives like the box, the sphere, the pyramid and the like are no longer function defining entities when it comes to the role they play in the generative process of a design, yet their ghosts seem to dominate the Nigerian building industry. The sophisticated generative processes as a result of the advanced problems of design have relieved the old primitive shapes of their authority as factors that define design. As a result for instance one seldom sees, or hears of a box-house;

[5] An exhibited research titled "raw hide" by Los Angeles-based architect Jason Payne is noted for its highly inventive and exploratory forms. Payne—and his practise office Hirsuta—encased a building in shingles which have curled drastically over the years in response to the freeze-thaw nature of the local climate. An exploration into the relationship between a building's "skin" and an animal's "hide" forms the basis of the study, the mass of curling shingles is presented as an architectural representation of a beast's pelt.

rather what is common in avant-garde design is a house that looks like a box (even though it physically assumes the form of a box). These primitives are called ghosts in this context because their well-deserved presence and appearance still intimidates the Nigerian architect; he is therefore scared to radically mutate them [3].

3.5 The Green Agenda

It has been almost twenty years since the Rio-Earth summit and Nigeria is yet to develop a comprehensive national strategy towards the global UN Agenda 21 initiative. It is imperative that a GBRS (green building rating system) peculiar to Nigeria is developed [5]. This has made the building industry a bit relaxed in developing a green motive of design. The building industry should not just wait for the full weight of global warming to grip it before it acts.

3.6 The Stereotype of Character

Very similar to the dogma of context, most Nigerians have been trained (by the rhythmic duplication of building forms in Nigeria) to have specific pictures of what a type of building should look like [3]. This gives birth to statements like "this building looks like a bank" or "that house looks like a restaurant". There is a particular character attribution to the physical outlook of a building in Nigeria that forces design into a stereotypical straight jacket of a series of rigid physical representations, a Nigerian architect is therefore surreptitiously forced to make his bank "look" like a "bank" or else he would have failed to accomplish his task.

These dogmas, rules and stereotypes should be jettisoned or re-conjured to allow a freer architecture; the quest for environmental design solutions should be at least as unrelenting as the problems. What we have in Nigeria is mostly "CAd"[6] and not CAD. CAD should extend from its traditional use for drafting to actually aid design; this is a major reason why educators in Nigerian schools of architecture should not take CAD as an adversary but as an ally.

4. Merging, Morphing, and Mutating Mud and a Comganism

4.1 Mud: A Brief Biographical Description

Mud is a mixture of water and some combination of soil, silt, and clay. Ancient mud deposits solidify and harden over time to form sedimentary rock such as shale or mudstone. Mud in this context refers to certain soil types mixed with water (and sometimes other additives to increase plasticity or compressive strength). Mud is a habitat for some animals, and for others it is a component for protective lifestyles. Mud is cheap, practical, and can be very attractive. It is easy to work with, and it takes decoration well. Mud is also abundant, especially where other building materials—such as stone or wood—seem scarce. In northern Africa, mud architecture evolved from a local need since no other building material was available. Although people in damp climates have constructed with mud in the past, mud is especially effective in dry climates where it dries out and does not face erosion from water.

Clay/mud has been used as construction material for buildings ranging from simple huts to complex, multistoried structures. The use of mud for buildings dates as far back as the earliest of civilizations, mud seems to be just a little younger than caves and the use of stone for building [6]. Nowadays technology appears to have contributed to the integrity of the material and mud now comes in different regular shapes and sizes like the usual sandcrete blocks. If mud were to be an element, its most innovative allotropes would be sand-bag earth (mud in different types of sand bags), adobe, and bricks. Almost a third of the people in the world live in houses built with earth [7], and tens of thousands of buildings have

[6] "CAd" here is termed "computer aided drafting".

practically “risen” from the ground on which they stand. In Uganda for instance 71 percent of Ugandans live in a hut [8]. Over the past seven decades, architects and specialists have made a deliberate attempt to increase the social acceptance of bamboo and mud and to promote their adoption as an inexpensive and environmentally friendly building material among both rich and poor [9]. Probably one of the most innovative researchers of mud is Nadir khalili, an Iranian born Californian architect whose has taken the use of mud as a building material as far as designing possible housing units in space and on the moon [7]. The positive results of the prospects of computationally and algorithmically controlling the NURBS character of mud will definitely increase the construction use of the material and flexibility of the design and building industry at large.

4.2 Mud in Nigeria

Mud seems to be ubiquitous in the Nigerian environment, however it has a wider geographical occurrence base than most would imagine. Mud has been in use for a long time in Nigeria; sources show that as early as the 15th century, houses, boundary walls and roofs in northern towns were built of mud [10]. In Nigeria, mud seems to be used everywhere from the sun baked north to the rain infested south, mud has represented a traditional means of building in Nigeria as far back as the history of traditional architecture goes [11-14]. Although the use of the material varies slightly in its preparation and method of engagement among different cultures, houses in rectangular and circular plans are the most common. In Nigeria, mud is still widely used via the wattle and dub technique up till today. The most admirable thing about mud architecture in Nigeria perhaps is the conservative love for the building material; in fact it is not strange to find an array of mud huts very close to an urban settlement with modern architecture. However, as much as Nigerians respect the use of mud for building, it is common to find a lot of them very reluctant to try it out in its most innovative form in modern buildings. A big exception of this however is Benue state, where one out of every three residential building is built of burnt mud bricks.[7]

4.3 Mechanical Properties[8]

Only the mechanical properties with close relationship to the current adaptation are experimentally confirmed and mentioned here. The most popular building standard code for earth in Africa remains the Zimbabwe Standard Code of Practice for Rammed Earth Structures [15].

4.3.1 Bending Strength

In the absence of direct experimental data, the design characteristic bending strength of rammed earth should normally be taken as zero [16].

4.3.2 Modulus of Elasticity

In the absence of direct experimental data the New Zealand Standard [17] takes the modulus of elasticity for earth wall construction as three hundred times the characteristic compressive strength value.

4.3.3 Compressive Strength

The compressive strength of earth is delineated in the Zimbabwe standard practice code as rammed earth (Table 1):

Table 1 Compressive strength requirements of the Zimbabwe Standard Code of Practice for Rammed Earth Structures [15].

Mechanical property	Bungalow	One-storey walls	Two-storey walls
compressive strength (N/mm^2)	1.5	1.5	2.0

Major centres of rammed earth construction include North Africa, Australasia, regions of North and South America, China and Europe, including France, Germany and Spain [18].

[7] The mentioned statistical information is based on a statistical research carried out by Stephen Ajadi in Benue state (2012) as part of an ongoing research into mud architecture in Benue state.

[8] A reasonable effort will be made to avoid the detailed numerical delineation of the mechanical properties of mud, this is because the primary aim here is to adapt the material and not to analyze its properties.

4.4 The Puzzle Method[9]

This method is devised by the author to turn patches of mud into ceramic control polygons on a NURBS surface. The idea is synonymous to a broken mug being glued back together. This method relies on the behavioural integrity of the spline, and the ease at which fluid clay can be adapted to achieve G0, G1, and G2 continuity levels even in the most complex NURBS surfaces, since all that is needed is only a mold of the surface to be adapted to. The spline remains one of the most basic and integral new primitives of the CAD age, almost all free form diagrams and figures are secondary to it. NURBS curves and surfaces are generalizations of both B-splines and Bézier curves and surfaces, the main difference however is the weighting of the control points, which makes NURBS curves “rational” (non-rational B-splines are a special case of rational B-splines). Where Bézier curves evolve into only one parametric direction, usually designated *s* or *u*, NURBS surfaces evolve into two parametric directions, called *s* and *t* or *u* and *v*. The NURBS curve can be represented in Cartesian two- or three-dimensional space. This is because it is possible to regenerate a polynomial function (the basic function of splines) in a polar form through what Lyle Ramshaw [19] refers to as a unique systemic multi-affine function [19] in this way, by evaluating a NURBS surface at various values of the two parameters, the surface can be represented in Cartesian space. This interesting possibility makes it easier to locate connected patches of NURBS surfaces (control polygons) in space. These patches joined together like an organized puzzle at different levels of continuity can be isolated and individually casted out via basic methods of ceramics, and then reassembled to achieve a clay version of the NURBS surface (see Figs. 1-3). The thickness of the source will depend on the mechanical requirements of the characteristics of clay with respect to the form of the surface. This can be simulated along with the generative process of the NURBS surface. As seen in the illustrations below, a case is studied in which two absolutely identical NURBS surfaces are generated via CAD and divided into 67 identical polygons. To delineate the idea of the puzzle method, some regions of the NURBS surface are aggregated and highlighted (see Fig. 1). The selected aggregates of the control polygons are then isolated in a simple fragmentation of the surface. These aggregates of controls polygons are then extruded along their surface to generate a surface with thickness (called a slablet) Molds for the slablets can then be generated via CAM[10] and mud versions of the aggregate polygons can subsequently be manufactured via simple but elaborate techniques of ceramics to fabricate the NURBS surface. The mold for the slablets will include a joint piece in form of a tongue and groove joint; this is decided as an effective fastening method in order to achieve a monolithic feel. Adequate joineries can then be filled into the grooves created by the joints as the surface comes into being. Further finishing techniques can be employed such as glazing and spray polishing to bring out a water-proof glassy impression.

4.5 Concerns

The structural implications of the surfaces are of great importance in the puzzle method of mud adaptation. Careful calculations need to be made in order to generate surfaces that will pose minimum structural concern. The reinforcement of mud can also spawn greater possibilities of surface achievements. It must not be ignored that as it is with the case of almost any construction of free form surfaces with impressive continuity levels, CAM cannot be ruled out in order to make the construction process accurate, time efficient and easy. In this case, CAM will be a suitable method for the fabrication of molds for the polygon aggregates. It must also be noted that for less complex surfaces, the

[9] Here the mathematics of the spline, b-spline, and NURBS will be dealt with based on an assumption that the reader has a prior knowledge of them, reading of papers and materials on the introduction to splines is therefore encouraged.

[10] CAM: Computer Aided Manufacturing.

polygons can be fabricated individually instead of in hybrid aggregates. Due to the fledgling stage of this method, small to medium size surfaces should first be attempted, with preference as interior design components until more is learnt about the prospects and weaknesses of the method.

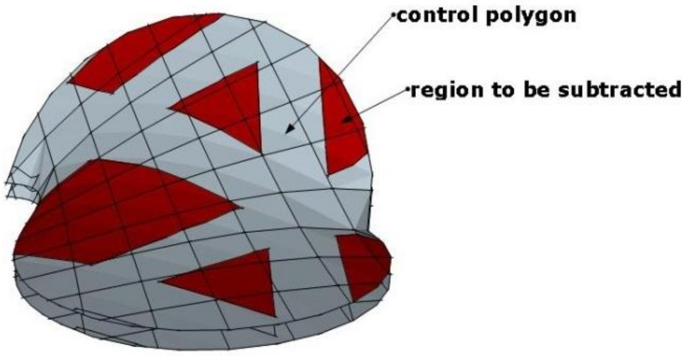

Fig. 1 Two identical NURBS surfaces divided each into 67 control polygons showing 6 selected aggregates.

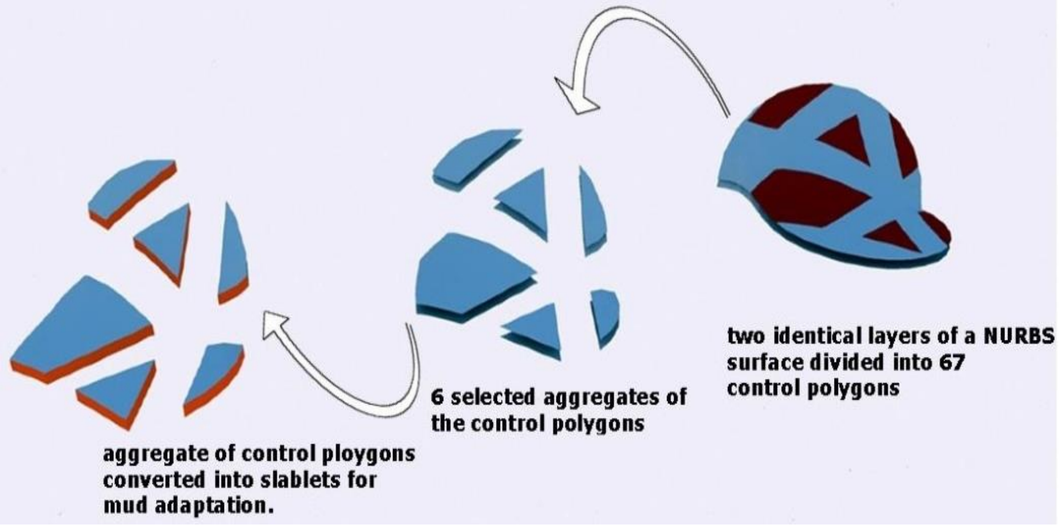

Fig. 2 The puzzle method of converting control polygons to mud slabs.

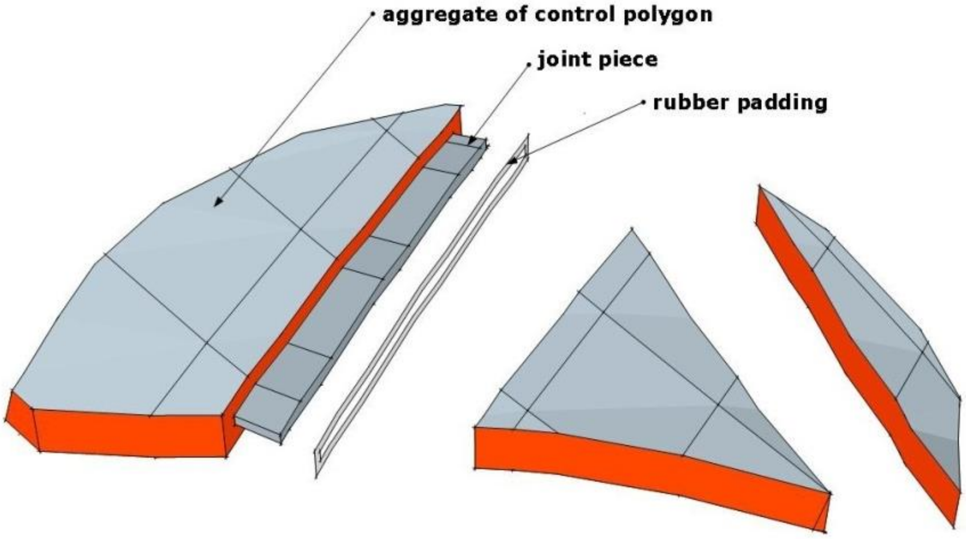

Fig. 3 A typical joinery method of a slab of burnt mud in the puzzle method.

5. Mud: Molding Morphologies

Here, mud is experimented in terms of thermal comfort and its use as a building membrane that is not wall-like. Though slightly different, clay and mud are looked at here from the perspective of their texture, a surreptitious reason why most builders and architects avoid building with it. It has this rough "old school-village" feel and it creates a stereotype of a dead trend to the public. This is probably one of the challenges that the idea of building with mud will have to face in the Nigerian society; it is easy to believe that an average Nigerian will be reluctant to let people know that his/her house was built out of mud. The integrity and symbol of the term "mud house" in Nigeria remains dim and paltry. It is expected that this particular study of the prospects of the change of the texture of mud as a building material will, in the long run, change the way mud dwellings are looked at in the twenty-first century. The wall has a primary character of seclusion: keeping out as well as keeping in, the membrane or skin on the other hand is interactive and also multi-functioning as a reclusive sheath and an opening, strategically selecting what comes in and out while still making a statement with its physical outlook.

The most popular physical and mechanical quality of mud or clay is that it is malleable, ductile and easy to mold into almost any form. The near limitless possibilities of form that could be generated from clay or mud are one of the most important reasons for this study of the development of new textures and morphologies of clay. The ability of clay to stand the test of time is relatively undisputed. When baked in an oven, clay becomes rock-hard, almost impervious to weathering. Some of the best-preserved artifacts are clay pottery of ancient cultures. The texture (and in turn the structural capacities) of clay can be dramatically regenerated by methods almost as simple as the ones used to produce pottery. There is this conception of what clay "walls" should look like, the idea is to change the conception of the physical outlook of clay in building and provide a new prospect for propensities of new textures that will spawn an infinite number of morphological configurations. The effort of these resulting textures though generated with current technology has allusions deep in the way mud was used in Iran's traditional mud dwellings, beehive houses in Nigeria and Syria, the fishing villages in Ghana and the ziggurat that stands 21 m tall in the Mesopotamian city of Ur. Clay can be redefined by generating highly functional membranes simulated within its structural limits; these morphologies can then be defragmented into singly constructible or moldable units that can be rearranged into the main unit. Methods of stereolithography can even be used to develop molds for a vast number of functional clay surface mutations. These molds can then serve as a means of producing ceramic forms of building components where needed. The characteristics of clay must be put into consideration when making new textures and morphologies, the limits of the brittleness, the compressive strength, behaviour under vibration (and other structural characteristics), thermal capabilities and the acoustic implications must also be strongly considered when developing mutations of the surface of mud or clay.

As a case study, the design of an enclosed space is attempted with the aim of not totally sealing off the outside space, and not totally opening up to it. The space enclosure is expected to be ventilated from the sides but at the same time it is not expected to physically look the part, since people are expected to sit in a circle within the space (i.e. the space should be circular); air flow is expected to flow in a circular manner along the circumference of the path; no windows are expected in the enclosing membrane and acoustics as well as the thermal conditions are also expected to be comforting. The simultaneous fulfilments of these entire functionalities rule out the installation of a bourgeois circular wall punctuated with windows (this is an obvious contradiction to a

Fig. 4 A typical mud wall texture in Nigeria.

number of dogmas in Nigerian building discussed earlier). The development of the membrane starts from computationally generating a component from the application of a three-dimensional graph function $Z = f(x,y)$. In order for the three-dimensional graph-surface to comply with the expected functionalities, in a hypothetical location in tropical Nigeria (assuming the topography is plain and the temperature ranges from 28 ℃ to 32 ℃) it is heuristically concluded that the variables should have the following ranges:

- *x* should range from -1 m to 1 m
- *y* should range from -1 m to 1 m
- the step width of *x* should be 0.1 m
- the step range of *y* should be 0.1 m

The function is expressed as $Z = x\ y$ in the *k*-tools[11] plugin of Google SketchUp 8 modeling software; the process of generation is illustrated (Figs. 2 and 3). The compact tectonic topology generated is then re-orientated to its most functional position based on careful calculations. The compact form which is an assembly of two graphs and a bridge is then transformed into an iterant as it is iterated along the circumferential path of the space which is 314.2 m^2 in this case. The structural implications prompt the development of other structural comments as seen in the rendered view in Fig. 4. The resulting structure allows air to flow round the circumference of the space as well as the center in a concentric movement. This simple example is only a tiny part of the oeuvre of morphologies that can be derived when tools and techniques like the computer, computational design and fabrication are applied and adapted to clay.

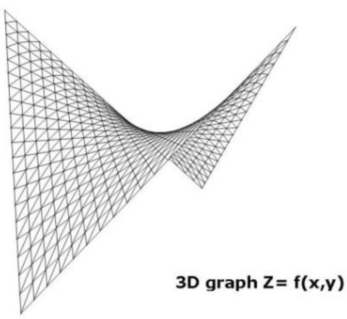

Fig. 5 Generated 3D graph $Z = f(x,y)$.

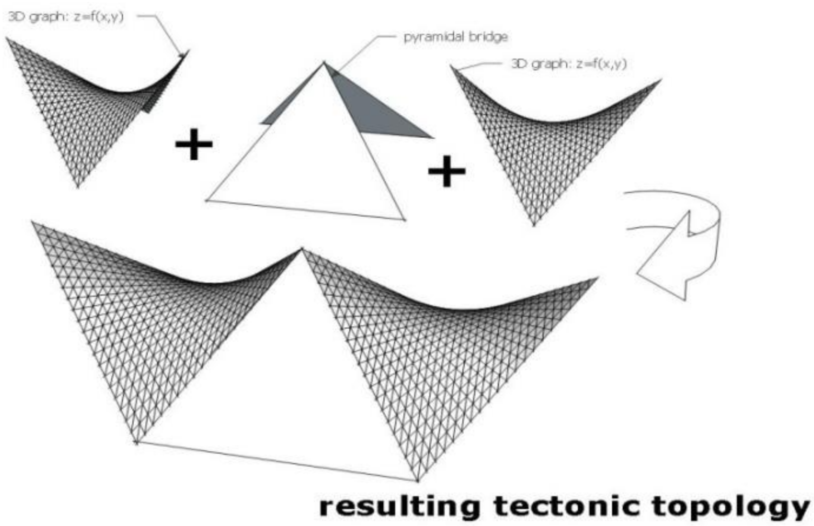

Fig. 6 Formation of the tectonic mass.

[11] k_tools 5.0 released November 2006 is a freeware SketchUp plugin for drawing 2D- and 3D-functions, and to do some geometrical construction and a simple HPGL-import. Author: Klaudius Krusch; Email: mail@klaudiuskrusch.de.

Fig. 7 Final structure showing iteration of the generated.

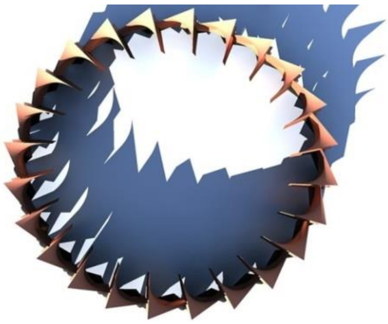

Fig. 8 Plan view of structure mass with primary support.

6. Conclusions

Mud has immense qualities and prospects that are not yet tapped; the availability of the material in Nigeria makes the methods and ideas discussed viable and realistic. However, the advanced approach comes with a need for builders, engineers and architects to be exposed to computer aided design and manufacturing. The clear prospects of the ability to build certain free-form programs will go a long way in helping the twenty-first century Nigerian architect rise to the impending challenges in the Nigerian building and design industry. Design must evolve to encompass computational design and CAM (computer aided manufacturing) and fabrication, via empirical and advanced 3D printing as well as advanced sterolithography amongst others. The Nigerian architect must be fearless in his/her search for advanced alternative options of design and planning. High class research must be encouraged in the schools of architecture from the grass root level. There is very little manual drafting can do in the development of advanced proto-design systems and biomimetic architecture for instance. Students must also learn to solve foreign architecture problems in different countries in order for them to gain a global perspective on the problems facing design. This will give future architects a more rigid intellectual stamina in dealing with the design problems of Nigeria. It is obvious that an avant-garde approach to architecture comes with a price, but Nigeria is well capable of handling the cost of making her cities and villages a better and safer place to live in. If we can spend a lot of money on our clothes, our cars, and the salaries of our statesmen, it is only logical, ethical and absolutely moral to spend on the motive of creating a place where all these can thrive.

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