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IMPROVING DURABILITY OF RURAL BUILDINGS IN RIVERINE NIGER DELTA REGION: A CASE STUDY ON NEED TO UTILIZE APPROPRIATE TECHNOLOGY

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ABSTRACT: *Most rural communities in riverine Niger Delta do not have buildings that are conducive for habitation because the materials used for their construction are of organic origin such as thatch, mud, timber etc. This made them biodegradable and decay quickly. More frequent replacement of such materials is required because of their low durability. Further, factors such as non-availability of conventional building materials, cost of transportation, incomes levels of the people, absence of available skilled labour and lack of appropriate technology in the manufacture of building materials affect the provision of durable and affordable buildings in the riverine rural Niger delta communities. Therefore, there is need to device other means of providing durable rural buildings in terms of materials for roofing, walls, foundation as well as construction methods. The utilization of appropriate technology for building materials and construction methods is recommended as remedy.*

KEYWORDS: Appropriate Technology, Construction, Thatch, Building, Periwinkle, Palm Kernel Shells

INTRODUCTION

A building is basically a shelter for the protection of man, his goods and animals. To this end, the whole development of building materials and construction techniques are related. Apart from providing shelter, a building must satisfy man's desire for mental and spiritual satisfaction from his environment as well the function of enclosing space so that satisfactory internal environment that is safe and comfortable may be created relative to the purpose of the particular building. To achieve this, buildings must be well designed and efficiently constructed to exclude not only the adverse environmental factors such as weather, noise and heat but should provide adequate light and ventilation. In addition, adequate strength and stability must be provided together with adequate fire protection for the occupants, contents and fabric of the building (Foster & Greeno, 2006).

Rural communities and cultures the world over had their own indigenous building practices. These building practices are usually very simple and un-sophisticated but serve the immediate need for shelter of the people. However, before the introduction of modern European architecture and imported building materials, Nigerian traditional communities built their houses to meet their social, cultural and religious needs. Building materials comprised mainly mud, wood, stone, thatch, grass and other appropriate vegetable materials (Online Nigeria, 2015). However, some of the buildings using these materials did not stood the test of time from a structural point of view (UAEinteract, 2015). Over times, modern technologies have

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renovated the use of raw earth materials to improve their performance (Mehta & Bridwell, 2004).

Various factors influence the type of building materials and construction methods that are employed in rural communities. Some of them are climate, socio-cultural requirements, need for permanent structures, available local building materials and labour supply. The Buildings in cold climates invariably require significant amounts of insulation while buildings in warm climates, by contrast, tend to be constructed of lighter materials and to allow significant cross-ventilation through openings in the fabric of the building (Saraydar &Arabi, 2015; Wikipedia-Vernacular architecture, 2015). Buildings may also take different forms depending on precipitation levels in the region leading to dwellings on stilts in many regions with frequent flooding.

The culture of building occupants is of great influence on rural building forms. In Nigeria, the size of family units, who shares which spaces, how food is prepared and eaten and how people interact will affect the layout and size of dwellings Building materials were simple but were superbly adapted to the demands of lifestyle and climate (UAEinteract, 2015; Osasona, 2007).

The type of structure and materials used for a dwelling vary depending on how permanent it is. Permanent building materials are usually heavier, more solid and more durable. They may also become more complicated and more expensive, as the capital and labour required to construct them is a one-time cost. Permanent dwellings often offer a greater degree of protection and shelter from the elements (Wikipedia-Vernacular architecture, 2015).

Availability of the local building craftsman is also important in the construction of rural buildings. Initially, every man who has come of age was supposed to build his own house with the help of family members and neighbours (Osasona, 2007). With time, people developed skills in building construction through intuition, and some families became known for building crafts. Thus, skilled building craftsmen are now employed to carry-out the building project with a fee.

However, most rural buildings lack durability and conditions for comfort as well as the strength and stability. From available data, more than 75% of rural buildings appear temporary in nature (Amasuomo, 2014). These buildings are constructed with thatch or zinc roofs, mud or locally sawn and untreated timber walls; and mud floors that are usually damp especially during the rainy seasons. Because, the building materials are of organic origin (Parry, 1980), they are not durable, deteriorate quickly with an expected durability period of between 3 and 5 years (Osasona, 2007; Parry, 1980). Therefore, they require frequent replacement than modern building materials such as sandcrete blocks, long span aluminium and asbestos roofing sheets (Obande, 1990). However, this study is concerned with improving the durability of rural buildings that will be cost effective and conducive for habitation through by utilizing appropriate technology for the production of materials from available local raw materials and construction methods using the available rural labour (Amasuomo, 2014).

Appropriate technology is a science or technology that is considered reasonable and suitable for a particular purpose that conforms to existing cultural, economic, environmental, and social conditions that is economically viable, regionally applicable, and sustainable. It is a technology that is suitable to the social and economic conditions of the geographic area in which it is to be applied, is environmentally sound, and promotes self-sufficiency on the part of those using it (dictionary.com, 2016; Merriam-Webster, 2015). Thus, the idea of appropriate technology is

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that local people, struggling on a daily basis with their needs, understand those needs better than anyone and can therefore suggest or invent the technological innovations necessary to meet those needs (Troy, 2015). Though, appropriate technology vary between fields and applications, it is generally recognized as encompassing technological choice and application that is small-scale, decentralized, labour-intensive, energy efficient, environmentally sound and locally controlled with emphasis on people-centeredness (Hazeltine & Bull, 1999; Akabue, 2000); less costly than the technology of industrialized societies(Evans, 1984). In the context of this study therefore, appropriate technology in terms of building materials and construction techniques can be applied in improving the durability of rural buildings in the riverine communities of the Niger Delta region by making use of locally available materials which are relatively inexpensive.

GEOGRAPHY OF THE RIVERINE NIGER DELTA REGION

The Niger Delta region (Figure 1), situated at the mouth of the River Niger located in the southern part of Nigeria and bordered to the south by the Atlantic Ocean and to the East by Cameroon. Historically and cartographically, the riverine Niger Delta region is comprised of present-day Bayelsa, Delta, and Rivers States (NDDC,2105; Wikipedia-Niger Delta, 2015; NDAMA, 2015).

Figure 1. Map of riverine Niger delta region
Source: Stratfor Global Intelligence, (2009)

Hydrology

The riverine Niger Delta region is a low-lying, broad and gently sloping plain of the lower River Niger. It has a height of about 500 m above sea-level. The relative height decreases downstream. It is surrounded by meandering creeks and back-swamps. The soil is alluvial formed by water deposits. It has a greater percentage of silt, a clay foundation and large swamps. Drainage is poor in this type of soil and pools of standing water persist from March to December. It is always inundated by flood and suffers a shortage of adequate dry-land (Udo, 1970). This is because, the underlying clay soil do not allow water to permeate through it as quickly as possible.

Vegetation

The vegetation of the region is the mangrove and fresh water swamp forests. The mangrove forest comprised of chains of low sandy barrier islands which protects the coast of the Niger Delta. It is characterized by low and high tide with salt marshes and poorly drained land. The mangrove forests consist of the red, white and black mangrove tree with its characteristic prop roots as well as the unique salt fern and salt grass and are bounded by an area of shrubs and small trees. The creeks of the mangrove forest is inhabited by many invertebrate species, such as crabs, shrimps, clams and eel like fish, periwinkles and mudskippers, etc(NDDC,2105; Udo, 1970). The fresh water swamp forest zone is the region's major source of timber and forest products such as palm trees, rattan (cane) and other deciduous trees like mahogany, obeche etc. The swamp forests are silt-laden and always subjected to annual flooding; and have very high fishery and agricultural potential. It also has large sandy river channels and numerous floodplain lakes (NDDC,2105; Udo, 1970).

Climate

The climate is the hot equatorial forest type and experiences wet season from March to November while the dry season begins in late November and extends to March. During the wet season, the soil is damp and muddy. The dry season is dominated by the North-Easterly winds called the harmattan winds which come with a dehydrating influence. The relative humidity is between 78% and 89%. Mean annual rainfall ranges from 2,500 mm to over 4, 000 mm. Temperatures are generally high in the region with average monthly maximum and minimum temperatures varying from 28 O^C to 33 O^C and 21 O^C to 23 O^C, respectively (NDDC,2105; Udo, 1970).The high temperature, relative humidity and heavy rainfalls also favour the occurrence of fungi, algae, termites, worms and mosquitoes.

The winds in this area are generally of medium strength and the wind velocity varies from 1.5 to 3.3 m/s blowing primarily from south-west during the rainy season and North-East during the dry season around December. The annual evaporation rate is about 100 mm which is relatively low indicating that the atmosphere and the soil are always laden with moisture. The soil temperature is also lowest in the rainy season owing to high water content and low degree of solar radiation.

People and their occupation

The people of the region are distributed as follows: Isoko, Itsekiri, Ijaw and Urhobo in Delta states; Ijaws in Bayelsa state; and Ijaw in Rivers state (NDDC,2105; Wikipedia-Niger Delta, 2015; NDAMA, 2015). The major human occupations are fishing, farming, processing oil palm fruits, hunting, local gin distillation from palm wine obtained from both the raffia and oil palm tree, mat making, thatch making (roofing materials), basket weaving from palm fibres and the rattan canes and wooden canoe boat carving(NDDC, 2105; NDAMA, 2015). These occupations which are usually at subsistence level, and are based on manual artisanal technologies and skills transferred chiefly through family upbringing and not via formal training or education.

Settlement type

The people of the region live in small rural settlements that are scattered with houses built haphazardly without recourse to town planning rules (onlinenigeria.com, 2015). Most of the towns and villages are located along the banks of creeks and rivers (Figure 2.), forming a lineal settlement pattern (NDDC, 2105). The population distribution and the pattern of settlement are largely determined by the availability of dry land and the nature of the physical landscape or terrain. Low relief and poor ground drainage are the primary factors responsible for the low number of large settlements in the region. The larger settlements are found in the interior parts

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where drainage conditions and accessibility are better (NDDC, 2105; NDAMA, 2015). The rural areas constitute about 99% of the total settlement while less than 1% is regarded as urban centres according to their population sizes. Most rural settlements lack comfortable buildings, good water and power supply and good transportation systems. An estimated 88% of rural dwellers in the region live below the poverty line (NDDC, 2105).

Figure 2. A linear settlement pattern at the background along river bank, and washing and fetching of water at the foreground
Source: Author' fieldwork, 2015

AVAILABLE TRADITIONAL BUILDING MATERIALS AND THEIR USES

The available raw materials for traditional building construction such as clay soil, river sand, river gravel, grasses, water hyacinth, rattan (cane), raffia palm, periwinkle shells, palm kernel shells, timber are presented in Table 1.

TABLE 1. Available raw materials for building and their products

Available raw materials	Traditional use	Materials produced through appropriate technology
Clay soil	Building of walls, plastering and flooring.	Brick walls and wall finishing
River sand	Building of walls, sandcrete block and aggregate for mortar and concrete	Manufacture of corrugated clay roofing sheets, clay bricks, aggregate for concrete and mortar.
River gravel	Floor finishing as pebble-dash, aggregate for concrete	Aggregate for concrete and floor finish
Grasses	Fibre reinforcement for producing roof covering and un-burnt bricks.	As fibre to reinforce un-burnt bricks and corrugated clay roofing sheets.
Water Hyacinth	No present traditional use.	As fibre to reinforce un-burnt bricks and manufacture of corrugated clay roofing sheets
Raffia palm tree	Leaflets for thatch-making, branches as bamboo for roof purlin and framework for walls, fibres (piassava) for tying.	The fibre from the tree trunk as reinforcement for the manufacture of corrugated clay roofing sheets and un-burnt bricks

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Oil palm tree	Kernel shells for flooring.	Fibre as reinforcement for manufacture of roof covering and un-burnt bricks and the kernel shells as aggregate for concrete manufacture
Bamboo (Indian bamboo)	Split to required sizes and used for roof purlin and framework for walls.	Leaves as reinforcement for manufacture clay bricks and corrugated clay roofing sheets
Periwinkle	Aggregate for concrete	Aggregate for concrete and floor finish
Rattan (cane) tree	Peeled skin for tying	No present use as building material
Timber	For construction of roof trusses, doors, windows, furniture, etc.	For construction of roof trusses, doors, windows, furniture, etc.

Source: Authors' fieldwork, (2015)

Some of these materials can be harnessed to produce durable building materials through the utilization of appropriate technology since they are in abundant supply in their natural form and less costly.

Clay soil

Clay soil is one of the most sustainable materials commonly used in the region for the construction of buildings. It can easily be excavated from the ground and requires little processing. This means, energy and many time-consuming processes are spared. As a construction material, the clay acts as a perfect brick for buildings and can be used for insulation, making it cost and energy efficient (Sustainable Materials-Clay, 2015).

River sand

The river sand is a naturally occur in the river beds as eroded limestone. It is scooped up from the banks or beds of river for use in general construction and landscaping Sepp, 2016; Cavette, 2016).

Figure 3. Carrying scooped river sand from transfer canoe to dump

Figure. 4. River sand dump for onward to building site

Source: Authors' fieldwork, 2015

River sand can be mixed with clay soil and other materials to manufacture brick; as fine aggregate for masonry mortar or concrete when mixed with masonry cement or Portland cement and lime. The river sand is in abundant supply in the river beds and sea-shore (coastline)

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of the Niger Delta as a result of deposition of alluvial soil transported from rivers Niger and Benue during the flooding period. It is a community property and do require any formality to excavate it for building projects (Figures 3 and 4).

River gravel

River gravel deposits (Figure 5) are being formed as a result of natural weathering and erosion of rocks by water. River gravel is mostly found naturally in riverbeds, dry-river and stream. The action of rivers and waves tends to pile up gravel in large accumulations and these are fetched from river beds and creek beds for various building and construction purposes (enotes.com, 2016). The river gravel in the riverine areas is fetched by diving into the river bed with baskets which sieves the sand away leaving the gravel behind in the basket. They are used as coarse aggregate for concrete for laying pathways of ornamental gardens.

Figure 5. River gravel
Source: Authors' fieldwork, 2015

Figure 6. Elephant grass

Elephant grass

The elephant grass (Figure 6) also called Napier or Uganda grass grows widely in the region. They grow over 3-7 metres tall, resembles sugarcane in appearance but with taller stems and narrower leaves (FAO, 2015; DAFF, 2014). The leaves are 0.60 – 0.90 m long, pointed at the ends, and about 50 mm wide with razor-sharp edges. It grows rapidly under dry or wet conditions, has low water requirements, and therefore can make use of otherwise uncultivated lands (Strezov, Evans & Hayman, 2009). The culms can be used to make fences, and the whole plant is used for thatch. Elephant grasses can serve as fibre reinforcement for stabilizing materials bricks during production of roof covering and un-burnt bricks.

Raffia palm tree

The raffia palm tree (Figure 7) is usually found in woody marshlands or along river banks (Figure 4). The leaves are as much as 25. 11 m long and composed of 80 to 100 pale green leaflets of up to 3 m wide which makes it the tree with the largest branches. The raffia fibre is obtained from the raffia palm tree (Figure 8). After harvesting, the strands of the freshly pale green fibre at the base of the leave are cut, torn into thin strips and sun-dried. The raffia fibre is soft, pliable, strong, durable, non-shrinking when wet and easy to dye and biodegradable making it an excellent material for weaving baskets, hats, mats, rugs, table skirts and widely used as tying ropes, supporting beams while the leaflets used for various thatch roof coverings (Figure 9)) are made out of its fibrous branches and leaves (Encyclopedia.com, 2015; Tropical

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Island Products, 2015; Global Natural Fibres Forum, 2015). The fibre and leaves can be used as reinforcement in the manufacture of roof covering and un-burnt bricks.

Figure 7. Raffia palm tree

Figure 8. Fibre (piassava) from raffia palm tree

Figure 9. Raffia palm tree leaves and leaflets

Source: Authors' fieldwork, 2015

Oil palm tree

African oil palm also grows widely in the region. The three predominant varieties of palm fruits are the tenera, pisifere and dura. Mature palms are single-stemmed and grow to 20 m tall. The leaves are pinnate and reach between 3-5 m long. The fruits are reddish, about the size of a large plum, and grows in large bunches. Each fruit (Figure 10), is made up of a thin soft outer layer (pericarp) followed by an oily, fleshy reddish to orangey layer (mesocarp) and then the black hard kernel shell (endocap which surrounds the palm seed).

Extraction of the oil is done by boiling the fruit after harvesting; the reddish-orangey-red palm oil is extracted from the soft fleshy part (the Mesocarp) by pressing. Once the oil from the Mesocarp is extracted, what will be left is the black hard kernel shell (endocarp) which is crushed to remove the seed. The kernel seed is used in the production of palm kernel oil (Olutoge, 2012), which is darkish and has a nutty smell. Palm Oil is used for cooking, soap making and food manufacturing (Natural Nigeria, 2015). After the extraction of the palm oil and the palm kernel oil, the kernel shells are regarded as waste (Obeng, Ocran & Anaba, 1997; Ibhadode & Dagwa, 2008) and are either burned to supply energy at palm oil mills or left in dumps to compost (Figure 11). They can be used as coarse aggregate for (Usman, Idusuyi, Ojo & Simon, 2012).

Figure 10. Oil Palm fruits

Figure 11. Discarded palm kernel shell dump

Source: Authors' fieldwork, 2015

Bamboo

Bamboo is a member of the grass family, and can grow to heights of more than 30 metres (Wicker Works-bamboo, 2010). The bamboo trees (known as Indian bamboo in Nigeria) are naturally anti-bacterial, relatively durable and also water resistant which makes it a superior product to many of the other hardwoods that are used today (Sustainable Materials-Bamboo, 2015). In Nigeria, it grows in natural vegetation among thick forest and in riverine areas. After harvesting (Figure 6), the culms in its natural form are used in rural areas as columns, framework for clay mud wall, construction of roof trusses, purlins, wood flooring in stilt buildings in flood prone areas. In urban areas, they are predominantly used on construction sites as temporary support to formwork during concrete work and scaffolding during plastering and painting works (Omotoso, 2003).

Figure 12. Bamboo or Indian bamboo tree

Figure 13. Harvesting Bamboo (Indian bamboo) for building construction

Source: Authors' fieldwork, 2015

Periwinkle

The periwinkles are small marine snails with dark or gray coloured spiral cone shaped shells having a round opening and dull interior (Badmus, Audu & Anyata, 2007; Dahunsi & Bamisaye, 2002; Adewuyi & Adegoke, 2008). They can also adapt to a variety of environmental conditions, including extreme heat and cold. The average winkle lives three years and grows to a shell length of between 20-50 mm and 16 mm wide. In Nigeria, they are found abundantly between tidal marks in coastal regions of Niger Delta between Calabar in the east and Badagry in the west (Beredugo, 1984, Umoh & Olusola, 2012, Ohimain, Bassey & Bawo, 2009).

The fleshy (edible) parts are used for food when they removed from the shell after boiling in water. The hard shells are usually discarded and dumped as wastes (Figure 14). These discarded hard shells have become a serious source of land pollution and environmental nuisance in terms of its unpleasant odour and unsightly appearance in open-dump sites in the areas where they are found (Dahunsi & Bamisaye, 2002; Adewuyi & Adegoke, 2008). The

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shell is used as coarse aggregate after the edible flesh inside is removed to produce lightweight concrete for non-load bearing walls and non-load bearing structural elements.

Figure. 14. Discarded periwinkle dump

Figure 15. Water hyacinth covered creek

Source: Authors', 2015

Water Hyacinth

The common water hyacinth is a water plant that has now infested every waterway in Nigeria. These plants grow aggressively and can completely clog up rivers and dams (Figure 15). For weaving purposes, the stem of the leaves are harvested; then dried and platted into ropes for weaving (Caneworld. 2015; Wicker Works-Water hyacinth, 2010).

Rattan (Cane) plant

Rattan (Figure 16) is a naturally renewable tree belonging to the palm family; superficially similar to bamboo and that grows in the tropical rain forest areas like Bayelsa, Delta, Edo, Rivers States and Lagos State (Anifowoshe, 2015). It grows to reach lengths of between 100 and 180 m, having slender stem diameter between 2 and 5 cm (Wicker Works-Cane, 2010; WWF, 2015). Unlike bamboo, rattan stems are solid, and most species need structural support and cannot stand on their own. Many rattans have spines which act as hooks to aid climbing over other plants, and to protect them from herbivores. Because it is extremely strong, lightweight, durable and relatively flexible as well as weather resistant, rattan is used for cane furniture making, house building in rural areas and other handicraft works (Wicker Works-Cane, 2010; WWF, 2015; Siebert, 2012). Rattan is harvested by cutting it from the forest and the spines and bark removed to form cane (Figure 17).

The unprocessed cane which is the thick solid core is used to make frames of furniture. The rattan cane is further processed by peeling off the skin of the strands and cut into long thin cane strips of uniform width and depth, referred to as peel (Figure 18). This product is used for weaving seats and chairs and to wrap the arms and legs of furniture (Wicker Works-Cane, 2010; WWF, 2015; Siebert, 2012).

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Figure 16. Rattan (cane) tree in peel for tying natural habitation

Figure 17. Removing the bark of cane

Figure 18. Cane

Source: Authors' fieldwork

Timber

Various species of timber can be found in the region. In the mangrove and coastal vegetation, the red, white and black trees (native name is Angala) are in abundant supply. They are hardwood used as posts and roof trusses in the construction of buildings. Because of their slender girth, they are not usually sawn but used naturally after cutting the tree and removing the branches. The freshwater swamp forest zone is the major source of deciduous trees with various trunk girths and may grow to heights above 50 m. They are usually sawn into smaller sizes of hardwood in rural communities (19) and transported to urban markets (Figure 20) for building construction, furniture and other wood products. The species commonly found are black afara, abura, mahogany, obeche, sapele and iroko trees.

Figure 19. Timber conveyed to waterside for vehicular transportation to urban area

Figure 20. Vehicle conveying timber to urban area from water transport point

Source: Authors' fieldwork, 2015

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TRADITIONAL BUILDING TYPES AND CONSTRUCTION METHODS IN RIVERINE NIGER DELTA

Traditional rural housing usually contains double-banked rooms opening off the courtyard. They are generally devoid of essential amenities like electricity and water. Only 11.2% of the houses have toilets with septic tanks. Most of the toileting take place in the river but pit latrine and bathrooms separate from the main buildings are also provided. The latrines and bathing spaces are constructed with uses pinned posts and any temporary covering (thatch, timber planks, polythene sheets, etc.) round it with an entrance. House floors are mostly made of mud with very few houses having cement-sand screed flooring.

The building design is the rectangular shaped with room and parlour combination. The buildings usually have long verandas for outside-sitting. Kitchens are built entirely separate from the main building, which kitchen also serves as the store. The kitchens are usually smaller than the main house but has large, low windows to let out smoke and let in plenty of air (Osasona, 2007). They are roofed in the same way as the main house but the rafters are visible. It has shelves constructed tree branches as up-stands and platform made from peeled outer hard cover of raffia palm bamboo leaves weaved into a mat form using piassava or cane peel as tying material. Most cooking with fire wood takes place under this platform. Usually fresh fish or meat are smoke-dried with the heat and smoke from the cooking fire.

The initial buildings were constructed with mud walls and thatch roofs (Figure 21), and room sizes between 2.70 m and 3.60 m square. During construction, the walls for various room spaces are marked-out and wooden posts are pinned along them at about 0.75 to 1.20 m intervals. The wooden posts which formed the vertical members of the wall are of the same height from the ground level while the wooden post for the kingpost is usually longer than the rest. The trusses were a combination of wooden wall plate and ridge piece with Indian bamboo or raffia palm bamboo the rafters. The purlins are made from split Indian bamboo tree or raffia palm tree bamboo of appropriate sizes. The purlins usually placed at right angles to rafter are fastened to the rafters by cane peel or piassava at appropriate intervals to correspond with the effective usable area of the thatch roofing sheet that will not allow passage of rain water. The thatch roof coverings are placed accordingly and fastened to the purlins with cane peel or piassava. The thatch is produced by knitting the raffia palm leaf-lets into sheets of 0.90 to 1.20 mm long with an effective width of 225 to 300 mm(Figure 22). The thatch laying process usually starts from the eaves and progress to the ridge of the roof. The ridge cap made of thatch covering is weighed down with logs of wood to avoid being blown off by wind.

In constructing the walls, a framework of split Indian bamboo or raffia palm bamboo of appropriate size spaced at 150 to 300 mm intervals are tied at right angles on both sides of the pinned rows of wooden posts with cane-peel or piassava. This process starts from the wall plate and progress to the ground level with provisions for doors and windows. The clay soil as walling material is usually prepared by digging a pit near the building site; plenty water is added and the well-moistened clay is trodden with the bare feet to soften it to a fine texture. The plastic clay is now scooped and filled into framework of the wooden posts and split Indian or raffia bamboo (Figure 23). The walls are plastered internally and externally with watery clay to cover the exposed framework after the clay walls are allowed to dry and harden in few days. The floor is filled with the clay soil to the required height. The ceiling is constructed with the bamboo from the raffia palm tree or split Indian bamboo. The pit dug for clay is usually filled gradually as disposal point for domestic wastes such sweepings and grass clearings.

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Figure 21. Traditional thatch roof and clay mud wall
Source: NDDC, 2015

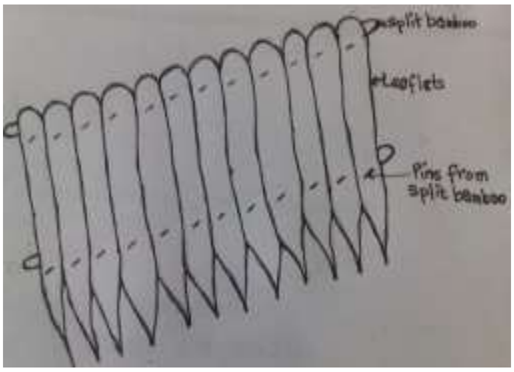

Figure 22. Method of knitting thatch roof covering

Figure 23. Framework for thatch roof and mud walls
Source: Authors' fieldwork, 2015

Figure 24. Zinc roof and mud wall

Though, the use of clay soil and thatch in building is a good economic measure, since it is readily available with little cost in construction, the frequency of maintenance is between 3 to 5 years (Osasona, 2007). Thatch is a degradable material; it leaks frequently during rains; rot away after a few years; and can easily catch fire because it has very little resistance to fire. Also, where the overhangs are not projected enough from the building, the clay walls are washed away with time from successive rainfalls over some periods.

With the introduction of corrugated iron roofing sheets (zinc), the buildings now used zinc as roof covering and clay soil for walls.

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Figure 25. Zinc roof and cement-sand plastered mud wall

Figure 26. Zinc roof and timber wall

Source: Authors' fieldwork, 2015

The construction of the roof trusses is virtually the same with that of thatch roof construction. In this case, the roof trusses which are sawn hard wood are fastened to one another with nails but there is no difference in the wall construction. The durability of the roof is more assured but the clay walls require constant maintenance due to effect of rains. The cost of these buildings is much higher than the thatch and clay soil buildings. The mud walls are sometimes plastered with cement-sand mortar to protect them from rain effect and to prolong the life-span of the building (25). However, the walls shrink over time when the inner wooden posts and split bamboo framework begin to decay making the plaster to give way, thus, exposing mud walls.

In addition, some people may go for corrugated iron roof covering and timber wall construction (Figure 26). This construction is faster and do not require the rigorous clay mud process. It is most suitable on stilt buildings with timber floor where the terrain is annually flooded during the rainy season. This type of building is prone to fire hazards and where the timber walls are not adequately protected by generous roof overhangs, they can decay easily, thus requiring periodic changing of the wall members.

Presently, there are few modern buildings with aluminium, asbestos or zinc roof covering and sandcrete block walls, and plastered and painted walls. However, only few people can afford such modern building. These buildings sometimes had the same design form with the traditional thatched roof buildings with the main building separated from the kitchen line. Along the kitchen line, provision is also made for bathroom and latrine. But in the modern building designs, the toilet, kitchen and rooms are provided within the building. These are more permanent and durable buildings and does not requirement frequent maintenance work.

CHALLENGES FACING THE PROVISION OF DURABLE BUILDINGS IN RURAL RIVERINE NIGER DELTA COMMUNITIES

The provision of durable rural buildings is often faced with a lot of challenges. These challenges are lack of conventional building materials; transportation cost; income level of the people; lack of available skilled labour and lack of appropriate technology in the manufacture of building materials and construction techniques.

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Availability of materials plays a major role in the budget of any project. Thus, using locally available vernacular materials may result in great cut in the budget of the construction. It will also reduce the transportation cost, labour cost, probability of any damage to the materials, etc (Pamnanit, 2015). But the rural riverine communities in the Niger Delta region lack access to conventional building materials such as Portland cement, chippings, rods for reinforcement, corrugated modern roofing sheets, etc because the building materials are sold in the urban or semi-urban areas where vehicular transportation is available. These urban or semi-urban areas are far detached from the riverine rural communities thus, making availability of conventional building materials not only difficult to procure but costly.

Figure 27. Out-board engine powered wooden surrounded boat loading building materials and a passenger speedboat

Figure 28. Hand-paddled dug-out canoes water hyacinth

Source: Authors' fieldwork, 2015

Transporting heavy building materials for long distances through the rivers and creeks in the rural riverine areas is a major challenge. Transporting building materials is usually by outboard engine boats, in-bound engine boats, speedboats and hand-paddled dug-out canoes (Figure 27 and 28). The cost of water transport is typically higher than road transport essentially due to higher cost of petroleum products in most riverine areas. The transport time is often longer compared with road. Many water borne goods also require the use of additional modes of handling before reaching their destination, which adds to the cost and time (NDDC, 2015). A typical scenario of building materials handling takes the following sequence: convey the goods to the nearby river transportation point (community); off-load the goods from the vehicle and load them into the river transport boat; off-load the goods at the destination community water-side; and then convey the goods to the construction site. All these modes of handing building materials are paid for and this in turn adds to cost of providing durable rural buildings.

The income level of the people is another challenge in providing durable rural buildings. In Niger Delta regional, about 46% of employed persons in the surveyed households earn less than 5,000 Naira per month. The proportion declines to 20% within the 5,001 to 10,000 Naira per month income group; and falls to 11% within the 10,001 to 15,000 Naira income range. The proportion of the employed declines further to 9% in the 15,001 to 20,000 Naira income group, while only about 14% of respondents earn 20,000 Naira and above (NDDC, 2015). With the income level of the people, providing durable rural buildings by individuals becomes a

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challenge since about 86 % of the people earn between 5,000 and 20,000 Naira or 20 and 70 US Dollars.

Another challenge is the absence of skilled labour that can carry out modern building construction. A skilled labour is a worker who have specialized training or skill to perform a work (Mahuron, 2016). He must possess a thorough and comprehensive knowledge of the trade, craft or industry in which he is employed (Negi, 2013). This group of construction workers who are masons, electricians, iron-benders, carpenters, fitter and plumbers, etc are always in short supply in most rural areas. They are imported from the urban areas at high cost for any building construction. The importance of skilled craftsmen is that they have the potential of eliminating inefficiencies arising from poorly constructed projects (Bilau, Ajagbe, Kigbu & Sholanke, 2015). Therefore, the quality and availability of skilled workforce is considered an important factor in the effectiveness of the construction of buildings.

Lack of appropriate technology in the manufacture of building materials is also a challenge in providing durable and affordable buildings. The rural folks with their low income levels depend on the costly building materials and construction techniques that are more appropriate for the urban areas. Thus, appropriate technology is considered more productive and less costly (Evan, 1984). Appropriate technology is reasonable and suitable for a particular purpose because it conforms to existing cultural, economic, environmental, and social conditions of the geographic area in which it is to be applied. By this, the local people can also invent, create, and contribute to the technological process of their area much more than what the outside experts can do (Troy, 2015); as they make use of materials which are available locally and relatively inexpensive.

NEED FOR APPROPRIATE TECHNOLOGY IN IMPROVING DURABILITY OF RURAL RIVERINE BUILDINGS

Provision of durable and affordable housing is one of the priorities in the development of any region especially in other to match ever-growing demand. The number of dwelling units reflects the size of population and the location of dwellings. Further, household size, culture and level of income reflect the level of economic activity. In the rural riverine areas, the problem of housing is one of sufficient quality to satisfy modern day standards and finding the means to provide houses that are relatively cheap. The present housing needs in the region is about 607,345 new dwelling units for which the riverine communities is a part (NDDC, 2015).

From the foregoing, measures designed to reduce the purchase of conventional building materials from urban centres became increasingly important since the farther away a building site is from the point of supply, the more costly it is to construct buildings in the rural areas. This has deprived people in most remote communities of modern buildings. Thus, researchers in material science and engineering became committed to having local materials to partially or fully replace these costly conventional materials. Many traditional building materials have benefited from innovative technologies in both manufacture and application as well as making several traditional building materials more financially feasible, environmental friendly and technically sound (ClimateTechWiki. 2015). It is therefore pertinent to utilize appropriate technology in building materials and construction techniques to reduce the problem of providing durable and affordable rural buildings.

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Appropriate technology for production of building materials for rural building construction

The need to use appropriate technology in the production of building materials for rural buildings is to ensure that materials so produced are durable. Some of the building materials that can be produced through appropriate technology are enumerated below.

Concrete materials: Concrete is a product obtained by mixing cement, fine and coarse aggregate in appropriate proportion with water to form a plastic mass. The cement and water react together chemically to bind the aggregate particles together; and when it is cast into suitable formworks and consolidated, it solidifies and get hardened like rock [62]. Mass concrete without reinforcement has considerable compressive strength but little resistance in tension.

TABLE 2. Properties of Periwinkle shell concrete (PSC) and Palm kernel shell concrete (PKSC

Periwinkle shell concrete (PSC)				
Properties	Experiment results	Design mix-ratio	Recommended minimum	Reference
Bulk density	515-517 kg/m^3	1:2:3 and 1:2:4	17 N/mm^2 for structural light weight concrete the minimum 28-day cube strength respectively.	Agbede & Manasseh, 2009; Osarenmwinda & Awaro, 2009)
Specific gravity	2.05			
Compressive strength	19.50 & 19.83 N/mm^2			
	21 N/m^2 & 15 N/mm^2	1:2:4 and 1:3:6		Adewuyi, & Adegoke, 2008)
Palm kernel shell concrete (PKSC)				
Bulk density	580 kg /m^3	1:1:2 at 28 days curing	17 N/mm^2 for structural light weight concrete the minimum 28-day cube strength respectively.	(Ojo, 2012)
Specific gravity	1.29			
Aggregate crushing value	5.02%			
Aggregate impact value	16.19%			
Grain size distribution	16.0 mm & 17.0 mm			
Compressive strength	5 N/mm^2 to 25 N/mm^2			
Compressive strength	23.00 N/mm^2	1:2:4 for 28 days curing		Williams, Ijigah, Anum, Isa & Obanibi, 2014)
Flexural strength	0.34, 0.34, 0.40 & 0.34			

However, the cost of concrete is directly proportional to the cost of crushed stones, which are sourced from urban areas. For a periwinkle shell concrete for 1:2:4 and 1:3:6 mix ratio respectively, the cost saving is between 14.8% and 17.5% when compared to the cost of granite concrete (Adewuyi & Adegoke, 2008). Thus, alternative lightweight concrete options can be adopted for non-load bearing walls and non-structural floors in buildings by using periwinkle shell (Figure 28) or oil palm kernel shells (Figure 29) as coarse aggregate for concrete production.

In Table 2, the results of experiments conducted by various researchers in recommending the use of periwinkle shell (PS)concrete [46], [62], [63] and palm kernel shells (PKS)concrete (Ojo, 2012; Williams, Ijigah, Anum, & Obanibi, 2014) as structural lightweight concrete at 28 days hydration (curing). However, PKS concrete cannot produce concrete with compressive strength above 30 N/m2. But, for concrete grade 25 and below, the material was found to compare favourably with other conventional aggregate such as crushed granite (Okafor, 1988) indicating that it is appropriate for lightweight concrete. Also, to produce a high strength value of PKS concrete will require low ratio of sand to cement (Ojo, 2012).

Figure 29. Periwinkle shell concrete) (1:2:3 mix)

Figure 30. Palm kernel shell concrete (1:2:3 mix)

Source: Authors' fieldwork, 2015

Walling Materials: The clay bricks of 240 to 285 mm length, 115-220 mm width and 115 to 135 mm high (Mundi, 1980; Hydraform International. 2014) can be produced from the abundant clay soil that is available. Un-burnt bricks are recommended here because of cost of energy to fire it. To produce the bricks or blocks, the clay, fibres (chopped grasses and other leaves, fibre from the trunk of raffia or oil palm trees or dried water hyacinth) and cement in 1:20 cement-clay ratio (Hydraform International. 2014) is mixed by adding water until it becomes semi solid. The mix is deposited into wooden or steel mould boxes; and after levelling with a straight edge, the mould is then removed. The clay bricks or blocks are allowed to cure slowly and sun-dried for at least 7 days to remove the moisture from them. The resultant brick becomes a composite material. The fibres act as reinforcement while the clay serves as the binder as it surrounds the fibres, and the cement as stabilizer (Dmochowski, 1990). These types of bricks have relatively high compressive and tensile strength (Auroville Earth Institute. 2009); better water, fire and impact resistance; and allow for thinner, higher walls to be built (Parry, 1980). This stabilised compressed bricks or blocks also have load-bearing strength two-thirds that of concrete masonry blocks (Mehta & Bridwell, 2004). It takes 3-5 times less energy to produce compared to conventional fired bricks [70]. Sometimes, manually operated presses can be used to produce the bricks (Mehta & Bridwell, 2004; Parry, 1980; Auroville Earth Institute, 2009).

Roof covering: Low cost and durable roofing sheets can be produced from the mixture of clay reinforced with fibres and stabilized with some quantity of cement and sand. It is manufactured

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by sieving sand to fine grain size of 2 mm, and then the fibres, sand and cement are mixed to together with water using spade or shovel.

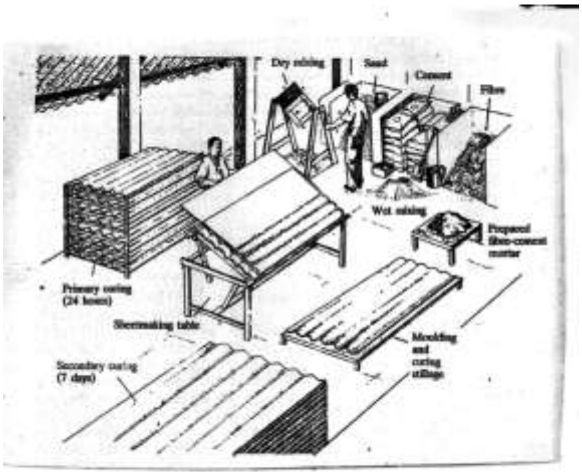

Figure 31. A typical fibre reinforced cement-clay-sand Corrugated roofing sheet production

Source: Parry, 1980

The mix when in a plastic state is poured into a corrugated mould and compacted by stamping. After treating the surface with a wooden trowel, the product and mould is transferred and stacked for 24 hours for primary curing (Figure 31). Secondary curing which lasts for 7 days is carried out by packing the products one on top of the other (Parry, 1980; Person & Skarendahl, 1980). The size of the sheets is 2.4 m and about 10 sheets can be produced a day using two workers. The only material that is bought is the cement (Parry, 1980).

Binding materials: The binding material can be produced from clay mixed with fibre and sand and some percentage of cement (Eneh & Ati, 2010) or sand-cement mortar mixed with water. But where stabilized clay soil binder only is used, it should be pointed with cement-sand mortar of 1:4 mix ratios (Visvesvaraya, 1980).

Appropriate technology for building construction

The adoption of improved construction practices through appropriate technology is the best means of providing durable rural buildings since the use of conventional construction methods attract huge cost.

Foundation construction: Foundation can be constructed by excavating trench of width, 450 mm and depth not more than 600 mm to avoid the effect of ground water during the rainy season period. Where the un-burnt bricks or blocks are used as foundation bedding, the length of the brick or block should be placed at right angle to the length of the foundation excavation to form the base. The bricks or blocks should be bonded together with either cement stabilized clay binder or cement-sand binder. Alternatively, where brick is not used as foundation base, river gravel, and periwinkle or palm-kernel shells can be used by mixing them with sand and cement in 1:2:3 ratio to produce concrete for foundation.

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Walls: The walls can be constructed by placing the locally produced un-burnt clay bricks or blocks along the centre-line of the foundation base allowing some projection of the foundation footing on both sides of the building walls. The bonding material for the walls is the clay soil binder stabilized with some cement and mixed with water (Figure 19). It is always better to use cement-sand mortar for the foundation walls below ground level to reduce the effect of ground water during the rainy season.

Figure 32. Typical clay brick-wall construction
Source: Hydraform International (2014)

Wall finishing: The un-burnt cement-fibre stabilized brick or block external walls do not require plastering or rendering in order to retain the natural beauty of the walls. If it is desired that the internal walls should be plastered or rendered, the clay plaster should be stabilized with a little amount of cement and mixed with water to near liquid limit. When this is applied in 15 mm thick layer and rubbed smooth with trowel, it provides greater bonding between mortars and bricks [Person & Skarendahl, 1980). However, cement-sand mortar used as bonding material for the clay brick or block walls provides a better key for effective bonding.

Roof structure and roof covering: The roof trusses are constructed with sawn timber with a king post and closely provided struts. The timber should be seasoned and preserved by painting it with insecticides. Wire nails are used as fasteners. The cement-sand-fibre reinforced corrugated roofing sheets are fixed to appropriate purlins with zinc nails. Roofs should have over-hang of about 1200 mm to protect the walls from the effect of rain water.

Lintels: In providing lintels, the span for doors should not exceed 750 mm to 900 mm wide and 1200 mm for window openings. It should be designed for use only where the crack widths can be kept to a low level [Person & Skarendahl, 1980). Periwinkle or palm kernel shell reinforced concrete can be used. The lintel reinforcement should be 8-10 mm smooth of twisted rod weave in a triangular or square cross-section. With a timber box formwork, periwinkle or palm kernel shell concrete is cast into it. The formwork is removed when the concrete is hardened.

Floors: The floor of the rooms after it has been filled with mud can be finished with clay stabilized with some cement; well compacted and rendered dust free. In the alternative, periwinkle or palm kernel shell concrete can be used for the floor bedding and screed with cement-sand mortar.

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Doors and windows: Sawn timber which is readily available is used to produce the simplest form of door and window construction. The batten and braced timber doors and windows can be produced by both skilled and semi-skilled carpenters.

COST SAVINGS IN UTILIZING APPROPRIATE TECHNOLOGY FOR RURAL BUILDING CONSTRUCTION

Table 2 shows the cost savings when appropriate technology is utilized. From the data, there is a lot of cost savings when buildings are constructed using appropriate technology. The savings in cost is about 19.70% depending on the type of materials used and the method of construction.

TABLE 3. Cost comparison between appropriate technology and conventional building procurement methods

Building element	Average percent savings in cost (%)	Mean average savings in cost (%)
Foundations	28 to 38	33
Floor	8 to 20	14
Walling	14 to 25	19.5
Roofing and roof covering	8 to 20	14
Doors and windows	10 to 20	15
lintels	20 to 40	30
Floor and wall finishing	10 to 15	12.5
Grand total		19.70

Source: (De, Gupta, Mangal, Moham, Rai, Sharma & Verma, (1980); Adewuyi & Adegoke, (2008)

BENEFITS AND CHALLENGES IN UTILIZING APPROPRIATE TECHNOLOGY FOR DURABLE RURAL BUILDINGS

Benefits in utilizing appropriate technology

The benefits of utilizing appropriate technology in providing durable and affordable rural buildings in the riverine Niger Delta is enormous. Some of the benefits (Parry, 1980; ClimateTechWiki, 2015) are:

1. Very little transport is required to convey the constituent raw materials when locally available resources are used.
2. It uses the cheap local labour that is readily available in the rural areas.
3. The equipment for production of building materials is simple, cheap and thus requires very little additional financial investment.
4. Electricity and elaborate use of fuel is not required.
5. Limited knowledge is required and therefore implementation cost is low.

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6. Provides job opportunities for local work forces, whose skills and experience are readily relevant since they are familiar with the materials and techniques involved.

7. Materials used in building construction are appropriate to local climatic conditions and energy efficient.

8. It nurtures local building material manufacturers and alleviates shortages of construction materials.

9. The resulting buildings will be socially and culturally familiar to the users.

Challenges facing the use appropriate technology

Irrespective of the enormous benefits that are derivable from utilizing appropriate technology for durable and affordable rural buildings, there are challenges in terms of its acceptance. Some of the reasons for non-acceptance are:

1. Inadequate publicity of research outcomes and the expected beneficiaries of such research works are not adequately informed.

2. There are no training programmes carried out in the rural areas on the techniques of producing building materials and their construction methods.

3. Government has not demonstrated the importance of these research outcomes by using the technologies in their building projects. Instead, government still uses the conventional techniques and materials in all their building projects.

CONCLUSION

Conventional materials and construction techniques for building construction was found to be costly. This was attributed to transportation cost of conveying bulk purchases of materials and the importation of skilled labour from the urban centres. These factors have contributed to the inability of rural dwellers to provide durable and affordable buildings. The only means of providing durable and affordable rural buildings in the riverine Niger Delta is the utilization of appropriate technology in the manufacture of building materials and construction techniques.

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