# A Review Of Retractable Vault Covered Housing For The Fulbe Nomads Of Nigeria

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***Abstract*—The quest for better living standards for humanity has stimulated mass movement of people across the globe. This has created a nomadic culture and spurned the re-evaluation of housing conditions, environmental standards, and the ever-changing requirements of nomads. The Fulbe nomadic tribe of Nigeria are particularly at risk due to lack of basic social infrastructure. The temporary structures in which they reside lack structural stringency, material strength and climate adaptableness. Hence, current housing and living conditions of the Fulbe require comprehensive review. Consequently, the government in 1990 to address these challenges introduced the Nomadic Education Programme (NEP). In furtherance of its objectives, this paper proposes the introduction of retractable vault covered (RVC) housing as a practical, low cost and sustainable solution to the housing crises among the Fulbe. It presents a comprehensive review of potential buildings with RVCs, variable location or mobility and other kinetic architectural forms to address the housing needs of the Fulbe nomadic tribe of Nigeria. The findings of the study demonstrate that retractable vault covers (portable buildings) can provide structural rigidity, material durability and climate adaptability to the current housing and living conditions of the Fulbe.**

***Keywords—Retractable, Vault Covered, Migrant-Fulbe; Housing, Northern Nigeria***

## I. INTRODUCTION

The living standards of humanity over the years have had numerous effects on the housing and the environment. Consequently, the quest for better life has stimulated mass migration across vast regions around the globe and ultimately the ecology, biodiversity and environment. Consequently, these changes have necessitated continuous assessment and re-evaluation of housing conditions, environmental standards, and the ever-changing requirements of people in various societies around the world. This has necessitated the constant checks on housing conditions and requirements of the people for keeping them up to acceptable standards.

This scenario is predominantly imperative for communities or groups of people such as nomads, who constantly need to migrate, relocate and re-establish their livelihoods seasonally [1]. The constant relocation of large numbers of people across vast regions can have tremendous effects on the socio-economic, cultural and geopolitical landscape [2]. In many cases the mass exodus and relocation of people to different regions has resulted in housing problems poor housing, illiteracy, poor access to water, sanitation, and primary health care as well as desertification, loss of habitat, and pollution.

In Nigeria, the Fulbe tribe, which constitute the largest group of nomads, are particularly at risk particularly due to temporary "organic" architectural structures in which they reside while in search of sustenance and pasture for their livestock. Traditionally, the Fulbe housing structures lack the basic characteristics of decent housing often evolving in response to their immediate needs. Hence, the temporary structures provide only functional spaces using natural light and easily erectable components [3]. Ultimately, this scenario reiterates the magnitude of the housing problems within nomadic settlements necessitating the urgent need to formulate improved housing programmes for the future. As a result, the Federal Government of Nigeria established the Nomadic Education Programme (NEP) in 1990 to address these challenges in addition to uplifting the poor literacy levels among the nomadic tribes [4]. In general, the programme was also established to stimulate the aspirations and needs of the nomads and promote healthier perceptions of nomads in Nigeria [5]. This is based on the premise, albeit erroneous discernment nomads are "housing carefree" individuals with no natural instinct for housing. Conversely, research on selected nomadic groups in Nigeria has demonstrated their need for housing with forms adaptable their environment [6, 7]. The findings of the group also demonstrate that adaptable housing typically represents the values, desires, and capabilities of the people as a group [7, 8].

However, the typically lack structural stringency, material strength and climate adaptableness which characterize current housing and living conditions of the Fulbe requires comprehensive review. Hence long term solutions to nomadic housing challenges and the effects of activities on the socioeconomic, environmental and geopolitical wellbeing of the nation needs to be addressed. This will provide long term, weather proof, intrinsically safe living spaces made from sustainable materials [9, 10], waste residues [11, 12] and architectural practices [13-16] for the nomadic Fulbe.

Consequently, this paper proposes the introduction of retractable vault covered (RVC) housing for the nomadic Fulbe of northern Nigeria. To the best of the author's knowledge, there have been no studies on provision of practical, low cost and sustainable solutions to the housing crises among the Fulbe in Nigeria. Therefore, the paper presents a comprehensive review of potential RVCs to address the housing needs of the Fulbe nomadic tribe of Nigeria.

## II. TYPOLOGY AND MORPHOLOGY OF NOMADIC HOUSING

The provision of housing and proposals for improving the living condition of nomads requires basic understanding of the current structures, patterns and features of nomadic housing. The Fulbe reside in temporary structures commonly referred to as "*Wuro*" or "*Suudu*" typically average 3.5 meters in diameter and height. These structures are traditionally erected with wood, mud and thatch roofing materials to cater to their immediate needs and the ecological conditions of their environment [17]. Furthermore, nomads spend a great deal of their time living and working open spaces for example, herding and hunting game. Consequently, the perception of housing amongst nomads often reflects the need to mobile, retractable and dismountable housing structures built from low cost, readily available and weatherproof materials from their immediate environment. Consequently, the housing needs of the Fulbe nomads can be addressed by the provision of structures or buildings with variable location or mobility, which can be adapted to their immediate needs. The most common class of these proposed structures includes a broad class known as retractable vault covered (RVC) buildings.

## III. BUILDINGS WITH VARIABLE LOCATION OR MOBILITY

According to the British Architect, *Robert Kronenburg* buildings with variable location or mobility can be classified into three (3) namely; Portable, Relocatable and Demountable. In general, the architectural applications of these categories of buildings are designed specifically for moveability and deployment in some form to different situations or locations for various purposes [18, 19].

The first group termed portable buildings can be transported, towed or carried completely with the method for transport frequently included within the structure. Second group, known as relocatable buildings are transported in parts but assembled at the site into usable built form. Lastly, demountable buildings are flexible in size and layout typically transported in a number of parts for assembly on site. Figure 1 presents an overview of buildings with variable location or mobility [20].

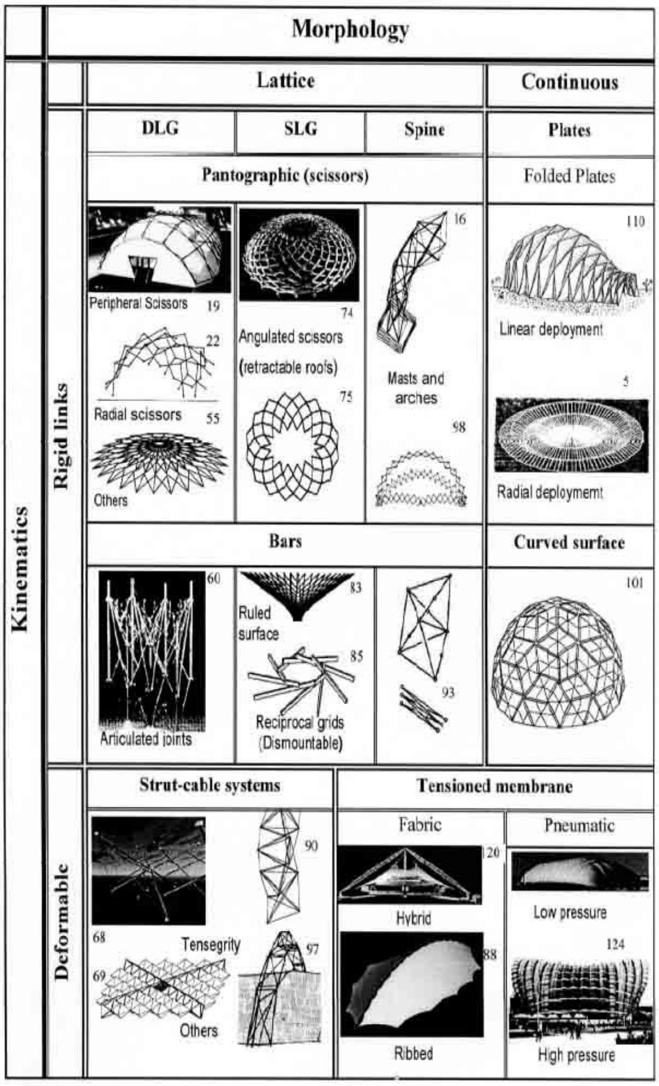


Figure 1: Deployable structures [20].

Figure 2: The retractable roof from above.

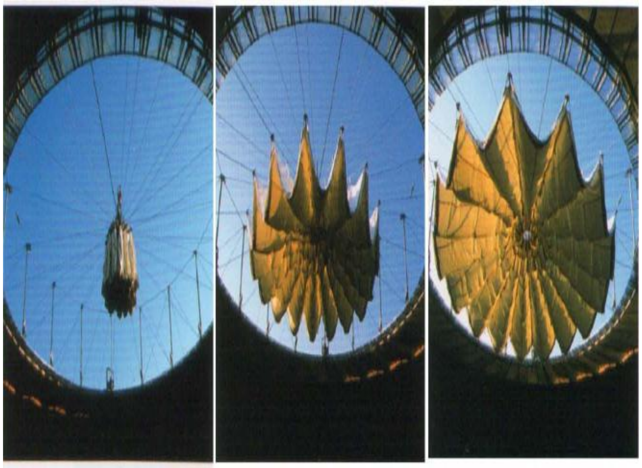

Figure 3: Closure of the Zaragoza roof seen from the inside the arena.

The kinetic structure is a proposal for an environmentally and socially responsible architecture. A convertible membrane tent, an outstanding design to provoke architects, is a proposal to expand their current way of thinking. Kinetic function is a design strategy of the membrane tents. This project presents a transformable membrane tent that responds to light, climate and people. The project proposes a responsive underground space (subway) deploying kinetic membrane tents, which consumes less resource and adapts itself efficiently to climatic changes. Primary design considerations are to use natural daylight in the underground space and to take advantage of the natural ventilation through the transformable membrane tent mechanisms.

The mechanism consists of two main components. The first is a circular membrane tent, which moves up and down, and the second one is stayed mast. Membrane tents are fixed to the masts with sliding joints at the center. These masts run the tents from underneath to the ground on the above through the ceiling from inside out. Moveable tents have a ceremonial presence to announce the weather changes and to reconfigure the space both in the station and in the public place above the ground. In the winter, the membrane tents run down the masts in the station although the form of the membranes does not allow hot air to rise. Simultaneously, rain and snow are collected and guided to the pool in the station. From inside the station, transparent membrane tents allow people to see the sun and the clouds during day, or the moon and the stars at night.

In the summer, the membrane tents are above ground in a public place (Figure 5). The new form of the membranes acts as a solar chimney allowing natural ventilation as pools cool the weather in the station. Above the ground, posts are utilized as lamps for the public place while the bench located around the membrane tents are illuminated with lamps placed on top the posts. As a result, the kinetic function of the membrane tents improves space performance in the station and public spaces. According to the weather conditions people realize two different space organizations both under the ground and above the ground.

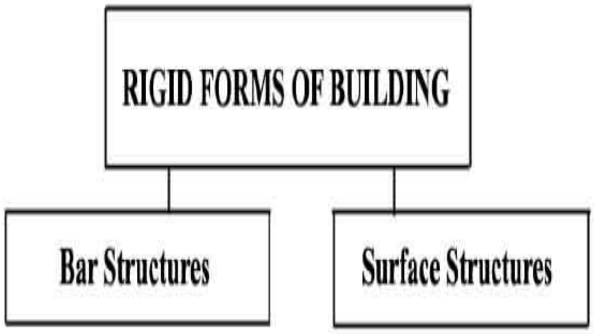


Figure 4: Classification of rigid forms of buildings according to the shape of structural material.

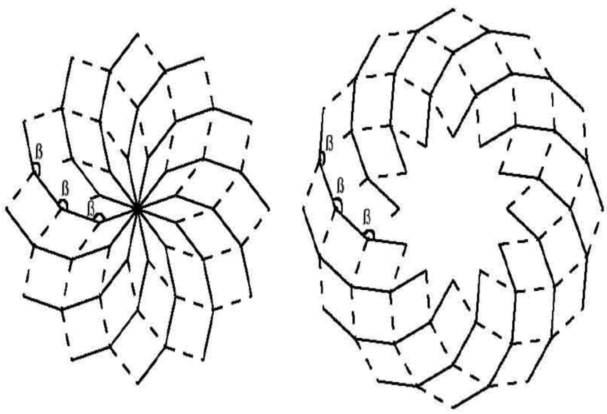


Figure 5: Angulated bars maintain a constant angle equal to β when the structure is expanded.

Each multi-angulated element can be composed of a number of bars, which are rigidly connected to each other, instead of separate angulated elements as designed by Chuck Hoberman [21]. Thus, the structure shown in Figure 5 can also be made from 24 bars, each with 4 segments with equal link angles while 12 bars are arranged in a clockwise and anti-clockwise each. At each crossover point, there is a revolute joint. The entire structure can be retracted radially towards the perimeter and generated for any plan shape. This makes them particularly interesting for sporting venues where retractable roofs must be able to retract towards the perimeter of the structure. However, as the perimeter of the structure varies during retraction, the supports need to allow this motion. The models in Figures 6 & 7 demonstrate the possibility of mounting the structure on pinned columns [21, 22].

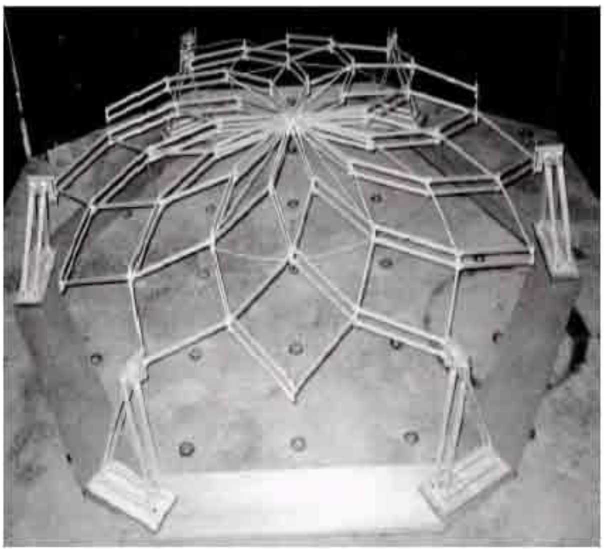

Figure 6: Retractable structure using multi angulated elements supported with pinned columns.

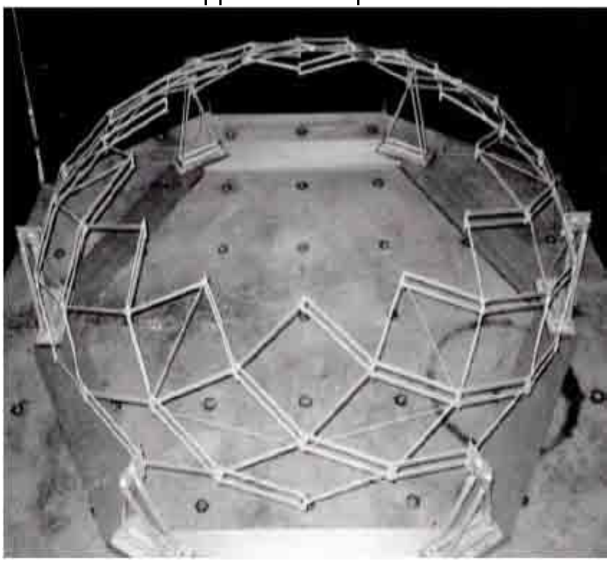

Figure 7: Retractable structure using multi angulated elements supported with pinned columns.

While studying on angulated elements Figure 6, it is determined that new types of scissor structures are also possible by connecting the angulated elements in different configurations. For example, a retractable arch can be made from these elements by creating a new type of scissor mechanism. The geometry of the retractable arch is determined by the new configuration of the scissor. In its simplest form, shown in Figure 7, the new scissor consists of two angulated elements with equal length (L) but in different positions.

A revolute joint connects these elements at the center. Thus, a retractable arch can be made from a number of these new scissors (Figure 7). A retractable-cantilevered arch is also possible by creating a new scissor mechanism from two angulated elements with different lengths (Figure 10). Thus, the structure closes at the top of the arch (Figure 9) [23, 24]. These new scissor types form the basis of new retractable structures.

Figure 8: Umbrellas at the Cologne Garden Exhibition.

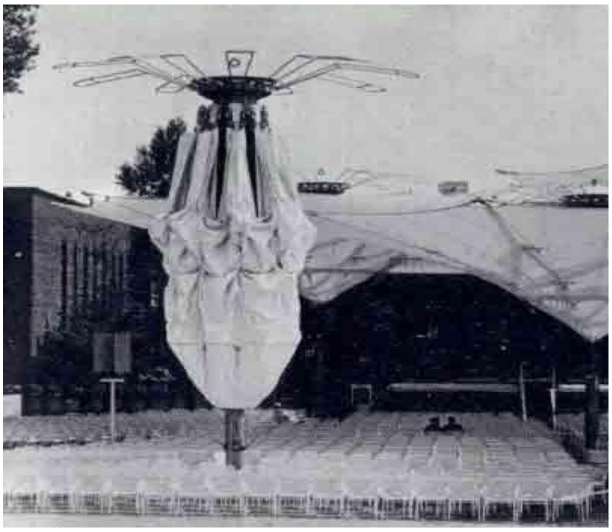

Figure 9: Umbrellas at the Cologne Garden Exhibition.

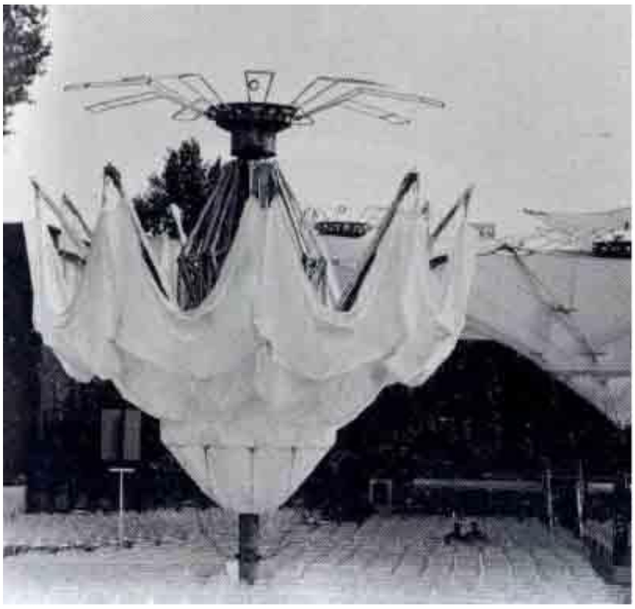

Figure 10: Umbrellas at the Cologne Garden Exhibition, 1971.

Flexible material on convertible kinetic structures is preferred for roof construction with a short span. The effective use of flexible cover material offers a more lightweight structure than rigid covering materials. It can be tied to the kinetic structure, because of this reason there is no need for additional system to tension the flexible material. At the same time, the movement of the structure does not affect the flexible material directly thereby lowering the risk of deformation. However, to obtain a designed form with any flexible material surface geometry, tension calculations should be determined with computer programs. There may be so many hanging and connection points that allow outer weather effect. Hanging points and connection details should be derived after a careful work. Alternative to flexible materials include the use of rigid plates attached to the structural members.

The shape of these plates should be such that they do not interfere nor overlap during motion. Each plate has to be attached to the bar structure in a way so the motion of the structure is not inhibited. These panels may smoothly slide over one another or fold during the conversion of the kinetic structure. For Iris Dome, Chuch Hoberman [21] designs an enclosure created by covering angulated elements with rigid plates, which are allowed to overlap in the retracted position [25]. Each cover is attached to a single angulated element so the motion of the structure is not inhibited. The Iris Dome consists of a large number of plates and bars, and requires many hinges. This can cause potential problems with reliability, which is why no large-scale structure has been built using this system.

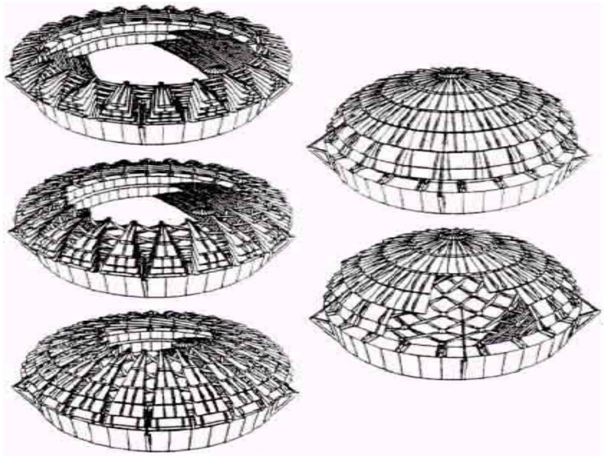

Figure 11: Iris dome covered with rigid panels.

Another example can be found in angulated elements, which grants an opportunity to create a retractable arch (Figures 12 & 13). Furthermore, this represents the prospect of designing a retractable vault by connecting at least two arches to each other by connecting the arches with rigid bars. Every bar is attached to double scissors that are facing one another. Rigid plates are used to cover the vault. Each plate is attached to a single bar between the arches so the motion of the structure is not inhibited and overlaps in the retracted position. Rigid covering materials are more useful than flexible materials for covering large-scale buildings.

Figure 12: Retractable vault covered with rigid plates.

Figure 13: Retractable vault covered with rigid plates.

These rigid materials offer a longer life because they are much more resistant to wind, snow or rain. They can be used as modules with clear details and can be partially replaced when deformation occurs. There are no small openings on the cover, which allow outer weather effect. However, rigid materials are heavier than flexible materials and the process of conversion takes more time.

The last categories of buildings are termed surface structures, which are typically comprised of sheets. These structures are converted smoothly between an extended structural configuration and a compact bundle, which behave as rigid plates connected by joints rather than as simple coverings. The structure's kinetic motion arises because the plates function as links of a mechanism operating in a folding sequence. Numerous examples of rigid surface structures can be found over swimming pools, restaurants, which take full advantage of the weather. These include hinged, opening skylights, sliding, flat roof panels and rotating, curved roof panels.

Figure 14: Folding egg.

Figure 15: Folding egg.

The folding egg is a prototype kinetic folding sheet structure that is constructed from a low-cost recyclable material by Bryant Yeh in Kinetic Design Group in MIT (Figures 14 & 15) [26-28]. The notable advantages are low cost, low weight, structural stability, high insulation value and many possible configurations. Special shapes of the sheets are determined, so the sheets do not overlap or interfere during the movement relative to one another between two extreme configurations [26]. There is an expressed need for the development of lightweight materials, which, in this case, must be able to accept hinges, pivots, gears, or hardware. While analysing the various kinetic structures according to the classification, it is observed that kinetic architecture is an interdisciplinary study between architecture, structural engineering and mechanical engineering [29]. This is unexplored architecture with a new design approach for the application of kinetic structures in buildings. The new architecture is a diverse field joining architectural design and engineering know-how [26]. The new designer is concerned with the task of combining the structure provided by today's advanced technology into an integrated whole with an engineering background. Simultaneously, the designer needs to be aware of the practical, functional, and aesthetic possibilities of contemporary materials. The kinetic structure solutions must consider in parallel both the design of the structure according to the mechanism design principles and the selection of proper materials for covering.

## IV. CONCLUSION

Consequently, this paper proposes the introduction of retractable vault covered (RVC) and kinetic structures for the provision housing for the nomadic Fulbe of northern Nigeria. The findings suggest that this is a potentially practical, low cost and sustainable solution to the housing crises among the Fulbe in Nigeria. Lastly, the paper presented a comprehensive review of buildings with variable location or mobility and RVCs as potential solution to the challenges of housing amongst the Fulbe in Nigeria.

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