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Towards Sustainable Houses in Rural Areas in Sudan

The case of Blue Nile state

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***Abstract*:** *The Paper describes the traditional Architecture based on observations made during the last 5 years in southeastern part of Sudan. Vernacular Architecture and how it's reflected in the severity of the climate condition, building materials and roof shapes are also examined. The Paper examines the existing situation and identify the strengths and weaknesses of architectural design, building materials used and the form of the roof, in a clear SWOT analysis. Then propose solutions to current problems and a suggested model of sustainable architectural design suitable to the area are also given.*

Keywords: *Traditional Architecture, mud houses, sustainable, roof shape, thatching roof.*

1. Introduction:

Traditional Architecture has evolved through many years, many generations and consequently through many trials and errors. The scarcity of materials and energy led to ingenious solutions in design which can be seen in micro as well as macro dimensions. Although such solutions may seem old-fashioned in this era, the idea, the approach, and the implementation of them are important.[1] Over time the human life evolved, and the urban communities developed, as a result of this development people stop using the traditional building materials and shifted to use new building materials.[2] The final product of this paper is a model of sustainable house that fit the context of the study area.

2. Problem Statement

The study area has been observed for the last five years and it was noted that there is a group of new architectural output added to the traditional buildings but then occupants didn't use those buildings and they settle in the old traditional Spaces. Most of those houses are empty. Occupants couldn't live in those houses because it's not comfortable and not appropriate for the climate condition of that area.

3. Objectives

The paper aims to find out reasons why that occupants left the new added houses, while traditional construction showed a remarkable consensus, through the study of the relationship between architecture and environment. This study are summarized in the following:

- The study of the existing situation of both types of buildings (new, traditional) and to verify the compatibility between architecture and its surroundings to avoid the use of inappropriate materials and inappropriate roof shapes.
- To provide practical recommendations on the issue of "compatibility between architecture and the surrounding environment and give a clear guidance lead to sustainable architectural design in the study area.

4. Methodology

This study is carried out using visual inspection for two main factors (Building materials and Roof shapes). General building inspection is first being carried out as to determine the existing condition of a sample of 20 houses, the overview and existing condition of roofs in those houses has been recorded using a camera. A thermometer used to record temperatures inside the spaces, 3 times a day for one year. In addition to survey used to measure occupants level of satisfaction, then the data were analysed and SWOT analysis was used to highlight the strength and weaknesses in this 2 main factors. SWOT analysis will be used as simple model in matrix form. The examination of the data structured, then the strengths and weaknesses of a number of the physical aspects of houses in study areas can address and analysed. After that, the paper gives a clear recommendation to solve the current problems and suggest the suitable model of the sustainable house for the study area.

5. The Study of The Existing Situation

The study area called Alroseires its located in the Blue Nile state in southeastern part of Sudan 60 km from the border with Ethiopia, it's the home of Alroseires Dam, the main source of hydroelectric power in Sudan, its next to Dinder national park the biosphere reserve park in Sudan, the economic activity is based upon agriculture and livestock. The population was 215, 857 in 2006.[3] The climate of this area is hot humid climate, the temperatures are always high, most rainfall (rainy season) is seen in April, May, June, July and October, it has dry periods in January, February and September, the warmest month is April, weather average summary is given in table 1 below.[4]

TABLE I: Climate data for Al Roseires,[4]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C	36	37	39	40	38	35	32	31	32	36	37	36	35.8
Average low °C	15	17	19	22	23	22	21	20	20	20	18	16	19.4
Average precipitation cm	0	0	0.3	1.3	5	12.4	16.8	20	14	3.3	0.3	0	27.4

The main topographical features in the study area are hills, no flat lands, the area surrounded by mountains and covered with huge plants and green grasses.[3] Mud has been the most essential building materials in this area, approximately 80% of all buildings are from mud and it was tested and tried for hundreds of years. Then in the twentieth occupants started to use different building materials, they used fired bricks for walls and corrugated steel sheets for roofs. This materials was obviously not friendly and harmonized with the surrounding environment, occupants left those houses and started to build a small mud units near to the new house and live on those added spaces. The paper will study the existing situation of both types of buildings (traditional and new houses).

5.1 The Traditional Type of Houses in the Study Area

This type of houses were made of very stiff mud prepared by mixing mud and water in the proportion of 1:3 and it is moulded into huge round wall. The thickness of this wall is 30 – 40 cm. Figure 1

Fig. 1: Traditional residential type of houses in the study area.

The roof is thatching roof made of straws, the local builders start by doing a complete frame of wood then they will cover it using straws.

5.2 The New Type of Houses in the Study Area

This type of houses were made of fired bricks composed of local clay bearing soil burned in kiln, its laid in cement mortar to hold the bricks together, the wall thickness is one and half brick plastered using cement sand mixture, roofs are flat corrugated steel sheets. After builders used this materials in the study area lots of problems noticed. Water damaged or stained interior walls. Cracks in interior walls. Plaster cracks, loose plaster, falling plaster, and mold on interior wall surfaces. Not only this, occupants ' could not settle in these houses they did most of their activities outside the house after a while they went back to their traditional houses with all their stuff. Figure 2

Fig.2: Occupants did most of their activities outside the new houses, they went back to their traditional houses.

6. Study and Analysis of the Existing Situation

The paper studied 20 houses to examine the building materials and roof shapes by identifying the strengths and weaknesses and verifying the compatibility between architecture and its surroundings. The map (Figure 3) below shows the study area and the sample.

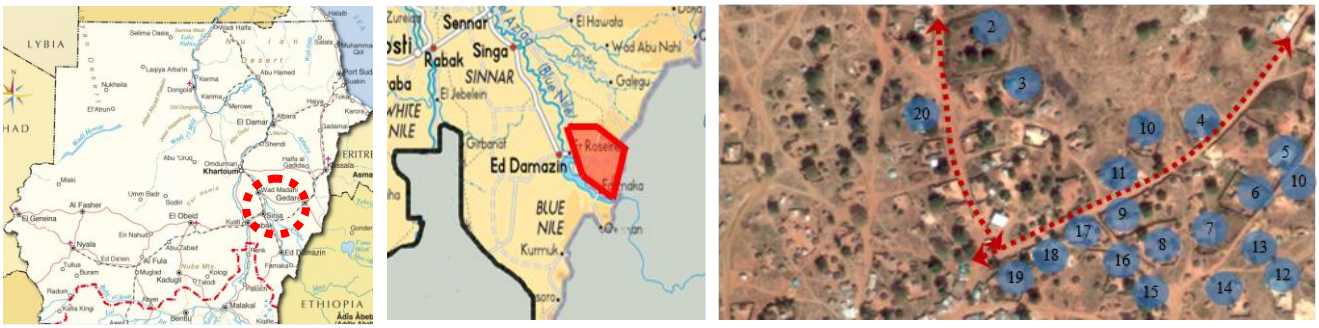

Fig. 3: The study area and the sample chosen.

6.1 Study of The Traditional Type of Houses In The Study Area

- **Building Materials:** traditionally occupants used mud in walls and wood frame with straws for cover in roofs. A lots of researches shows that mud offer superior level of thermal comfort for energy efficient design,[5] the paper proof that a considerable energy saving was achieved by using mud walls specially with large thickness (35 and more), a thermometer used to record temperatures inside and outside the spaces daily for one year, Optimum insulation thickness for wall has been calculated by implementing the Degree-Day method (The number of Degree-Days is the difference between the base temperature and the mean outdoor ambient temperature). Mud houses in the study area uses only simple natural materials (soil, water and added up with straws) which can be easily recycled, its durable, it provide cool air from the massive walls (inside building temperature is about 26 °C – 28 °C in summer). As shown in table 2.

TABLE II: Temperature recorded each month at 1:00 pm, Source: Author

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year

Outside –max. °C	32	34	36	37	30	30	29	29	29	33	35	34	32.3
Outside –min. °C	13	16	17	20	22	22	20	19	20	18	18	17	18.5
Inside °C - at 1:00 pm	24	24	25	26	23	22	22	22	21	23	23	23	25.4

- **Roof Shape:** traditionally builders use thatching roofs, it's the craft of building a roof with dray straws, layering the straws so as to shed water away from the inner roof. This type of roof is style employed by builders in developing countries usually with low cost local straws, in contrast in some developed countries it is now the choice of ecologically friendly roof. Good thatch dose not required frequent maintenance Thatch has some natural properties that are advantageous to its performance. It is naturally weather-resistant, and when properly maintained does not absorb a lot of water. There should not be a significant increase to roof weight due to water retention. A roof pitch of at least 30 degrees allows precipitation to travel quickly down slope so that it runs off the roof before it can penetrate the structure. Thatch is also a natural insulator, and air pockets within straw thatch insulate a building in both warm and cold weather. A thatched roof ensures that a building is cool in summer and warm in winter.[6] Figure 4

Fig.4: The roof of the traditional houses.

6.2 Study of the New Type of Houses in the Study Area:

- **Building Materials:** walls were made of fired bricks, it is strong, hard, durable, row materials is available, very low maintenance cost is required, reusable, recyclable, and highly fire resistant.[7] This method has some disadvantages as it produce environmental pollution during manufacturing process of fired bricks because people in the study area uses a traditional kiln to burn bricks.
- **Roof Shape:** roofs are made of flat corrugated steel sheets, slightly inclined in one side (not more than 15°**.** Figure 5.

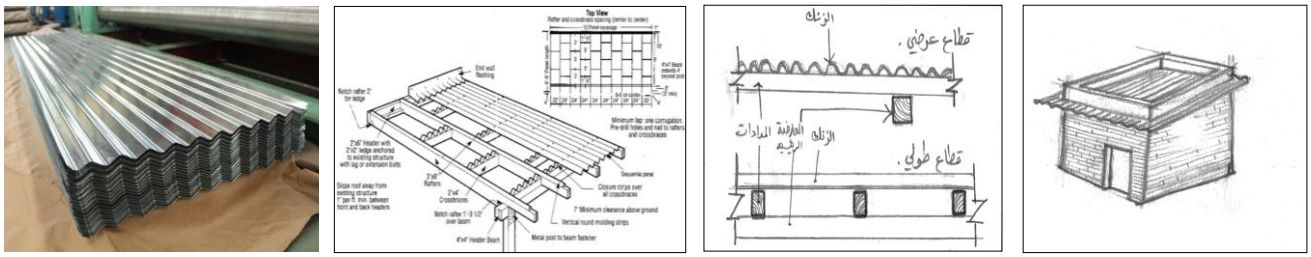

Fig.5: The roof of the new houses.

Steel is very durable in cold weather, 100% recyclable, rusting (required maintenance to prevent corrosion), even with additional coating added on top of the corrugated sheets, camera recorded a weak points in the roof which cause water leak because of heavy rain (rainy season is almost 5 months), steel also has very high heat conductivity. The temperatures recorded were similar to the outside temperatures in most months, in April and May it is slightly lower, in August it is one degree higher than outside temperature.

6.3 SWOT Analysis

The table below compare between the two type of houses based on the previous analysis, to examine which one more environmentally friendly based on green dimensions and sustainable aspects. Analysis will base on SWOT analysis technique to discover the Strengths and Weaknesses of a study area; the Opportunities for development; and the Threats that may disrupt implementation). Table 3.

TABLE III: SWOT analysis was used to highlight the strength and weaknesses in tow main factors, Source: Author

Type	Factors	S	W	O	T
Traditional houses	Building materials	Mud show thermal comfort, energy saving achieved, thatching roofs are durable, recyclable, low cost.	Low level of occupants' satisfaction, Its look old, does not match the modern life style.	Using the natural materials, but in modern design.	Occupant's acceptances, lack of research fund to build the proposed model.
	Roof shape	Pitch roof shed water away from the inner roof, does not required frequent maintenance, easy to drain rain water.	Low level of occupants' satisfaction, Its look old, does not match the modern life style.	Using the natural materials, but in modern design.	Occupant's acceptance, lack of research fund to build the proposed model.
New houses	Building materials	Bricks are strong, hard, durable, row materials is available, very low maintenance cost is required, reusable, recyclable	produce environmental pollution during manufacturing process, walls cracks, loose plaster, rusting and corrosion in steel, steel has high conductivity (no thermal comfort)	Introduce better manufacturing process for fired bricks	Lack of research fund to build the proposed model.
	Roof shape	None	Flat roof is not suitable in heavy rain areas (drain issues), water leaked to the inner space.	Change roof shape, use pitch roofs.	If roof shape changed, the steel is not suitable (no thermal comfort)

6.4 Assessment Criteria and Evaluation Rubric:

Internationally there are several assessment criteria for sustainable evaluation of buildings, four out of these various criteria's are dedicated to assess residential buildings (JAPAN - CASBEE for Urban Development, U.S - LEED for Neighbourhood Development, U.K - Breeam Communities, U.A.E - The Pearl Community Rating System for Estidama),[8] after comparing these four assessment criteria's, the paper followed the Pearl Community Rating System for Estidama. Estidama has seven main sections for assessments,[9] as shown in table 4 below. Each one of these seven criterias has a weight. These points are used to rate the two types of houses in the rubric given below in table 4.

TABLE IV: Evaluation based on Pearl Community Rating System for Estidama.

Credit section		*Maximum credit points (weight)*	*Traditional houses*	*New houses*
IDP	integrated development process	10	9	8
NS	natural systems	14	14	12
LC	liveable communities	38	38	10
PW	precious water	37	35	30
RE	resourceful energy	42	30	12
SM	stewarding materials	18	15	8
IP	innovating practice	3	0	0
TOTAL		**159***	**141**	**80**

As shown in the table above the traditional houses is more environmentally friendly and more sustainable in building aspects. According to the credit points awarded it has got 4 pearls.

7. Practical Recommendations:

In this final part of the paper, a model of sustainable house that fit the context of the study area is suggested. After analysing the questionnaire 84% of the occupants mention that they prefer modern look of the house not the traditional look, so the main intention of this proposed model is to design a sustainable house from local materials while also considering users' needs in today's modern world. The design mainly focuses on keeping the use of local natural materials, but in a modern way where users also need unique, beautiful, modern areas. As the examples shown in figure 6.

Fig.6: Examples of modern houses made of traditional materials and thatching roofs.

Practical recommendations for the proposed design are given below:

Walls: two alternatives are suitable,

1. First: mud wall in 40 cm thickness but it is recommended that builders uses the method of rammed earth (damp earth laid between frameworks and moulded and compacted by ramming)
2. Walls of locally made bricks to minimise embodied energy content. (consider not to burn wood in kiln)
3. Adding some stone walls will add value to the design of houses especially because stone is available in the study areas from the surrounding mountains.
4. The lower part of the wall should be from stone, to prevent it from damp and water.
5. Smaller opining in the south elevation to reduce sun penetration during summer.
6. Glazing elevations or bigger opining in the southern elevation to maximize sun penetration.
7. Add plantation (Big trees) in the southern part to provide shaded façade during summer.
8. **Foundation:** should be added to walls, it's prefer to be a continuous stone foundation.

Roofing:

9. Pitch roof in a degree of 30◦ and more is required because of the heavy rainy season.
10. Continue using a main frame of wood, then straws are used as a mats, this mats are soaked in adhesive resin and are allowed to drain and dry. Mats are glued together under high temperature and pressure to form a small panels in a modular dimension and in different colours. These panels used in the roof as a cover supported by the main wooden frame. (Method was suggested by the author and tested in (BRRI) Building and road research Institute, in Khartoum)
11. An overlap should be provided in the southern part of the roof to prevent the opening from direct sun, and also in the northern part if not a glazing, Landscape and green walls and roofs could be added.

Flooring:

12. Reused wood flooring is often derived from remiled salvage timbers. It can also be salvage from old roofs or floors. It is used for the first floor. (It can be used for the ground floor also).
13. Stone will be used for the ground floor and the outside paving corridors in the courtyard.
14. Minimum earthwork by designing the house to follow the contours of the land.

Refer to figure 7 for all these recommendations.

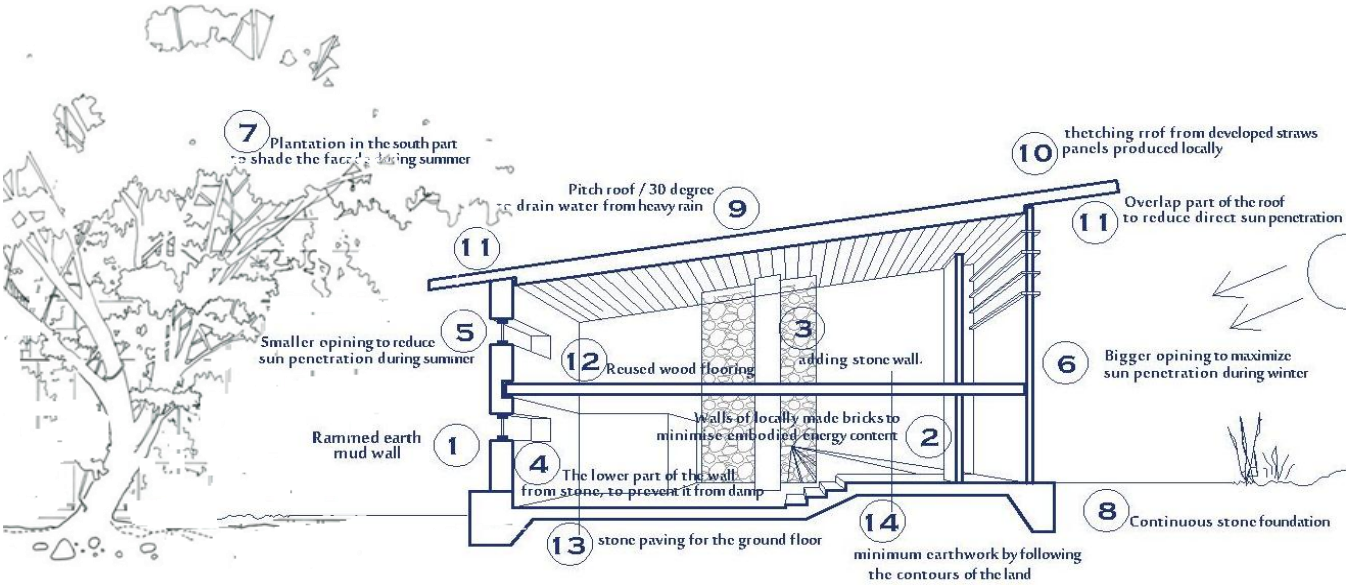

Fig.7: fourteen practical recommendations for the ideal sustainable house in AlRosaires

The paper suggest to build this model as a step further in this research to increase occupant's level of satisfaction and acceptance for mud and straws as a building material by reinventing the vernacular architecture in the context of contemporary architecture culture, especially if they saw a unique model in the area (build model should be beautiful and modern in interior and exterior look and compatible with the environment of the area and low cost, also the built model will be examined easily for its climate behaviours.

8. Acknowledgements:

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