DESIGN CRITERIA IN SHIBAM BUILDINGS

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ABSTRACT

The city of Shibam situated in the middle of the valley of Wadi Hadramawt , is one of the supreme and unique examples of Yemeni art and architecture . All houses in Shibam are constructed out of mud brick . The present paper discussed the types of building materials , building elements and construction stages . physical comfort by day depends mainly on a reduction of the intense radiation from the sun , ground and surrounding building through a proper orientation of the building . The present paper also investigated on transient heat transfer through surfaces exposed to the sun , the results show that the elevation receive the lowest heat loads aimed at reducing energy consumption in housing sector in Shibam .

KEYWORDS

Mud brick ; Orientation ; Radiation ; Bioclimatic , Thermal comfort

INTRODUCTION

Mud has been well known as a building materials used in the construction of housing for millennia . The witness of mud construction " Babel Tower " up to 90 m high constructed in the 700 BC in Baghdad (Samea , 1991) . Shibam city considered one of the integrated historical events in the south of the Arabian Peninsula in Yemen . The city of Shibam situated in the middle of the valley of Wadi Hadramawt is one of the supreme and unique examples of Yemeni art and architecture , which kept its architectural criteria throughout the history (started from 700 AC till know) were Shibamies builders maintain their houses till to day (Ibrahim , 1991) .Shibamies understood the physical and engineering properties of mud e g easy moulding, suitability environment to desert climate and its resistance to thermal (Ramooda et al., 1988). Shibam city consists of 500 houses and 8 mosques surrounded by a mud wall 7 - 8 m high with one gate . All buildings in Shibam are constructed of mud brick up to 8 storey (30 m) . The present paper high lights on the types of traditional building materials locally available which have specific and distinguish properties to natural thermal system and thermal balance due to weather changes .The paper focused on the construction technique , building elements and construction stages The physical comfort by day depends mainly on a reduction of intense radiation from the sun , ground and surrounding buildings through the proper orientation . The present study investigate on transient heat transfer through surfaces exposed to the sun .

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MATERIALS

The source of building materials used in the construction of houses in Shibam is locally available materials which is of earth (clay soil / mud) as a major material , timber straw , tree branches (palm tree) , tree trunk (palm trunk) , lime , ash (Ramad) out product of the burning of white lime , wadi stones and etc . The brief description about the major materials used are :

Clay Soil : It is an earth material consisting of clay soil or mud is available in the Wadi of Hadramawt consist of differente elements as tested in the laboratory and the results are given in Table 1.

Straw : It is known as (tibn) brought from the land around the roots of palm tree , the straw is sieved , the chopper straw of approximated sizes 30 - 50 mm is used in the manufacturing of the mud brick . The finer straw is mixed with mud and water where used in the process of the flooring and plastering .

Mud brick (Madar) : Manufacturing of mud bricks is a fundamental stage in the traditional method of the Shibamies habits to construct their houses . The stages of the manufacturing the mud brick started with , the clay soil is pulverised and mixed with 15 - 20 percent by weight of straw (tibn) thoroughly mixed dry , then adequate water is added to make it easy to mould (Malleable) , then the paste is placed in the wooden mould (Miltol) laid on the ground , manually compacted and demoulded , kept for sun dried . After the sun drying the mud bricks were arranged in to rows near the site ready to used . The final size of the mud brick is about 30 x 50 x7.5 cm .The study found that the air dry mud brick is shrink at a rate of 10 % of its volume (wet volume) . Attempts has been made to study the crushing strength of the mud bricks and results found between 1.1-1.32 N /mm^2 .

Table 1 . Components analyses of clay soil sample

Components	Symbol	Percentages (%)
Aluminum	Al	24.0
Silicon	Si	50.0
Lime and Magnesium	$CaCO_3$ & Mg	6.0
Ferrous Oxide	FeO	8.0
Organic material	—	2.0
		100 %

BUILDING ELEMENTS AND CONSTRUCTION STAGES

Most of the buildings in Shibam consist of different elements which are : excavation, foundation , load bearing walls , slabs , stairs , partition walls , columns etc . The description of these elements with their construction stages are as follows :

Excavation : when the site is selected , leveling work is started as well as excavation work take place , where the depth of the foundation and its base should be rested on a hard soil or strong soil strata , with depth of excavation about 1.6 - 2.0 m and with a width of 1.6 m.

Foundation : Masonry stone footing is usually used with a width of footing of 1.5 m or twice thickness of the base wall with a depth of footing 1.6 - 2.0 m . The construction stages were started at the excavation level were animal waste (droppings) is spread equally in all the eccavated trench upto thickness of 30 mm , a layer of rock salt is placed on the animal waste with 80 mm thickness , the function of this salt is to absorb the water and deters any under ground insects coming upto the floor . Then a wooden logs (Idaan) 100 - 200 mm diameter were laid parallel to the length of the wall placed on the layer of rock salt . Another layer of white lime and ash (Ramaad) of about 20 - 30 mm thick is placed and mixed with wooden logs until it leveled . A layer of broken stones (50 - 150 mm diameter) is placed upto 400 - 500 mm thick as a hard core . Then the construction of rubble masonry strip footing is started upto a height of 0.5 - 1.0 m above the ground level (GL) as shown in Fig.1 .

It can be seen from the figure that the lower layers of the construction of the footing contain animal waste , ock salt , wooden logs and (lime + ash) respectively of total thickness 340 mm which are a natural erials acting as a cushion below the stone footing which can be absorb any impact load , in addition to

this function , it can be prevent capillary action and minimize transfer of the thermal due to earth .

Wall Foundation : The masonry strip footing ended at the GL then , the wall foundation constructed with the same thickness of the footing (1600 mm) with reduction slope from external side of the wall foundation (LHS Fig. 1) up to the wall thickness 860 mm .

Load bearing walls : These walls are constructed after the wall foundation with thickness of 860 mm upto the height of the ground floor (3.5 m - 4.0 m) , then the wall continue till the roof height . The technique used here that the gradual decrease in the thickness of the wall till the roof reached to 300 mm thick . The reduction of the thickness from the external side of the wall , where as from the internal side remain straight or vertical as shown in Fig. 2 .

Slabs : After finishing the construction of the all walls , the joists (ud) are arranged in equal distances of 300 mm (brought from Christ's - thorn tree known Ilb) . The branches of palm tree is used to covered the gaps between joists and then carpet (hand made from leaves of palm tree) is spread on the area . On the top a mixture of mud straw with adequate water is placed and leveled . (150 - 200 mm thick) till it dried a layer of slaked lime is spread on the mud floor as a finishing material . It is observed that the mud floor constructed with a steady slope .

Stairs : As it is mentioned that Shibam buildings are a multi storey buildings , the stairs are of the important elements , all the stairs are constructed with a central column built from mud bricks , the steps are constructed by wooden beams logs and covered with mud straw .

Openings : All the openings and windows are concentrated in the main facade of the buildings providing overlooking the street and squares yard of the town , inorder to receive enough lighting in day time and also prevent neighbours house overlooked . From the field study it is observed that the exterior and interior position of the openings determines the amount of the lighting required by widened or narrowed the openings size for the purposes of ventilation and visibility . Beside the windows there are openings used for ventilation purposes placed at shallow height .

Roofs : Similar technique has been used as slabs construction . In addition a finishing material to the surface is used , where ash and lime are mixed and spread on the surface of the roof . It is observed that this finishing materials had sufficient resistance to the weathering condition e.g rain , wind and reflection of the sun rays .

Plastering and Finishing : From the field observation it is found that there is two methods are used for plastering . (1)External plastering : all the walls are plastered by a mixture of mud and sieved straw (fine straw) with water , kept until it dry , then next layer of mixture 30 % of fine sand and mud is placed , then finishing take placed either by slaked lime or by ash . It has been found that in the back walls a mixture of (lime + ash) is applied to resist water and moisture . (2)Internal plastering : It is done by mixture of fine straw with mud , then finished by slaked lime which is polished by special stone to give surface shinning .

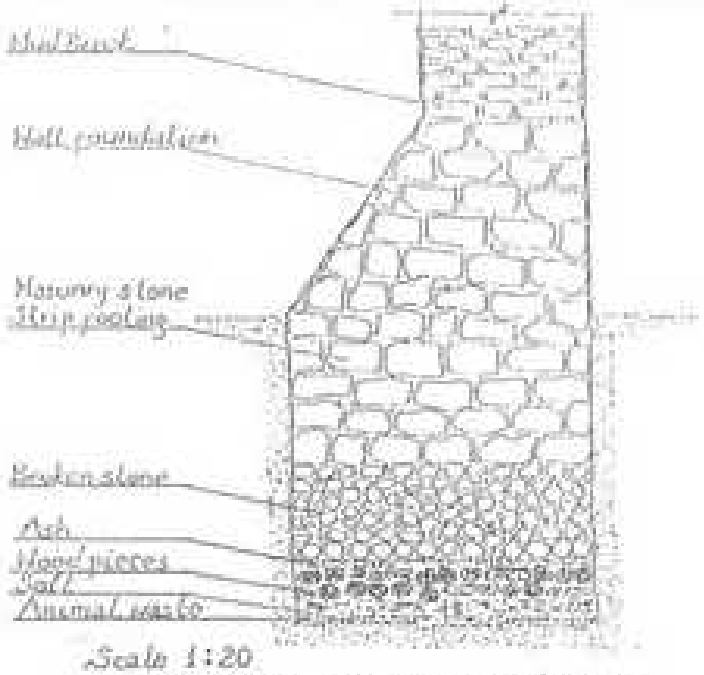

Fig. 1 Construction Detail of Footing .

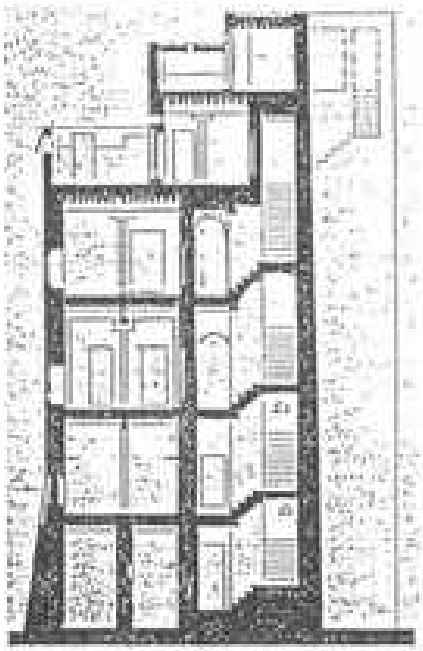

Fig. 2 Construction Detail of Walls .

ORIENTATION

The thermal comfort in a building is depends to a great extent on its orientation characteristic , materials used and type of construction adopted . In Shibam buildings there is practically very little choice of materials were all the materials are locally available . a simple method of construction teclunique were adopted . The only way to ensure maximum possible thermal comfort is correct orientation of the building Shibam situated in the middle of the valley of Wadi Hadramawt, Shibam city consistsof 500 houses and 8 mosques surrounded by a mud wall 8 m high with one gate. The traditional architectural heritage of mud construction had been practiced for centuries in Yemen The perfect bioclimatic architectural design of buildings have stood , the test of time as some buildings are 500 year old These houses were planned and designed to interact with climatic conditions as well as social traditions to minimize costly needs for comfort cooling and heating The methods and principles of city design and planned used, reveal an advanced functionalism , which reflected in the adoptation of architecture in its details , to public and private needs , security and defence requirements Among that also specific environmental conditions detailed that the city had been planned around narrow and shady streets Buildings are constructed from mud bricks were used in the construction of walls , slabs , floors and roofs with different types of openings and ventilation which provide climatic comfort (Daniluji , 1987).

Climate Analysis :

In the south east of the Arabian Peninsula in Yemen especially Hadramawt and similar locations the air temperature during summer is very high . Wadi Hadramawt located at 16° latitude and 49° longituale has extreme hot and dry condition in summer and low temperature in winter shows a typical desert climate as shown in Figs . 3 and 4 with considerable difference between the seasons of 14° C and a rather wide diurnal temperature range (approx. 10° - 13° C). The climate in Shibam is dry with very little rain Normally the prevailing wind is from south - west to east . The west wind however is not comfortable and accordingly the location of the main rooms in Shibam buildings has been found on the eastern side as for as possible to protect it from westerly sun in the after noon as well as from the high westerly wind . The field study investigated that most of buildings in Shibam face the direction of prevailing wind so that they obtain the maximum benefit from air movement even on days when there is only slight movement of air out side .

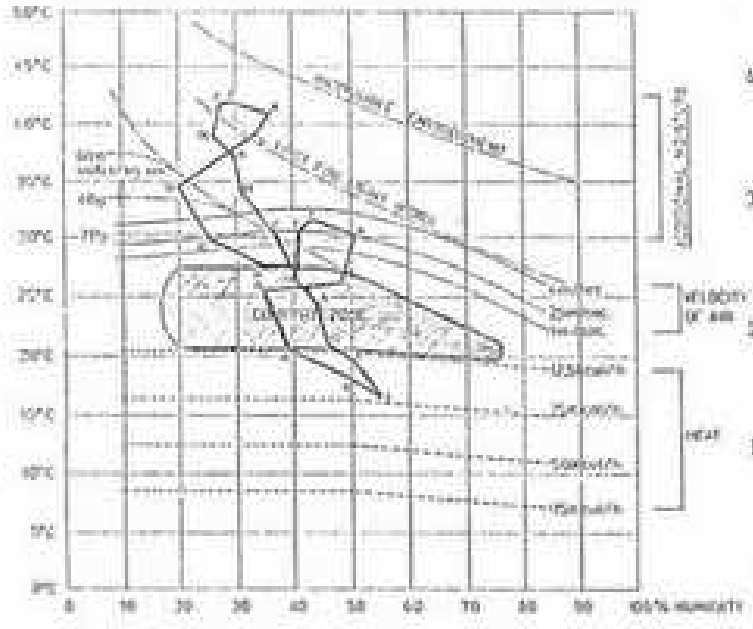

Fig. 3 Bioclimatic Chart of Shibam

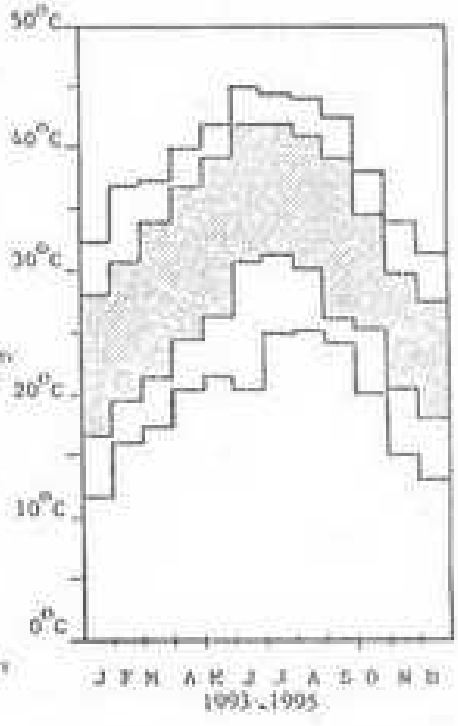

Fig. 4 Diurnal Variation of Ambient Temperature at Shibam .

Orientation due to wind movement

Orientation with respect to wind is an important factor because of its cooling effect . The study found that the buildings in Shibam have been fu'lfilled the consideration of selecting the orientation and planning of the houses where the two main factors are : (i) The incident solar intensities which depends on the altitude and azamuth of the sun . (ii) The direction of prevailing winds during different months of the year . The only way to ensure maximum possible thermal comfort is correct orientation of the buildings . The study observed that in Shibam buildings maximum advantage of sun and wind have been considered to satisfy bio climatic needs of the occupants . The study also found that , to minimize the heat gain in summer and gain the benefit heat in winter the longer walls of buildings in Shibam faced north - south and shorter walls faced east - west as in Fig .5 so that it is clearly observed that the minimum wall area is exposed to the rays of the after noon sun .

Air Movement

It is important to take in to account the difference in temperature and the difference in pressure which causes air movement . Hot air arises , and air flows from areas of positive pressure to areas of negative pressure in due openings close to the ceiling help the escape of foul air and are good from ventilation point of view . The study found that in Shibam buildings the inlet openings is low enough to ensure maximum ventilation at the normal living level , where as the location of the outlet openings dose not noticeably affect the interior air flow as shown in Fig .6 It is known that the opening on both the sides is more or less equal , which is good for cross - ventilation . While consideration take placed by orientation , wind movement and opening with air movement , it should be pay attention to the roof which is exposed to the direct sun radiation , the more heat the roof reflects more heat inside the rooms ,with insulation less heat penetrate through the construction .In the Shibam buildings it is observed that , the surface of the roof is plastered by a layer of white lime which is the best and cheapest treatment , which is absorb 21% of solar radiation.

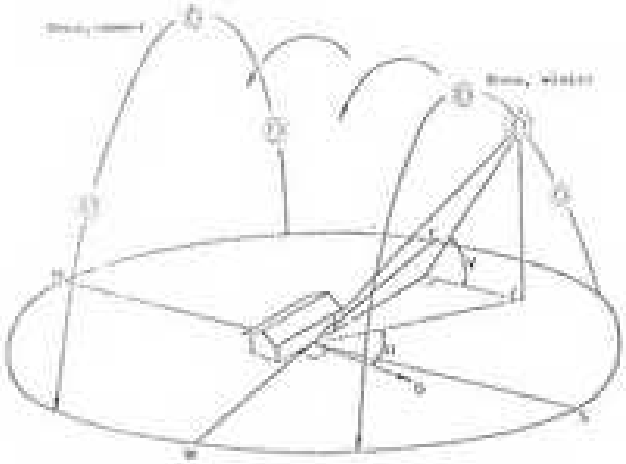

Fig.5 Plan of the Sun Path .

Fig.6 Cross - Ventilation .

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THE INFLUENCE OF THE MOST COMMON BUILDING MATERIALS ON THE ECO-QUALITY OF THE SOLAR HOUSES HEAT STORAGES

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ABSTRACT

In this paper the influence of some building materials which are most commonly built in the monolitisation of the solar house heat storages is treated from the Eco-quality aspect. The ambiental air Eco-quality of the solar house directly depends on the building materials built in the heat storage. The special accent is given to the indoor environment Eco-quality from the radiation aspect. From this point of view, the gas radon (^{222}Rn) the main influence on the indoor environment air quality.

In the design of the solar houses heat storages the most common building materials are: concrete, stone, sand and brick. These materials were specially observed in this paper. The contents of the natural radionuclides and the total equivalent radioactivity in these materials. The knowledge of contents of the natural radionuclides and total equivalent radioactivity in these building materials are the relevant factors for architect's by decision on the "health" materials. According the ICRP and UNSCEAR recommendations, the Eco-quality of the solar house indoor air is defined.

KEYWORDS

Solar house, heat storage, building materials, Eco-quality, natural radiation, gas radon.

LOW TEMPERATURE SOLAR ENERGY HEAT STORAGES

Solar energy is a time dependant energy source. The success of its application is reflected through the efficiency factor of its useful accumulation and its adequate conversion. The designers decision on the location of the heat storage, which may be placed on the house, in the house or out of it, is dependant on the season sun rays amount, heat demands of the house as well as applied system. In the passive made architecture, the attempt should be made to store solar energy by the massive elements of the house, such as facade wall panels, floor and inter floor construction, water containers, stone storage etc.

The thermoaccumulative mass should be directly exposed to the sunrays so that it can maximally accumulate incoming heat and in the same time present overheating of the indoor environment. In the design phase the attempt should be made to make the accumulative

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