EMBODIED ENERGY IN VERNACULAR HOUSES: CASE STUDY OF GORAI SETTLEMENT, MUMBAI; INDIA

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Abstract

The paper is based on overview of vernacular architecture of Greater Mumbai. There are numerous vernacular settlements in Greater Mumbai. Their territory can be distinguished in different parts according to the peculiar socio-cultural and economical elements acquired during the centuries and to the natural aspects that make each place unique. Nowadays the old settlements are mostly abandoned and new houses are not responsive to local conditions leading to destruction of ecological balance and affecting the environment of the place.

The aim of the paper is to analyze the main characters of the vernacular architecture in the old settlement named Gorai pointing out both the typological and the technological aspects (local materials and construction processes), focusing on their environmental sustainability. Energy density of vernacular house and contemporary house is compared. Due to the complexity of the size, structure and construction of various houses, comparison of the main components of each building, instead of taking the house as a whole is preferred. Data and conclusions are the result of quantitative analysis. A house is composed of three main components: roof, wall, and floor. This analysis gives the general understanding of the embodied energy and ecological value of our vernacular architectural heritage and need to search for a more sustainable method of development. Through re-assessing our traditional dwellings under an ecological perspective, we appreciate the wisdom embodied in the vernacular architec ture in its relation to nature and its distinct advantage in low energy architecture.

Keywords: *Vernacular architecture, Energy density of houses, Gorai settlement, Mumbai*

Introduction

The city of Mumbai earlier known as Bombay was renamed in 1996 as Mumbai. It is the largest city having population18.0 million with a land area of 437.79 sq km in the western state of Maharashtra, in India, making it one of the top six largest agglomerations in the world. It is a coastal city with a deep natural bay. From the British period Mumbai was developed as port due to its geographical location at the sea coast. Presently this island city of Mumbai is the capital of Maharashtra state, commercial capital and economic growth engine of India. Mumbai has a long history of human settlement. The region with fertile land, huge vegetations and plenty sources of water were the main attractions to human for establishing settlements here. Most of the evidences of ancient settlements do not physically exist because of changes over the years. Sociological development of Mumbai was interrupted, altered, and at times almost destroyed by foreign culture and beliefs strongly impacting the natural advancement of vernacular architecture and traditional dwellings. Vernacular architecture can be found in various places exhibiting special and diverse architectural characteristics. Gorai Settlement is taken for the detailed analysis as it lies within the limits of Municipal Corporation but it has preserved its vernacular character. As the house forms are carrying, developing and maintaining the traditions from generation to generation for thousands of years, so it is valid to describe them to understand the origin and the spread of vernacular architecture in Mumbai. Energy density of vernacular house and contemporary house is compared.

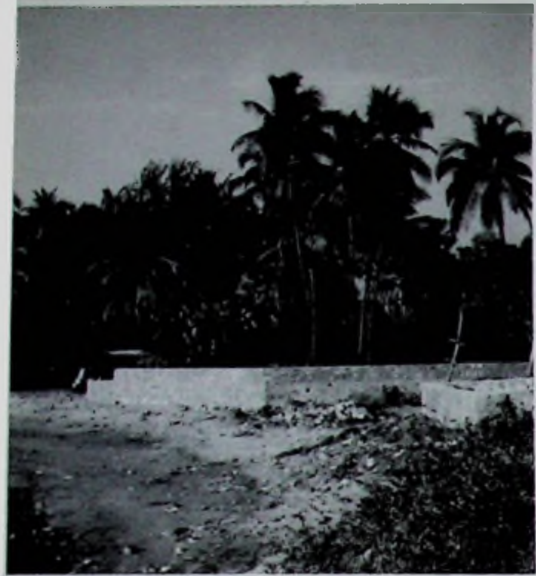
Gorai Settlement

Location

Gorai lies at the northern extremity on the western side of Mumbai Municipal limits. Built in pre 16th century. Settlement is purely residential with population of about 10,000 people.

Landscape setting

The settlement edged by sea on the western side and Manori –Gorai road on the East with agricultural land. The north is bound by creek and agricultural lands while on the south lies the settlement of Culvem. Manori-
Jetty –Gorai is a major path on the eastern side that passing through the settlement. Nearly half of the fabric has already undergone major transformation. The remaining structures, which form about 49% of the Built fabric is retained.



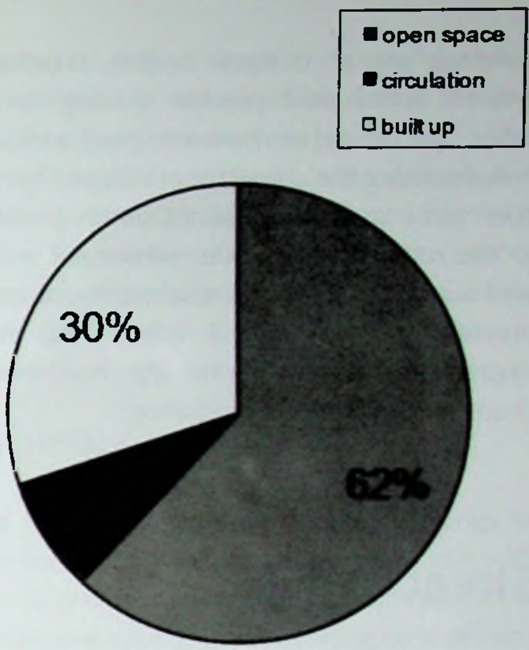
Prevailing wind direction

Climatic analysis

Settlement Level: Orientation

The general layout of the settlement is linear and growth towards south and the site bears gentle slope oriented towards north-northeast. The houses are mostly located on the northern slope. This orientation facilitates cooling wind from the prevalent wind direction and effectively blocking the harsh monsoon winds from the southwest.

Panoramic views of the surrounding areas of Gorai settlement



Existing settlement map and distribution of surface covers

Open spaces and built form

The houses are built on existing topography and are generally one or two storied, and predominantly detached or semi-detached either arranged, where the building line of the houses is set close to the street .The small open spaces well interspersed with the streets. Few houses bear high plinth-better exposure to breezes, for flood protection and as defense against insects. Settlement was constructed primarily for residential use.

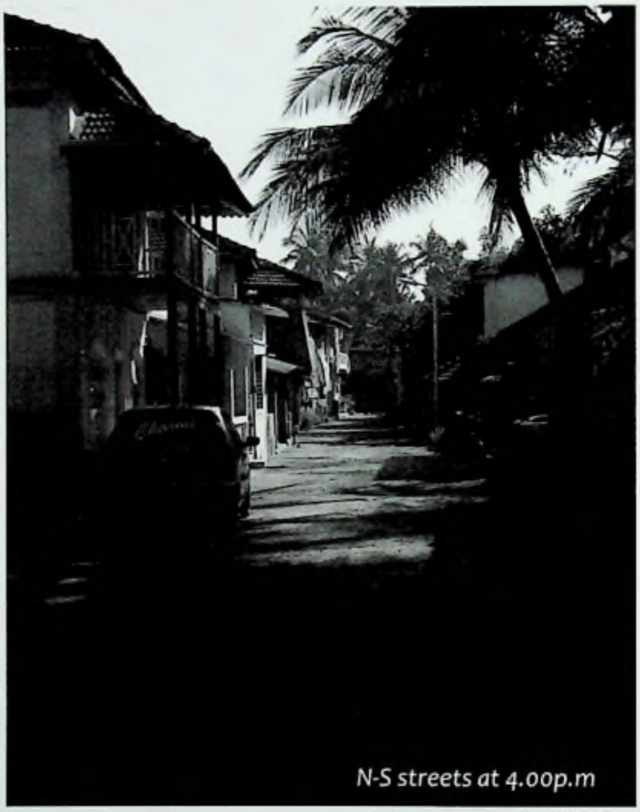
Greenery in the settlement

Community space in the settlement

Buildings are of unequal heights creating an uneven skyline and provide shading to each other. The natural environment plays a vital role in maintaining the character of Village. There are open plots at strategic points, which contribute to the rural identity of the settlement and are well used by the local community. Greenary provides a break in the built fabric. Ample vegetation helps in giving the much-needed shade and low reflected radiation.

Street layout

Manori- Jetty –Gorai is a major path on the eastern side that passing through the settlement. This path has two main spines running parallel to the settlement, positioned on the either side. These spines merge at regular intervals forming important activity nodes. The settlement is characterized by narrow internal streets or lanes 1.5-2 m wide along N-S and 2.5-3.0 wide along E-W .The broader main streets running being 9.0m wide. The internal streets are at 30 deg. to the prevailing wind direction thus enhancing air move ment. Street spaces are long and straight to facilitate air movement Street orientation and walls height to the width of a lane ensures the building facades are partially shaded by the overhangs or by the opposite buildings. Thus create shadow to the pedestrians in hot seasons and acts to decrease air temperature.


N-S streets at 4.00p.m

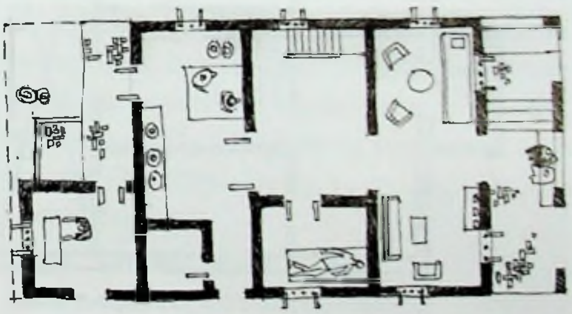

shading on west façade

Dwelling level:

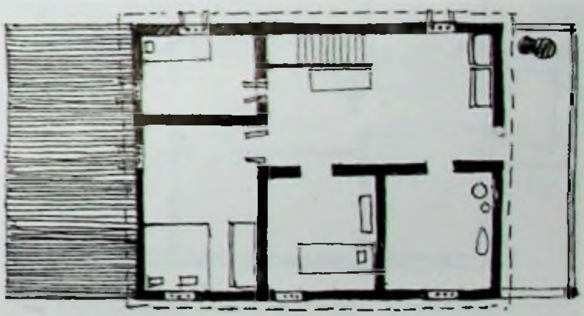
Depending on the socio economic status of inhabitant, there are two typologies of houses. The Koli typology (fisherman's house) belongs to fishing community. These houses are densely packed along the streets running parallel to the beachfront. The koli houses have probably the oldest origins of buildings. These houses form are developed with a hierarchy of spaces (public to private), which are apportioned into four prominent bays or parts. The outermost bay is usually a full-length, narrow verandah, where the users work on their nets, dry fish and interact with the community. The second bay accommodates the multipurpose living space, where guests and relatives are entertained. This bay is used as a bedroom at night, and as an extension of the verandah during the day. The third bay is the inner core of home with a family room. Small bedrooms, alcoves and ladder to the attic are approached from this room. The last bay accommodates the service areas including bathing washing and cooking spaces.

Type-II: -

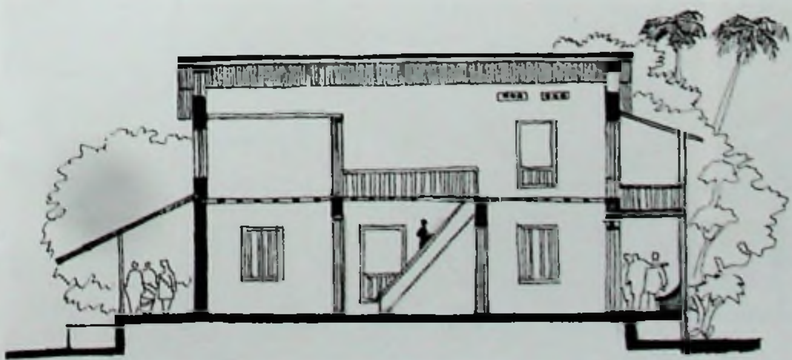
The East Indian housing typology belongs to the Roman Catholic community. Low rise with one or two storied houses. House is divided in to two main parts, the first being semi-private, consisting of front and back verandah, porches, outdoor rooms and an



Ground floor plan



First floor plan



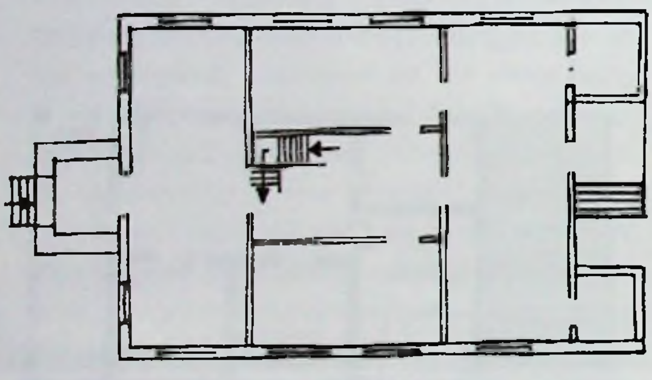
Section

Elevation

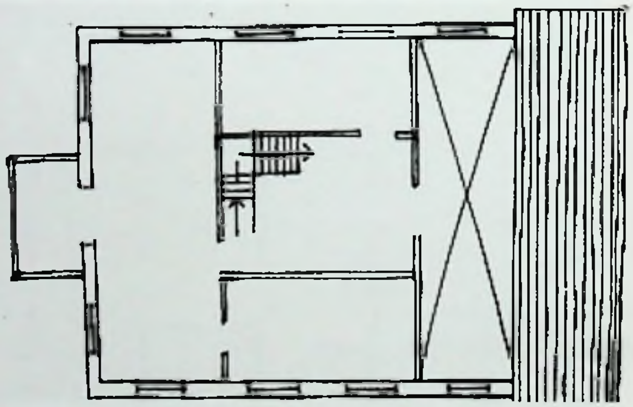
View from North West

North Elevation

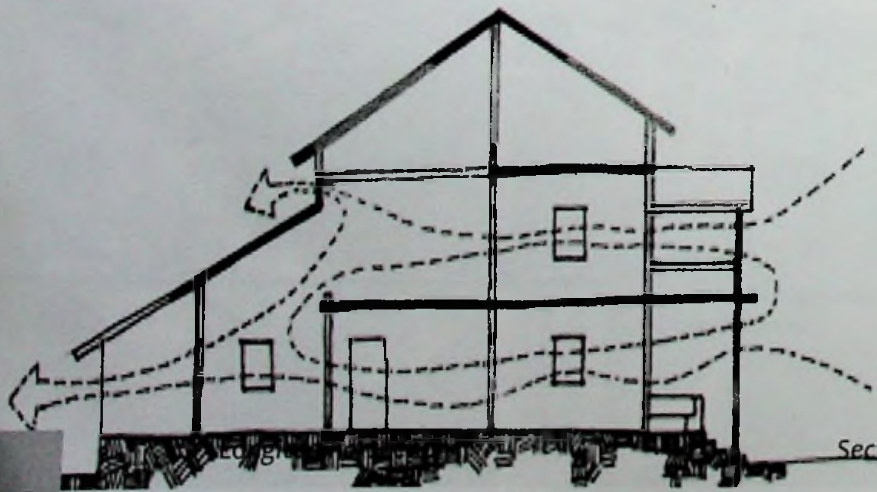
external staircase. The second part beingprivate consists of a multipurpose hall, a dinning and family room, bedrooms, kitchen and toilets. The house is entered through a covered verandah, which forms a transition space from outside to the inside of the house. The Verandah is a multipurpose area. It functions as a socializing space, a buffer for privacy, and as an extension of the hall. It provides natural light and ventilation to the adjoining rooms. The roof of the houses is mostly sloping, covered with country or



Ground floor plan



First floor plan



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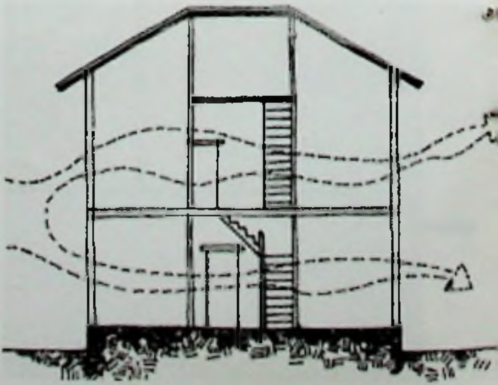

Mangalore type tiles. Some of the houses have an attic below the roof that is accessible by a ladder, and used for storage.

A East Indian house is analysed.

Orientation

Oriented along east –west direction to minimize solar radiation on the external surface and thus reduce heat gain. The house has a rectangular plan form with the spaces arranged centrally around a central lobby. It bears a narrow cross section, which facilitatethe natural ventilation with ample air velocities. All habitable rooms have two external openings for cross ventilation. The house is a ground + 1 structure with "potmala" or the attic floor. Heat, and odor- spaces such as kitchens, baths and w.c are placed on the leeward side. Stairways and lobby is placed centrally the central space acts like an atrium .the balcony towards north above the porch. Houses typically have sloping roofs cape with country tiles (Pitch being 20-25 deg.with the horizontal).

Building Envelope

Walls

Walls are 30 cm (time lag-08 hrs.) or more in thickness built of rubble masonry in mud mortar finished with lime plaster. The temperature difference between day and night is minimal with high level of humidity the walls work well by absorbing the excessive humidity and helping the walls to breadth.

Roof

Roof of the buildings is typically pitched wooden structural frame and the countrytiles above. It provides shelter from heavy rains and promote air flow. Roofs are 15 to 20 cm thick (closely spaced timber rafter, Mangalore tiles laid over the timber purlins spaced 45 cm c/c) with the attic floor space below. The roofs enclose a large insulated airspace with gable windows at the two ends to provide ventilation. This ensured air circulation thus, keeping the lower areas cooler.

Details of roof construction

Fenestrations and openings

The windows are located on the opposite sides to each other with similar dimensions. Maximum no. of openings is on the north and south facades. The sill is kept at the finished floor level measuring as 2.5 x 6 feet with the top 2.5 x 2.5ft of every window is kept open. The percentage of openings is more on the north and south facades and less on eastern and western facades where the sizes remain the same. Windows are fitted with heavy timber shutters.

Window on southern facade lits up the lobby area and also acts as outlet for the heated air

View of the hall on the first floor at 4p.m.

Building Materials and Finishes

The materials and finishes strongly contribute to this character. The materials, which were locally available such as mud, stone, timber bamboo, were used for the construction. The structure consisted of timber framed roof and bearing heavy stone mud mortar finished with lime plaster internally and externally. Pitched tiled roofs with traditional techniques of construction that evolved the vernacular architectural character overtime.

There are three environmental advantages:

1. Taking advantage of local wood and stone resources, while reducing the energy involved in transportation;
2. They provide rigid structure and a good resistance against the strong monsoon winds.
3. Mud absorbs the excess humidity, there by allowing the structure to breath.

Embodied energy of the vernacular houses

Traditional natural materials, for instance, wood, bamboo, stone, raw earth are good for energy performance. In terms of ecology, traditional materials possess clear advantages because of their local availability, low environmental impact in their production, renewability and even natural dissolution. Energy and resources are critical issues in today's context.

The General Energy Requirement (GER)

includes all the resources and energy, which were expended into a building, from processing, transportation, up to the completion of its construction. However, GER of a building as embodied energy coefficient, it is hard to achieve accuracy, due to its complexity. Transportation energy consumption has a big range of variety, depending on the situation, and does not constitute a reliable or general figure. And though construction energy consumption represents a valid figure, it is relatively small, roughly 10–15% of GER. So, in energy comparative analysis, Processing Energy Requirement (PER) is a more reliable and feasible factor for the evaluation of the embodied energy of a building. PER is the energy consumption involved in the exploitation and processing of a building material. Energy coefficient is calculated as Mg/kg.1

Energy density of typical houses

Materials and constructions of all traditional houses are quite same. Even within each type, individual houses vary widely in style. So, the most typical case with reference to each kind is selected. Due to the complexity of the size, structure and construction of various houses, comparison of the main components of each building, instead of taking the house as a whole is preferred. Data and conclusions are the result of quantitative analysis.

A house is composed of three main components: roof, wall, and floor. First, the weight of a component per square meter is calculated according to the construction of each member. Then, by multiplying the material's weight and its energy coefficient (MJ/kg), we will get the total energy per square meter, which is the density of energy of the main components. This format and the data of energy coefficient are mostly derived from the method outlined in the book (Architectural Material, Energy and Environment: Towards Ecological Oriented Development, by Dr. Bill Lawson and David Rudder, Australia (2000).) Some houses, although they are unique in building forms, share similar materials and construction, which means that they would have similar embodied energy. The design and construction of each house has to be carefully examined, in order to calculate their energy density.

To the format above, the tables of the relevant data are as follows:

Energy Density Of the traditional houses

Components	Construction	Sq.M (m)2	Volume (v)3	Density	Weight	Energy coefficient	Energy density	Total
Walling	Stone (300mm)	1	0.03	2700	810	1	810	810
Up Floor	wooden boards (30mm)	1	0.03	500	15	3.5	52.2	52.2
	Log beam 75x100 @450mm c/c	1	0.015	500	7.85	3.5	23.47	
Ground Floor	Concrete (80 mm)	1	0.08	2400	192	2.3	441.6	441.6
Roofing	wooden rafter	1	0.0228	500	11.418	3.5	39.93	

Energy Density of Modern house

Components	Construction	Sq.M (m)2	Volume (v)3	Density	Weight	Energy coefficient	Energy density	Total
Walling	brick 230x115x75	1	0.23	1700	391	5	1700	1955
Up Floor & Ground floor	Concrete (80 mm)	1	0.08	2400	192	2.3	441.6	441.6
Roofing	Concrete (100 mm)	1	0.1	2400	240	2.3	552	639.5
	Steel net	1			2.5	3.5		

Comparison of the cases

House Components	Walling	flooring	Roofing	Total
Vernacular dwelling	810	47.25	441.6	1298.85
Modern dwelling	1955	441.6	639.5	3036.10

As we see in the table, energy densities of all the main structural components of a new concrete house are greater than those of the traditional house. The vernacular house has the smallest energy density. This indicates that traditional houses possess a significant advantage in terms of embodied energy consumption.

Their attractiveness is especially apparent when we consider increasing shortages of energy and resources. The data above constitute a rational ground for rejecting the claims that "traditional materials should be completely replaced". Although these data form a rough estimation, this analysis gives the general understanding of the embodied energy and ecological value of our vernacular architectural heritage and need to search for a more sustainable method of development. Through re-assessing our traditional dwellings under an ecological perspective, we appreciate the wisdom embodied in the vernacular architecture in its relation tonature and its distinct advantage in low energy architecture.

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