ENVIRONMENTAL ASPECTS OF HOUSING: A CASE OF PUNE, MAHARASHTRA, INDIA

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ABSTRACT
In recent years, metropolitan cities and areas are growing fast. With increasing urbanization, housing sector is also expanding with equal pace. Scarcity of land in urban areas has influenced housing to be developed with a single intention of achieving maximum possible usage of available land. In this process the environmental concern is many times overlooked and in turn the urban housing is proved to be less energy efficient. To overcome this problem it is necessary that we should have a policy and guidelines for implementing environmental aspects as an integral part of site planning and building design for housing. In the absence of the environmental aspects the housing is becoming more and more dependant of artificial ways to satisfy the need of light and ventilation causing over usage of energy sources. The paper is an attempt to survey the selected housing developments in Pune and to analyze the same leading to a set of guidelines to achieve energy efficient housing (Study period is of two years from 2011to 2013). Site planning, appropriate orientation of the buildings is the simple measures to achieve the goal. It also presents the experimentation of light and ventilation using relevant software as a part of analysis. The set of guidelines will be also useful for similar proposed housing development in other metro cities in India.

Key Words: Housing, Orientation, Site planning, Metro cities, Environmental issues, Sun path, Wind rose

INTRODUCTION
Environment cannot be looked at as a secluded subject any more. Human activities have an impact on environment as well as environment has an impact on human existence itself. The built environment is a major contributor to the environmental loads generated by society. From the perspective of housing, environmental concerns are focused on the provision of a healthy, safe, supportive living environment that is sustainable within the natural environment. There is an emphasis on resource conservation and pollution prevention, both in providing the built environment of the home and in supporting the way people live within that environment.

Increasingly, the housing industry is focusing on the concept of sustainable development in the design and construction of housing. The term, green building is often used to describe housing that is more in balance with the environment. Although green building can take on many different meanings, examples might include energy-efficient construction, water-conserving, passive solar design, indigenous building materials and recycled construction products.

In order to better understand the choices and trade-offs that must be made in order to develop sustainable housing a broad understanding of environmental concerns is needed.

AIMS AND OBJECTIVES
Thus, a typical study of environmental issues in housing, in the context of today, might encompass the following content. A global perspective on environmental issues, energy management, waste management, water quality and conservation and hazardous substances. The impact on the environment what is used, taken away or altered is equal to the upgrading what is replaced, preserved or enhanced.

METHODOLOGY
A typical method is adopted and shown in Fig. 1.

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Fig. 1: A typical method adopted in environmental issues in housing

**Pune's climatic zone**

Pune city falls under moderate climatic zone.⁴ Pune (Latitude: 18.53° N, Longitude: 73.85° E, Elevation: 559 MASL). The climatic conditions in Pune are mostly warm (Table 1 to Table 3). The day temperatures are relatively high during March, April and May, the corresponding night temperatures are within comfort level (Table 4).

**Table 1: Climatic zones of Pune**

<table>
<thead>
<tr>
<th>Place</th>
<th>Climatic zones</th>
<th>Comfort conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Jan</td>
<td>May</td>
</tr>
<tr>
<td>Pune</td>
<td>M-D</td>
<td>M-D</td>
</tr>
</tbody>
</table>

**Table 2: Classification of temperature in Pune**

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Symbol</th>
<th>Meaning</th>
<th>Average mean daily temp. for the month (in deg.cel.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>V.H.</td>
<td>Very hot</td>
<td>&gt;35</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>Hot</td>
<td>30 to 35</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>Moderate</td>
<td>20 to 30</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Cool</td>
<td>15 to 20</td>
</tr>
</tbody>
</table>

**Table 3: Relative humidity in Pune**

<table>
<thead>
<tr>
<th>Relative humidity</th>
<th>Symbol</th>
<th>Meaning</th>
<th>Relative humidity (in %)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>V.D.</td>
<td>Very dry</td>
<td>0 to 25</td>
</tr>
<tr>
<td></td>
<td>D.</td>
<td>Dry</td>
<td>25 to 50</td>
</tr>
<tr>
<td></td>
<td>Hu</td>
<td>Humid</td>
<td>50 to 75</td>
</tr>
<tr>
<td></td>
<td>V.Hu</td>
<td>Very humid</td>
<td>75 to 100</td>
</tr>
</tbody>
</table>

April is the hottest month with average daily maximum temperature of 37.4 °C and a corresponding relative humidity of 19%. Evaporative cooling is indicated in these months during daytime. In monsoon months (June to October), ventilation is required to provide comfort throughout the day. Winter months (January, February, November and December) are generally comfortable during the day and cool at night.
Table 4: Comfort values for Pune

<table>
<thead>
<tr>
<th>Key no.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition</td>
<td>Very Cold</td>
<td>Cold</td>
<td>Cool</td>
<td>Comfortable</td>
<td>Warm</td>
<td>Hot</td>
<td>Very hot</td>
</tr>
<tr>
<td>Effective temp. range (in deg. cel.)</td>
<td>&lt;15</td>
<td>15 to 18</td>
<td>18 to 21</td>
<td>21 to 24</td>
<td>24 to 27</td>
<td>27 to 30</td>
<td>&gt;30</td>
</tr>
</tbody>
</table>

Survey and analysis

Study approach
Mostly approaches used for the design at site level are generally water conservation design, energy efficient lighting, solar water heaters, solid waste management, etc. But while designing at site level we need to consider two basic approaches i.e. sun and wind. After studying these two criteria, apply the analysis for the designing of guidelines.

Analysis techniques for site
The goal of these analysis techniques is to determine what potential benefits or problems may arise from the sun and wind on the site. People tend to be comfortable within a fairly narrow range of temperature and relative humidity called the comfort zone. It is possible, by analyzing the site’s seasonal sun and wind pattern to place the building and outdoor spaces to take advantage of the prevailing climate. So technique will be of three types:

1. Sun
   a) Sun dial
   b) Sun path diagram

2. Wind
   a) Wind rose
   b) Adjustment

3. Overlap of Sun and wind: Micro-climate analysis

Sun
The goal in the preliminary solar study is to figure out where solar heat gain is most extreme and the best way to mitigate it. The assessment is used to determine shadows resulting from the project. Because the sun rises in the east and travels across the southern part of the sky to set in the west, a project's earliest shadows would be cast almost directly westward. Throughout the day, they would shift clockwise (moving northwest, then north, then northeast) until sunset, when they would fall east. The graphic material depicts shadow conditions during an instant in time. Because shadows are in constant movement, there may be cases when the graphic material is not sufficient to clearly illustrate how incremental shadows occur on a site (Fig. 2 to Fig. 4).

Fig. 2: Sun dial
Fig. 3: Use of sun dial at site level
Determining impact significance
The goal of the assessment is to determine whether there are significant effects of shadows on a site. Shadow impact occurs when the shadows from a project falls on a site element and reduces direct sunlight exposure. Determining whether this impact is significant or not depends on the extent and duration of the shadow and the specific context in which the impact occurs.

Performing the detailed analysis
Once the three-dimensional computer model has been set up, shadow analyses should be performed within the timeframe window of analysis only for each of the representative months of interest. The solar shadow is generated with ecotect analysis (software), with its shadow system, utilizing the longitude and latitude of the area, along with the particular date and times needed and then together rendered a frame a minute for the full daylight period. The models for the project were based on the building design plans. Full shadow analyses for the project were prepared for four representative months as follows: January, May, August and November.

Timeframe window of analysis
The shadow assessment considers those shadows occurring between 3.0 hours after sunrise and 1.5 hours before sunset. Shadows occurring earlier and later are long, move fast. At times outside the timeframe window of analysis, the sun is located near the horizon and the sun’s rays reach the earth at close to tangential angles diminishing the amount of energy delivered by the sun’s rays and producing shadows that grow in length exponentially until the sun reaches the horizon and sets. Because of these conditions, the shadows occurring between 3.0 hours after sunrise and 1.5 hours before sunset are not considered, and their assessment is not required. For the assessment, standard not daylight savings, time is used.

Design principle
For analyzing the survey findings, it should be compare with the design principles. The design principles states that, to have better living conditions.

Any place during the winter season should be exposed to sun to gain heat. During summer the buildings should be in shade to provide protection from excess heat.

The analysis will be derived from the comparison of survey findings with the design principles.

Wind
The goal of study is to understand the prevailing wind patterns of project site can be useful when it comes to designing ways to take advantage of

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**Fig. 4:** Sun path diagram for Pune, Maharashtra, India
natural ventilation or to screen occupants from uncomfortable windy conditions. The wind in Pune is beaufort no. 3 which is known for gentle breeze\(^5,6\) (i.e. hair disturbed and clothing flaps). In this land condition is wind extending flags (Fig. 5).

**Performing the detailed analysis**

Once the three-dimensional computer model has been set up, wind analysis should be performed within the timeframe window of analysis only for each of the representative months of interest. The wind survey is generated with Autodesk Vasari Beta 2 (Software), with its wind tunnel analysis system, utilizing the longitude and latitude of the area, along with the particular month and time needed. The models for the project were based on the building design plans (Fig. 6). Full analysis for the project was prepared for four representative months, for morning and evening time as follows: 1) January 2) May 3) August 4) November.

![Wind rose](image)

**Fig. 5 : Wind rose**

![Airflow around objects](image)

**Fig. 6 : Airflow around objects**
**Design principle**

After the survey is conducted on case study area, the survey findings need to be analyzed. For analyzing the survey findings, it should be compare with the design principles. Which states that, to have better living conditions. During summer season free wind movement is expected, to relief from heat and for achieving better comfortable living condition. During winter season on contrary wind movement is restricted, to protect from harsh cold and dry wind roses.

**Sun and wind**

The technique helps to determine micro-climate on a site, using the weightings for climatic elements by climate and season. Determine shadow patterns using sun-dial and site model to plot the shaded areas of the site for the time periods and critical months of the seasons, under consideration. Determine wind flow patterns for the site with summer and winter directions. Convert the site shadow and wind pattern drawing to grid-cell system. Give each climatic condition a different graphic representation and analysis in Fig. 7.

![Diagram](image)

**Fig. 7**: Analysis procedure

**Few principles need to be ignored**

Air movement is driven by density. Cool air flows downhill because it is denser than warm air. At night, a cool layer forms near the ground, setting into low areas and depressions and behind anything that will form a “dam.” Convex, higher elevation land forms shed cool air, while low elevation, concave forms collect it. Temperature varies with elevation. Solar radiation varies with terrain aspect. Larger water bodies moderate the daily and annual temperature range. High mountains create wet windward slopes, while low hills create wet leeward slopes.

**Case study area: Blue Ridge, Pune**

Blue Ridge is located in Hinjewadi. The total site area is 138 acre. The apartments have range of 1, 2, 3, 4 and 5 BHK apartments and duplexes set in 25-storey high towers. There are total 31 buildings of apartments. Phase-I have six buildings with height of 30.0 m. while Phase-II have three buildings with height of 35.0 m and 39.0 m. The multiplex and mall is in one building and height of building is 24.0 m. The school is an international school with height of 18.0 m. It has the 9-hole golf course. The river side is developed as an entertainment zone. It contain garden, play area, restaurant, etc. (Fig. 8 and Fig. 9)
Solar survey analysis
The solar analysis involves comparison of the survey finding and design principles, to understand the design implication on solar pattern. The Project involves the construction of 31 buildings in height 90.5 m above ground level (Fig. 10).

RESULTS AND DISCUSSION
The result of survey conveys that the orientation of apartment T9 to T17 buildings is N-S and NE-SW (90°, 145° and 175° respectively to North), building height is 90.5 m. Therefore the road side i.e. NE side, which is a paved area, will be in shade throughout the year. While the other side i.e. SW side, will be exposed to heat of sun throughout the year. Due to this situation one side (SW side) of building will always get sunlight, but the other side (NE side) won’t get direct sunlight. It is observed that the present layout of these buildings contradicts the design principles. The result of survey conveys that the orientation of IT buildings is NW-SE (70 deg to North), building height is 30.0 m and spacing between the building is 14.5 m. Therefore, the spaces between the IT buildings
are mostly in shade. This means that due to mutual shading, these spaces between buildings are in shade. But this are IT buildings, which are always air-conditioned and with artificial lighting. So the shade of sun is not a problem for IT buildings.

<table>
<thead>
<tr>
<th>Color Shading - Elevation</th>
<th>Color Shading - Rear Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>January: 9.00 am to 5.30 pm</td>
<td>January: 9.00 am to 5.30 pm</td>
</tr>
<tr>
<td>May: 9.00 am to 5.30 pm</td>
<td>May: 9.00 am to 5.30 pm</td>
</tr>
<tr>
<td>August: 9.00 am to 5.30 pm</td>
<td>August: 9.00 am to 5.30 pm</td>
</tr>
<tr>
<td>November: 9.00 am to 5.30 pm</td>
<td>November: 9.00 am to 5.30 pm</td>
</tr>
</tbody>
</table>

**Fig. 10**: Blue ridge solar shading- elevation and rear elevation

The result of survey conveys that the orientation of studio apartment buildings is NW-SE (70° to North), building height is 90.7 m. and spacing between the buildings is 19.0 m. Therefore, the spaces between the studio apartment buildings are in shade in the month of January and November, while they are exposed to sun in May and August. This means that the studio apartment buildings will be in shade during winter season and exposed to heat of sun during summer season. It is observed that, the present layout of studio apartment buildings contradicts the design principles.

The result of survey conveys that the orientation of apartment T18 to T23 buildings is NW-NE (70 deg to North), building height is 90.5 m. and spacing between the buildings is 28.0 m. Therefore, the spaces behind i.e. NW side, of apartment T18 to T23 buildings are in shade in the month of January and November while they are exposed to sun for little time in May and August. This means that the spaces behind apartment buildings will be in shade during winter season, but partially exposed to heat of sun during summer season. It is observed that, the present layout of these buildings fulfills the some design principles.

The result of survey conveys that the south side of studio apartment building will always exposed to heat of sun. But South side of studio apartment buildings is protected with the vegetation. This means that the spaces over here will be protected till the vegetation height. The result of survey conveys that river side spaces will always exposed to heat of sun. But this side is well protected with the help of vegetation (**Fig. 11** and **Fig. 12**).
Wind survey analysis

The wind survey analysis involves comparison of the survey finding and design principles, to understand the design implication on wind rose. The wind survey analysis results are as following:

Following areas will always face wind shadow, so these areas won’t get air. The result of survey conveys that the orientation of IT building, studio apartment buildings, apartment T3 to T6 buildings, apartment T18 to T23 buildings is 70\(\degree\), 70\(\degree\), 160\(\degree\), 90\(\degree\) to North, building height is 30.0 m., 90.7 m., 90.5 m., 90.5 m. respectively and spacing between the buildings is 14.5 m., 19.0 m., 40.0 m., 28.0 m. respectively. Therefore, the spaces over here are facing wind shadow throughout the year. It is observed that, the present layout of buildings contradicts the design principles (Table 5).

The result of survey conveys that the orientation of apartment T9 to T11 buildings is 90 deg to North, building height is 90.5 m. and spacing between buildings is 3.0 m. Therefore, the spaces from road side i.e. North side are facing wind shadow in the month of January (morning), August (morning-evening), November (morning). This means that, the one
side of buildings i.e. North side will be in shade during rainy season and winter season, while free wind movement is expected in summer season. While the other side of buildings i.e. South side will be in free wind movement during rainy season and winter season, while in wind shade during summer season. It is observed that, the present layout of buildings contradicts the design principles. (Table 6) While few areas like river side and few area of golf course won’t face high pressure or low pressure throughout the year.

Table 5 : Blue ridge- wind shadow

<table>
<thead>
<tr>
<th>S/N</th>
<th>Area</th>
<th>Time period</th>
<th>Building (ht. meter)</th>
<th>Spacing between building (meter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Area between IT buildings</td>
<td>Throughout the year</td>
<td>30.0</td>
<td>14.5</td>
</tr>
<tr>
<td>2</td>
<td>Areas between studio apartment</td>
<td>Throughout the year</td>
<td>90.7</td>
<td>19.0</td>
</tr>
<tr>
<td>3</td>
<td>Area between apartment T3 to T6</td>
<td>Throughout the year</td>
<td>90.5</td>
<td>40.0</td>
</tr>
<tr>
<td>4</td>
<td>Area between apartment T18 to T23</td>
<td>Throughout the year</td>
<td>90.5</td>
<td>28.0</td>
</tr>
<tr>
<td>5</td>
<td>Few area from road side area of apartment T9 to T11</td>
<td>Jan morn, Aug morn-eve, Nov morn</td>
<td>90.5</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>Areas between studio apartment and IT buildings i.e. road</td>
<td>Jan eve, May morn-eve, Aug morn-eve</td>
<td>90.7 and 30.0</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 6 : Blue ridge- high pressure wind area

<table>
<thead>
<tr>
<th>S/N</th>
<th>Space</th>
<th>Month</th>
<th>Building (ht. meter)</th>
<th>Spacing between building (meter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Theme square</td>
<td>Jan morn-eve, Aug morn-eve, Nov morn-eve</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>T2 &amp; T3</td>
<td>Jan eve, Aug morn-eve, Nov morn-eve</td>
<td>40.0</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>T6 &amp; T7</td>
<td>Jan eve, May morn-eve, Aug morn-eve, Nov morn-eve</td>
<td>90.5</td>
<td>54.0</td>
</tr>
<tr>
<td>4</td>
<td>T8 &amp; T9</td>
<td>Jan morn, May morn-eve</td>
<td>79.0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>T11 &amp; T12</td>
<td>Jan morn, Aug morn-eve, Nov morn</td>
<td>66.0</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>T14 &amp; T15</td>
<td>Jan eve, Aug morn-eve, Nov morn-eve</td>
<td>59.0</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>T17 &amp; T18</td>
<td>Jan eve, May morn-eve, Aug morn-eve, Nov morn-eve</td>
<td>61.0</td>
<td></td>
</tr>
</tbody>
</table>

The result of survey analysis (solar survey and wind survey) conveys that the orientation of studio apartment buildings is NW-SE (70° to North), building height is 90.7 m. and spacing between the buildings is 19.0 m. Therefore, the buildings are exposed to heat of sun and shadow of wind, throughout the year (Fig. 13). While it creates high pressure zone of wind for some period of time. The result of survey analysis (solar survey and wind survey) conveys. The orientation of apartment T18 to T23 buildings is NW-NE (70 deg to North), building height is 90.5 m. and spacing between the buildings is 28.0 m. Therefore, the buildings are in partial solar shadow in summer season and wind shadow throughout the year. It is observed that, the present layout of buildings fulfills some design principles.
The orientation of apartment T9 to T17 buildings N-S and NE-SW (90°, 145° and 175° respectively to North), building height is 90.5 m. and spacing between the buildings is 3.0 m. and 60.0 m. Therefore, the buildings are in solar shadow throughout the year and partial wind shadow. The present layout of buildings contradicts the design principles. The orientation of apartment T1 to T6 buildings 160° to North, building height is 90.5 m. and spacing between the buildings is 40.0 m. Therefore, the buildings are exposed to heat of sun and wind shadow throughout the year. While it creates of high pressure zone of wind for some period of time. It is observed that, the present layout of buildings contradicts the design principles.

**CONCLUSION**

Site layout has a big impact on daylight, sunlight and ventilation of buildings and the spaces around them. The main objective of this study is to understand environmental aspects for housing in urban planning to ensure good access to solar gain, daylight and ventilation. Its aim is to enable to produce comfortable, energy-efficient building surrounded by pleasant outdoor spaces, within an urban context that minimizes energy consumption through orientation of building. In urban planning this is the important factor affecting the sunlight, solar heat and ventilation due to wind. When planning a new development, its impact on existing buildings nearby should be considered. The role that can be played by orientation of building in the efforts to achieve development, without causing lasting environmental damage is the theme of this project. This project will concentrate on the practical steps that can be taken to achieve a more eco environment and in particular, it will outline those concepts useful in the process of urban design. One aspect of airflow and its link with urban form
is the way in which built form can be used to reduce the heat loss caused by wind blowing against building. Analysis of the simulation results confirms the current understanding that an environment sensitive layout has a distinct influence on thermal comfort in open spaces (as well as indoors). Street orientation and spacing between buildings were found to be important factors influencing temperature and urban microclimatic changes. Corridors following the prevailing wind direction would support ventilation at a local scale (not noticeably affecting adjacent streets). Even when wind speeds are low, a cooling effect would increase thermal comfort in open spaces.

Proper orientation and use of non-conventional energy can reduce environmental impacts on building. Good urban planning will also provide an attractive exterior environment, pleasantly sunlight, cool and shaded in summer. In general, exploration of and improvement to, climate comfort can effectively increase the urban quality of life in light of future climate conditions. Conducting urban climate simulation studies in collaboration with urban planners and architects to test effects of block layout alternatives, would improve climate sensitive block design.

REFERENCES