Designing Eco Adaptable Residence in a Hot & Humid Climate, in Kolkata, India

Eco Adaptable Residence based on Computational Analysis

Florina Dutt
University of Pennsylvania
scorpio.rina@gmail.com

Subhajit Das
University of Pennsylvania
subhajit.design@gmail.com

ABSTRACT
The research paper outlines the novel design methodology undertaken to redesign an existing apartment building in Kolkata India. The aim of the research is to significantly improve the design of the individual apartments as well as their spatial arrangement to enhance the indoor comfort level experienced by the inhabitants. The initial in-depth study of the existing design of the apartment building encompasses a short survey of the comfort level experienced by its inhabitants in terms of day lighting, natural ventilation and thermal comfort. The survey revealed the way in which these issues affected the behavioral pattern of the inhabitants in rearranging their spatial needs for the given design conditions. Consequently, the endeavor proposed promised to significantly improve the aforesaid areas of problem & discomfort for the building occupants. At the same time, exploiting contemporary computational simulation tools and digital three-dimensional modeling techniques the project leverages the same to prove the improvements proposed by research data in the form of scientific & mathematical tables and values.

KEYWORDS: Sustainable Design; Solar Architecture; Wind Tunnel Test; Eco Adaptable Housing;

Introduction

The research project is located in Salt Lake, Kolkata. It is the newly developed eastern extension of the old city of Kolkata, predominantly for residential use. The site was selected in the newly planned residential zone such that the research project undertaken could provide a design framework for the future residential building design that is entirely controlled by the municipal rules and guidelines .The existing design process is guided by the floor area ratio benefits that could be obtained by the architect and developer to acquire maximum profit in the process. The large range of factors that are mostly overlooked in the design process is the living conditions offered to the inhabitants after the property is being sold. The future inhabitants, i.e. the potential buyers who buy the apartment building largely stay unaware of the fact that they are paying more value not only for the area they are buying but also in terms of accumulated extra cost they pay as exhibited in the life- cycle analysis of their apartment building (Hensel, 2012; Smith, 2008). The new design proposal was given in a single site comprising of two-community apartment building, each 4 stories high, such that the existing living conditions and energy cost of each household could be calculated which could act as a base level for comparison. There is no existing fixed baseline design standard in terms of life cycle cost analysis of residential buildings in Kolkata. The existing building study thus gave plenty of information that would otherwise remain unexplored.

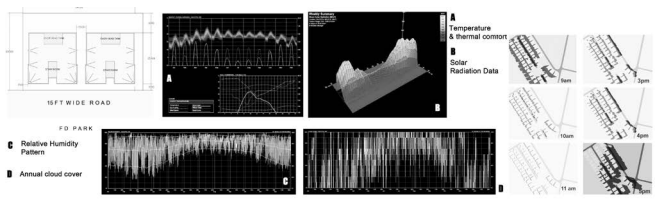

Fig. 1. Shows the existing climatic & site analysis in Ecotect Weather Analysis Tool. Also reflects the sun-shading pattern of the site neighborhood during summer season.

Climatic & Site Conditions

The study of the site and local climatic conditions were accomplished through local site survey and weather data collection. Analysis of the weather data was done in Ecotect to get the graphical analysis of the same. Refer Fig. 1. The analysis results show that that the city predominately experiences a hot and humid tropical climate, with very long summer and monsoon season

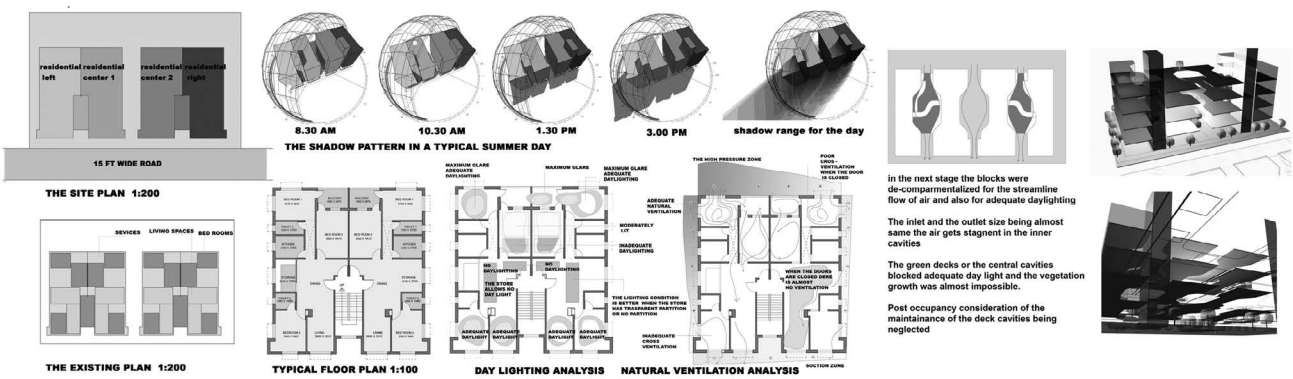

Fig 2. Shows diagrams depicting existing day light & natural ventilation analysis enlightening areas of concern & poor design in the building. Also shows initial idea of creating smaller inlet & larger outlet to allow south wind to rush in the building due to suction effect. The courtyard in the center helps augment the suction effect & behaves as a light well.

and a short winter season. During the summer, the highest temperature can often reach up to 42 degree centigrade in the month of May and June. The relative humidity during the monsoon from July- September can be up to 98 %. During the winter, the average Temperature is between12 -14 degree centigrade, with little or no rainfall. The most thermal discomfort remains during the summer (March - June) and the monsoon season (July - October) to combat very high temperature as well as high humidity. The predominant wind direction is south east in summer and monsoon; North West in the winter.

The site is located in one of the dense residential block of Salt Lake, Kolkata opposite the community park of the block. The site is rectangular and has a north east and southwest axis directed towards the park. The adjacent residential blocks are built on rectangular plot areas and typically 4-5 stories height. The site comprises of two individual freestanding four stories building with an adjacent gap of 3.5 meters and 4 – 5 meters .with the neighboring housing units. The road adjacent to the site is 6M wide. The shadow and CFD analysis of the existing site with the neighborhood-building model reveals that the close spacing of the adjoining sites and built form hinders free flow of air and adequate day light in the existing apartments. Refer Fig. 4.

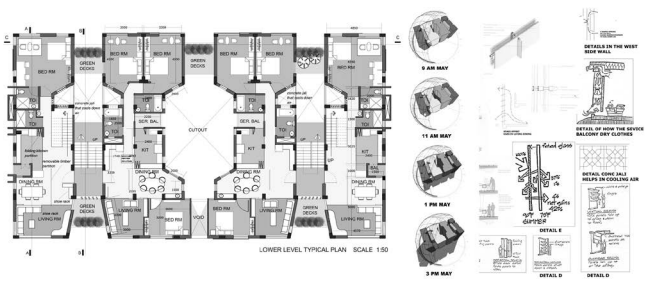

Fig. 3. Shows the re designed floor plan, having enhanced wind flow & ventilation pattern in the same site. It exploits the contextual environmental parameters to aid better living conditions to the residents.

Existing Design Survey

The existing design survey consisted of two major parts. The first part comprised of the 24 hours continuous temperature reading in a hot summer day with clear sky condition, spot measurements light illumination and mapping the air circulation in CFD tool (we used Flovent CFD tool) with the help of average wind speed obtained from the generic weather data. The second part of the survey was done with the help of intensive questionnaires to the inhabitants. The questionnaire mainly comprised of the hourly usage pattern of each functional spaces in the apartment and the comfort level experienced by each member using the space under categories of day lighting, ventilation and thermal comfort (daytime and nighttime). The level of comfort was graded between1 to 5, 1 being the least and 5 being most comfortable.

Survey Findings

The survey results from both sensors and the questionnaire were merged to get the following deductions:

1. Extremely dark indoor spaces in the service areas and living areas of all the four apartments in the building in each floor.

2. South facing rooms faced suns glare most of the day and afternoons.

3. North facing rooms were exceptionally cold during winters due to lack of sunshine and heating.

4. Inappropriate location of windows and size of openings obstructed the possibility of cross ventilation and thus incoming wind could not be channelized to other parts of the apartment.

5. West facing wall faced extreme solar radiation and thus enabled uncomfortable indoor spaces adjoining it.

Consequently, the endeavor proposed to significantly

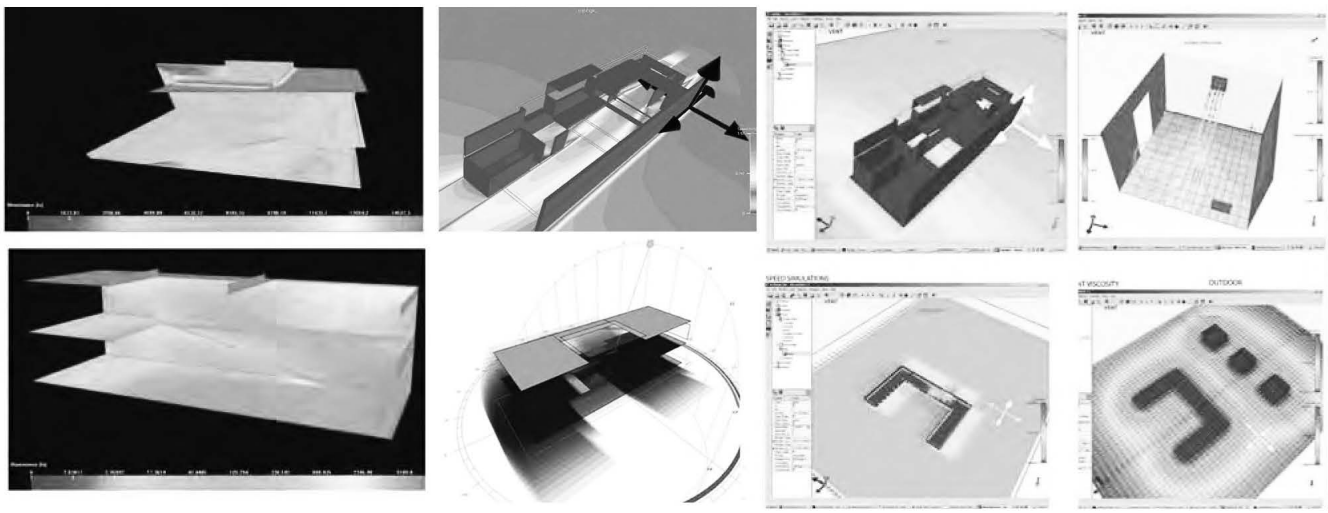

Fig.4. Shows the CFD simulation diagrams highlighting areas of higher & lower wind pressure in the redesigned apartment building. We also used Ecotect Radiance to understand the impact of light in the indoor light well.

improve the aforesaid areas of problem & discomfort for the building occupants. At the same time, exploiting contemporary computational simulation tools and digital three-dimensional modeling techniques the project leverages the same to prove the improvements proposed by research data in the form of scientific & mathematical tables and values.

Inferences

Based on the survey findings from the existing building users & analysis of local climatological data, from computational simulation in Revit & Ecotect, with Kolkata weather map, enabled us to formulate following research objectives for the design venture

1. Design the volume of the building such that it aids in the process of proper channelization of the fresh wind from southeast direction using the site condition advantage.

2.Suction effect of wind, from high-pressure zone to low pressure zone principle has been applied by positioning lower inlet opening at the south side and larger outlet opening at the exit side, which is north in this case. It largely enabled south side wind to enter the light wells/ courtyard and gain momentum / velocity in the process and re channelize in to the apartments to augment substantial gain in indoor ventilation quality.

3. Appropriate incorporation of light wells, or mini courtyards in the center of the building to allow day lighting and ventilation to reach the core of the apartments, which largely encompasses living areas & service spaces.

4. Adequate measure in the form of application of a trombe wall on the west direction not only provided sun protection from radiation but also aided to store the solar heat to be re used at night or later as usable fuel.

Design Process

The site is a square block, and so is the apartment building after leaving the mandatory setback spaces. The site faces the north & south direction, while the east & west façade are partly shielded by adjoining buildings. In a hot humid climatic zone, high speed of air circulation in the interior spaces increases the comfort condition. The idea was to create four separate streamlined building volumes contrary to the previous bigger and clunky building volumes. Each of the four subdivisions are adjoined by two narrow gaps and a wider gap, to channelize the south wind inside, wherein a light well and courtyard is positioned to enable ventilation and daylight to be distributed to the inner spaces of the individual apartments and stairwell. Complementing the south facing gap, a larger gap on the north direction is facilitated, which essentially allows incoming wind velocity to gain momentum while leaving the building from north. In this process, the increased wind velocity helps it to be re-channelized into the four floor plates and thus significant improvement over the present ventilation condition was recorded. This was further tested with reduced heat gains level in the summer and CFD simulations. The CFD simulation of the whole apartment and individual rooms shows that the revised design could subsequently improve the air velocity in the apartments compared to the existing model. Apart from the overall design of building volumes, revised space planning is also a necessary part for effective design process (Keitsch, 2012). The existing apartment designs are all similar modules in each floor and they were simply mirrored along the stair well or service space. The primary reason for indoor conditions of discomfort is caused by the two freestanding apartment buildings with exactly similar floor plans without taking into consideration their physical placement in site and individual orientation of each individual apartment. The proposed design optimizes the space use criteria

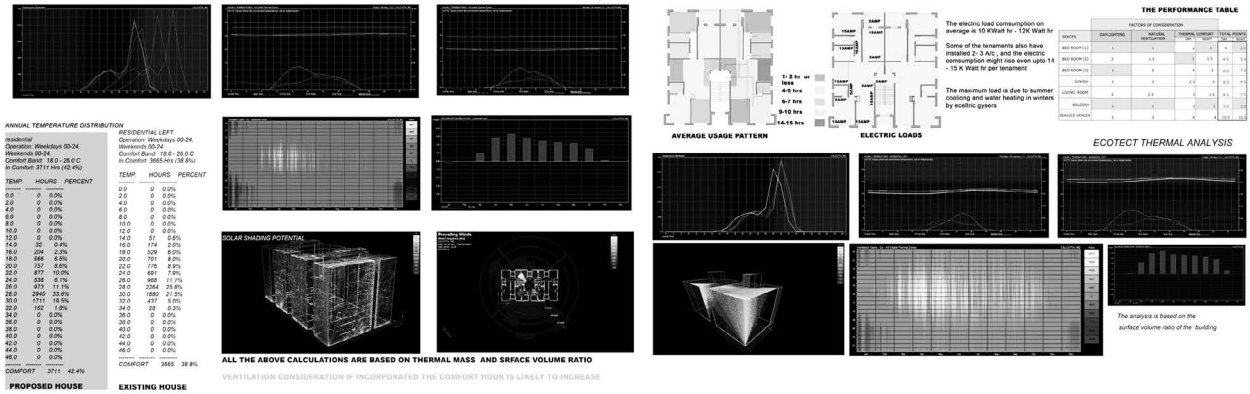

Fig. 5. Explains the final comparative analysis of the existing & proposed apartment tower, with enhanced energy efficient design features. In the table above, it has been shown by computational thermal modeling & solar insolation analysis, that the building performance level is substantially enhanced due to the changes proposed in the re designed model.

as well as their location with respect to the site. Type A is a duplex, with level 1 comprising of one bedroom having a south facing opening, and dining area & service spaces each having adequate day light from opening either east or west side of the building and also diffused light from the north. Level 2 of the duplex comprised of one bedroom on the south side and one towards the north. The north side bedroom gets adequate diffused light from the north, west or east side of the building. Adequate wind circulation is insured from positioning of its opening in the south facing terrace / deck. Refer to Fig. 3. Type B is designed more compact with two of its bedrooms facing south –east. The service spaces were ensured adequate day light through a wide courtyard in the center.

The research paper delineates the comparative analysis of the enhanced features of the improved design over the existing one. An in depth thermal model of the current building volume was developed in Revit, which was later, tested in Ecotect Solar & Thermal analysis simulations. Ecotect was used to obtain the possible temperature distribution for each of the four-design volume, calculating the solar insolation, and solar shading potential of each volume. This would further help us in micro level design changes of fenestration and making provision for trombe wall in different parts of the building. The finding from Ecotect obtained expectedly, outlined exceptional discomfort level during hot & humid summer months from April until September each year. Later after the redesigned volume was developed similar CFD simulation & analysis were performed which delineated significant gain in comfort level in summer conditions in the building.

Micro Design Elements & Material Usage

The generic spatial design is complimented through micro-level design element selecting the right façade material and fenestration pattern depending on its orientation. This selection process was further confirmed though Ecotect solar shading potential visualization of the apartment models. The west side of the wall was proposed to be trombe wall with small v shaped vent. The building roof was proposed to be paved by broken china mosaic finish to decrease heat gain in the top floor. Shading devices are used in opening that would create sun glare. (Fig. 5)

Conclusions

Overall, the project exploits the current technological innovations in computational architecture, to significantly improve current comfort conditions for building occupants. The design process, aids commendable insights from the interdisciplinary fields of building physics & thermodynamics. CFD simulations & wind flow logistics augments indoor air quality & thermal comfort conditions.

References

Hensel, M.U., 2012. Sustainability from a Performance-Oriented Architecture Perspective – Alternative Approaches to Questions regarding the Sustainability of the Built Environment.. *Sustainable Development*, p.146–154. Available at:

Keitsch, M., 2012. Sustainable Architecture, Design and Housing. *Sustainable Development*, pp.141-45.

Smith, C and et.al., 2008. Putting Residential Development in a Sustainable Context. In Department of Landscape, *Residential Landscape Sustainability: A Checklist Tool*. Oxford,UK: Blackwell Publishing.