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Early Decision Support for Operational Energy Assessment in Multifamily Residential Apartments - Impact of Change in Orientation

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Abstract : *With an accelerated pace of growth in India, there would be a tremendous increase in the residential requirements of developing India, thereby putting pressure on residential electricity demand. This paper studies the life cycle operational energy requirements of an existing low rise multistoried apartment in composite climate zone in Jamshedpur, Jharkhand, India based on the orientation of individual apartments in a block. Design adaptability to orientation change was modeled using EnEff.ResBuild India, Toolkit for energy efficient residential buildings in India, software to assess the energy needs of the said building as a whole and the current building energy efficiency standards to measure the potential savings offered based on the existing building design through difference in deviation results. Results show that apartments with lower wall window ratio in south west than the same in north east have a higher operational energy requirement in terms of cooling energy and there is a mean average deviation of cooling of the order 5.35% over a period of a year. The findings indicate that the orientation change can be readily incorporated at the design phase to optimize the operational energy requirements of the low rise multistoried apartment.*
Keywords: *Consumption of Electricity, EnEff.ResBuild India, Operating Energy, Orientation.*

I. Introduction

In India, a large number of residential buildings are constructed every year, and many of the buildings perform very poorly in terms of energy conservation. It is projected that the residential sector of India will grow many folds in the next two decades hence the share of energy consumption of this sector in the total energy consumption of the country will dramatically increase. With a near consistent 8% rise in annual energy consumption in the residential and commercial sectors, building energy consumption has seen a increase from 14% in the 1970s to nearly 33% in 2004-05 [1]. Consumption of electricity in domestic sector was around 22% of the total electricity consumption in India, after 44% in industries, during 2013-14 [2]. Significant growth was predicted in aggregate floor area of buildings in the tune of 400% and an addition of 20 billion square meter of new building floor area by 2030 [3]. Projections done by the Planning Commission show that the electricity consumption in residential buildings is expected to increase seven-fold during the period 2012 to 2032, and the residential sector will become the largest consumer of electricity in the country with a 36.5% share of the total electricity consumed in 2032 [4]. Since residential buildings are consuming a large amount of energy and that operating energy (89%) of the residential building is the largest contributor to life cycle energy of the building, followed by embodied energy (11%) [5].

II. The Role Of Orientation On The Model

Decision on proposed orientation of the building is made at early stage of architectural building design process. Passive solar building design is the utilization of the sun’s energy together with local climate characteristics and selected building materials to directly maintain thermally comfortable conditions within a built-environment [6]. Design which uses passive means to provide thermal comfort in a built environment reduces the requirement of active thermal controls and with equal occupational requirements reduces the net energy use [7]. Properly orienting a residence is a highly effective way to lower energy use and, if planned early, may be simple and inexpensive to accomplish [8]. Furthermore, proper orientation in the first place can create potential for additional savings from more sophisticated passive solar techniques. Fadzil et al [9], studied the effect of direct sunlight penetration and daylight distribution in a building with 12 bays of continuous orientation and showed that the results indicating that the best bay with the least sunlight penetration is with orientation 0° and the worst is with 240°; those with orientations 30°, 180°, 330°, 60°, 90°, 300°, 150°, 120°, 210° and 270° follows in order. The main issue when one considers the orientation of a building is the orientation of the windows and the potential of the solar penetration through windows in hot climate, and its effect on the elevation of the indoor temperature, depends greatly on the orientation of the windows [10].

The orientation of the building should be based on whether cooling or heating is predominant requirement in the building [11]. To consider whether or not to take advantage of the sun's rays, for which orientation is to be decided, day and night temperatures and the mean maximum temperature of the region needs to be studied based on the broad classifications of temperature ranges.

Table 1. Classification of Temperature Ranges :

Below 15ºC	Cold	Sun's rays advantageous
15ºC to 20ºC	Cool	
20ºC to 30ºC	Temperate	
30ºC to 35ºC	Hot	Protection from sun's rays advantageous
Above 35ºC	Very Hot	

Source: Indian Standard, Recommendation for Orientation of Buildings, Part I, Nonindustrial Buildings, IS: 7662 (Part I) – 1974 (Reaffirmed 2004)

From previous studies it has been established that the ideal orientation in Indian conditions for sub-tropical /composite climatic conditions for least summer heat gain and maximum winter heat gain, along with proper ventilation is with longer side aligned along north-west, south-east making an angle of 45 degrees with the east-west axis [12]. The following case study was selected to identify the effect of orientation on the operational energy, specially for cooling, as applicable to the individual apartments of an low rise building.

III. Aim Of The Paper

The paper focuses on the initial recognition that considers how new buildings are designed and built [13] so that there is operating energy use reduction later [14]. The main concern of this paper is to judge the energy efficiency of the individual apartments in a low rise multistory residential apartment building based on their orientation, thereby noting how the selection of orientation of existing designs affect the operational energy consumption. Studies show significant impact of orientation on variations in energy use [15]. There are many influencing factors identified as variables that affect the complex thermal performance of a building, amongst which some are independent while others are inter-related. Floor to ceiling height and the volume of a room are amongst such dependant variables [16]. Also it is to be taken into consideration that analysis of various parameters at the initial design stage can increase the design time and hence the cost, but it is the architect who makes most important energy sustainability at the initial stage of the design [17]. Good orientation, one of the elements in passive solar design, is relatively easy way of achieving high operating energy saving option can reduce the energy requirements of a residence by 20% [9]. This study focuses on low rise multi-family residential apartments in Jamshedpur, in the composite climate category of the five climatic zones in India, and an attempt is made to show the variations in Operational Energy and other related parameters to have informed design decisions from the earliest phases of design to help to focus on energy reduction for residential areas less than 500 Sqm. of conditioned area.

IV. Methodology

4.1 Selection of Software: Various energy simulation software tools delved into by scholars were studied [18, 19]. In order to examine the effects of orientation on the thermal performance of low rise multi apartment residential buildings in this climate, EnEff.ResBuild (EERB) India, a toolkit for residential energy estimation and rating software was used. The study focused on estimating the total energy requirement of sample designs in terms of appliance, lighting, heating and cooling loads. EERB has been validated through TRNSYS by TERI and Fraunhofer IBP [20]. The comparative study of the results calculated by this assessment and simulation tool for various parametric cases was done and it was found that the deviation in most of the cases were within acceptable range of deviation. Thus it can be concluded that the assessment tool gave validated results within acceptable range of deviations and was robust and user friendly. Operating energy of the building included electrical energy used for cooling, heating, lighting and appliances/ miscellaneous equipments used in a household. The calculation was based on heating load for an apartment complex with Unit Building Method (UBM) [21] wherein for heating or cooling operational energy requirements of the whole block was calculated by summing up of individual apartments requirements of heating or cooling energy.

The estimation of the operational energy of the individual apartments was undertaken by two approaches: i) using Conditional Demand Analysis (CDA) [22] where energy use data for individual houses was collected from the monthly electricity energy bills and ii) by simulation through EnEff.ResBuild India toolkit. Amongst fifteen of such identical residential blocks, one block was randomly selected for running simulation model, which was Block 2. There were eight different simulations based on the orientation of 16 nos. of apartments present in the block selected for study. The details of orientation are as given below. In the toolkit there is no climate specification for the city of Jamshedpur, but for reference the climatological conditions of composite climate at Patna, a neighboring city, was considered. Two scenarios were developed for each orientation of the apartments, one where the electrical energy used on monthly basis from the data collected and the other which the software has modeled with the given data.

4.2 Running of The Model: According to the purpose of this case study, the simulations are done with ITToolkit: Resbuild India and the type of results explored. Resbuild India is exclusively energy assessment tool to predict residential energy use in India without going into detail energy simulations. The software, in combination with building envelop, cooling/ heating system and hot water system, predicts monthwise energy consumed and simultaneously identify energy saving potential. General information regarding the project to be assessed was entered in form of key features of buildings such as number of apartments, total apartment area, total conditioned area, common area, building envelope reference, lighting power, heating, hot water system, orientation, geometry, and technologies used for space cooling, heating, lighting and hot water. The climate data for the five climatic zones in India is included automatically through inbuilt system. The software uses a simplified method to do on time calculations and display results in an overview area wherein the impact of every change is updated along with the reference building after every change and the reference energy demand is simultaneously calculated. For the case study at hand, eight orientations were investigated in more detail, all of which are discussed here. The eight were chosen because they illustrate effects postulated in the discussion.
The graphs in Figs. 6-13 use a common format. They show predicted heating, cooling, appliances and lighting loads based on simulations of identical individual apartments having eight orientations (the four cardinal and four intermediate directions). The X-axis represents different months of the year, from left to right. The vertical axis is the total amount of electricity consumed in kW. Actual data is plotted in red line while the blue line symbolizes the simulated loads.

V. Case Study

5.1 Description: Jamshedpur town (Figure 1) is located in Jharkhand state of India, which is a part of the Chhota Nagpur plateau region. The place of study lies in latitude 22°48'38"N and longitude 86°10'24"E. The altitude of the place is 135m from mean sea level. The residential apartment block identified for study was one of the 15 number of blocks of Low Rise Multi-family Residential buildings known as "Professional Apartments A," on Kadma-Sonari Link Road, Kadma, Jamshedpur, Jharkhand. It is occupied by the officer grade employees of the Tata Iron & Steel Company (TISCO).

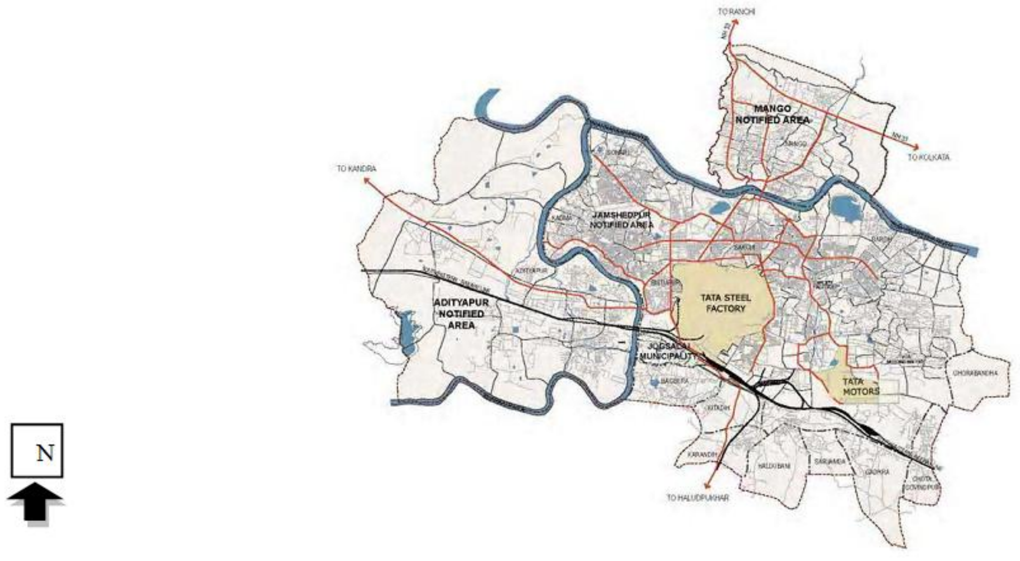

Figure 1. Jamshedpur City Plan Source: Source: JUSCO (Jamshedpur Utilities & Services Company)

5.2 Climate: The study area of Jamshedpur has composite type of climate, as classified in the climatic zonation of India, and has five seasons: summer, monsoon, fall, winter, and spring. Summer is typically between April and mid-June with average maximum 40° C to 45° C and monthly mean maximum relative humidity of 62.13%. The south-west Monsoon appears generally between mid-June and September and is characterized with average maximum temperature of 30.48°C, average minimum temperature of 22.53°C, and monthly mean maximum relative humidity of 76.83%. Rainfall in Jamshedpur varies between 1200 millimeters to 1400 millimeters during this period. Winter is typically between December and January with average maximum temperature of 23.25°C, average minimum temperature of 6.2°C, and monthly mean maximum relative humidity of 68.78%.

Spring is typically between February and March with average maximum temperature of 26.2°C, average minimum temperature of 12.25°C, and monthly mean maximum relative humidity of 72.53%.

5.3 Details of the Residential Apartment Blocks: The selected buildings were a multi storey concrete framed structure. Each block consists of 4 nos apartments in ground floor (Lvl +1'6") for half of the covered area of the other half being parking at 0'0" Lvl building, 4 nos of apartment in mezzanine floor (Lvl +8'6"), another 4 apartments at Lvl +12'6" Lvl, the next at the lvl +19'6". Table 2 provides the basic physical parameters of individual block some of which were used as inputs in the simulation.

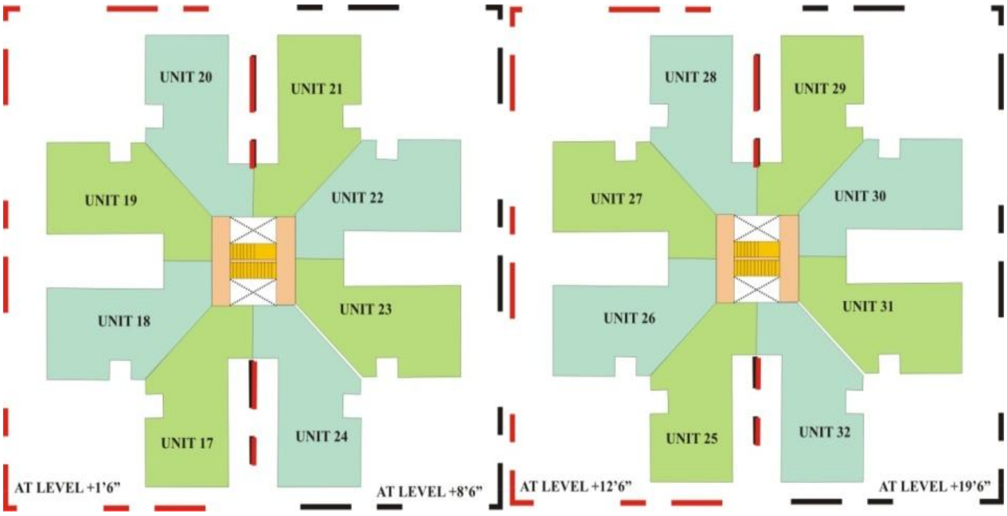

Figure 2: Position of different Apartments at different levels in the identified Individual Block

The electricity from the Tata power grid was the only operating energy used by the apartment. The bedrooms of each apartment were the only rooms which were conditioned using window air conditioner or split air conditioner. The comfort temperature of the indoor environment were set to 25°C and all lighting controls of the building were manual.

Table 2. Basic parameters: Single Block :

Sl. No.	Description	Details
1.	Residential Floors	Floor 1 at +1'6" Lvl @ 4 apartments each of 88.0 Sqm
		Floor 2 at +8'6" Lvl @ 4 apartments each of 88.0 Sqm
		Floor 3 at +12'6" Lvl @ 4 apartments each of 88.0 Sqm
		Floor 4 at +19'6" Lvl @ 4 apartments each of 88.0 Sqm
2.	Total No.of Apartments	16 Apartments in each block
3.	Ceiling height	3.3 m
4.	Service life	75 years
5.	Usable floor area	380.11 Sqm
6.	Structure	RCC
7.	Envelope	Brick masonry
8.	Foundation	RCC
9.	Interior Walls	Brick masonry with plaster finish
10.	Exterior Walls	Brick masonry with plaster finish
11.	Floor	Vitrified Tiles Flooring
12.	Roof	RCC apartment roof

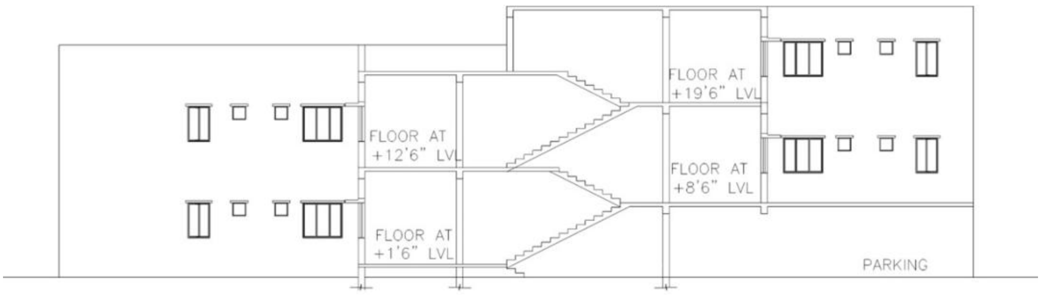

Figure 3: Schematic Section of a typical individual block.

Figure:4 : Individual Apartment Floor Plan & Ground Floor Plan: Individual Block

Figure 5: Typical Floor Plan Individual Block & site photos of study area

Table 3. Yearly & Monthly Electrical Energy Consumption of Apartments : Block 2: Professional Apartments

Flat No.	MODEL NO	TOTAL CONSUMPTION in kWhr month wise												Total Yearly Consumption
		Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	kWhr
17	B3801299	199	186	180	395	408	625	691	409	412	141	180	186	4012
18	B3803299	160	144	167	528	701	671	693	650	261	376	341	225	4917
19	B4000299	77	72	198	466	795	755	517	534	475	345	126	78	4438
20	B3801199	135	97	136	125	283	568	440	251	191	129	119	127	2601
21	B4000999	706	421	666	690	941	1255	1270	906	680	622	523	695	9375
22	B3802199	225	191	129	301	406	491	507	524	456	355	38	199	3822
23	B3800499	179	168	162	281	385	660	804	550	440	321	291	165	4406
24	B3903599	384	372	147	415	525	604	550	318	295	337	258	261	4466
25	B4007599	371	305	488	727	710	823	778	803	546	490	231	387	6659
26	B4003099	210	266	257	634	801	815	734	545	435	353	320	195	5565
27	CON01399	23	626	750	587	658	811	775	876	778	950	550	86	7470
28	B3802099	660	530	863	885	1244	1110	1275	1065	1205	1301	718	619	11475
29	80902299	233	193	424	760	785	743	587	572	503	472	428	345	6045
30	80902699	429	274	349	535	552	650	310	473	399	507	295	376	5149
31	80902205	441	344	447	854	1158	1093	677	870	572	620	297	349	7722
32	80902499	937	726	830	841	1153	1025	875	899	843	900	889	929	10847
Total Block		5369	4915	6193	9024	11505	12699	11483	10245	8491	8219	5604	5222	

Source: Monthly Bills, Town and Electrical supply, JUSCO, TISCO, Jamshedpur, India

Table 4. Orientation & Wall Window Ratio of Apartment: Block 2: Professional Apartments

		Balcony Side					Bedroom & Toilet Side					Bedroom & Kitchen Side				
Flat No.	Flat No.	Orientation	Exposed area (m2)	Net Wall area (m2)	Window area (m2)	% WWR	Orientation	Exposed area (m2)	Net Wall area (m2)	Window area (m2)	% WWR	Orientation	Exposed area (m2)	Net Wall area (m2)	Window area (m2)	% WWR
25	17	SW	23.22	18.76	4.46	23.77	SE	34.45	31.105	3.345	10.75	NW	27.66	24.51	3.15	12.85
26	18	NW	23.22	18.76	4.46	23.77	NE	34.45	31.105	3.345	10.75	SW	27.66	24.51	3.15	12.85
27	19	NW	23.22	18.76	4.46	23.77	SW	34.45	31.105	3.345	10.75	NE	27.66	24.51	3.15	12.85
28	20	NE	23.22	18.76	4.46	23.77	SE	34.45	31.105	3.345	10.75	NW	27.66	24.51	3.15	12.85
29	21	NE	23.22	18.76	4.46	23.77	NW	34.45	31.105	3.345	10.75	SE	27.66	24.51	3.15	12.85
30	22	SE	23.22	18.76	4.46	23.77	SW	34.45	31.105	3.345	10.75	NE	27.66	24.51	3.15	12.85
31	23	SE	23.22	18.76	4.46	23.77	NE	34.45	31.105	3.345	10.75	SW	27.66	24.51	3.15	12.85
32	24	SW	23.22	18.76	4.46	23.77	NW	34.45	31.105	3.345	10.75	SE	27.66	24.51	3.15	12.85

VI. Results & Discussions

The previous studies analysed the fact that the operation phase dominated over other life cycle phases of a building by a shear 89% [5] to others including manufacturing of construction materials, construction phase and demolition phase, a mere 11%, hence their conribution is insignificant to the operation phase. When activity wise the operational energy was anlysed in the case study done in this paper, it was found from the graphs that maximum energy consumed is for space cooling in this type of climate. Hence, reducing the operational phase cooling load consumption through changes in building design, one of the easiest alternatives, can be targetted with the fact being incorporated at the early design phase. Keeping in mind the above intention, differently orientated individual apartments were simulated with similar floor area, construction material and wall window ratio, keeping their core service/ common area in form of passage and staircase unaltered then there is change in the cooling requirements of the apartments. This is clearly illustrated by the following graphs.

6.1 Results obtained for different orientations:

Table 5. Wall areas and WRR

		Balcony Side					Bedroom & Toilet Side					Bedroom & Kitchen Side				
Flat No.	Flat No.	Orientation	Exposed area (m2)	Net Wall area (m2)	Window area (m2)	% WWR	Orientation	Exposed area (m2)	Net Wall area (m2)	Window area (m2)	% WWR	Orientation	Exposed area (m2)	Net Wall area (m2)	Window area (m2)	% WWR
25	17	SW	23.22	18.76	4.46	23.77	SE	34.45	31.105	3.345	10.75	NW	27.66	24.51	3.15	12.85

Table 5 gives the exposed wall area, net wall area, wall window ratio (WRR) % of apartments no. 25 & 17 for each exposed wall of the apartment, both of which face the same orientation. From Fgure 6, it is clear that the cooling loads for the months March to October is additional to the existing electrical energy requirements of the apartments throughout the year.

Case 1: For apartment no. 17 & 25

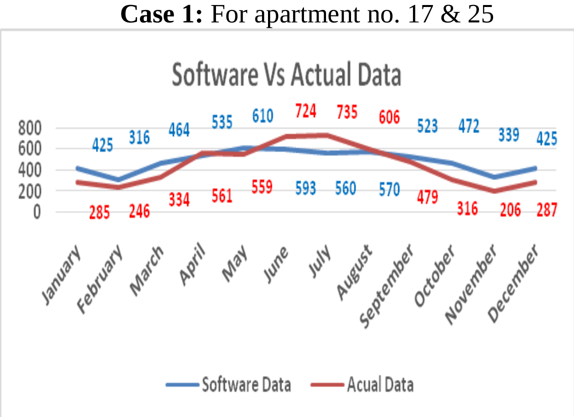

Figure 6: For apartment no.17 & 25:

Case 2: For apartment no. 18 & 26

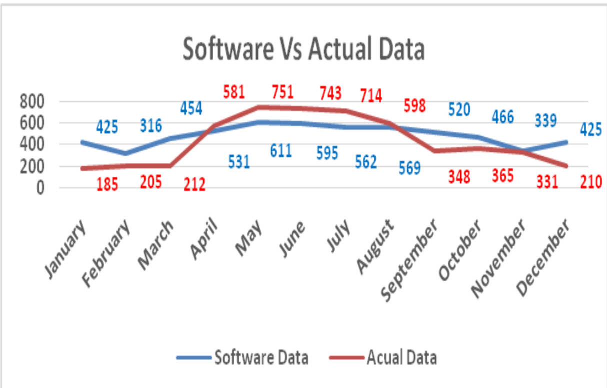

Figure 7: For apartment no.18 & 26

Electricity consumption vs. months of the year

Case 3: For apartment no 19 & 27

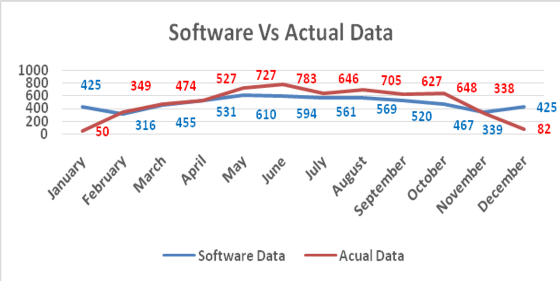

Figure 8: For Apartment no.19 & 27:

Case 4: For Apartment no 20 & 28

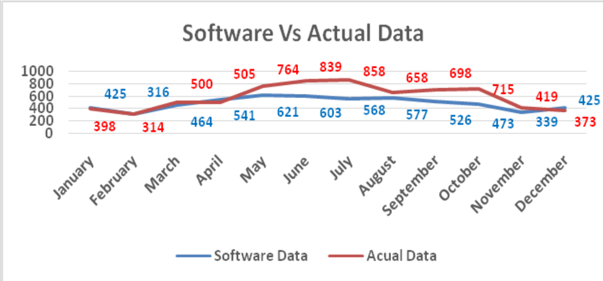

Figure 9: For Apartment no.20 & 28:

Electricity consumption vs. months of the year

Case 5: For Apartment no 21 & 29

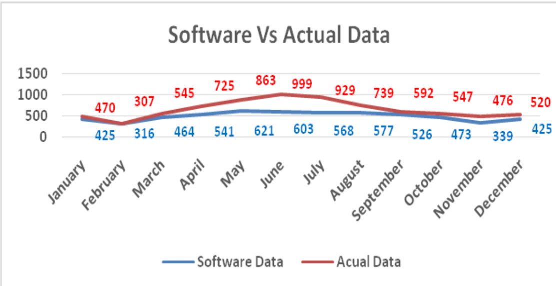

Figure 10: Apartment No. 21 & 29:

Case 5: For Apartment no 22 & 30

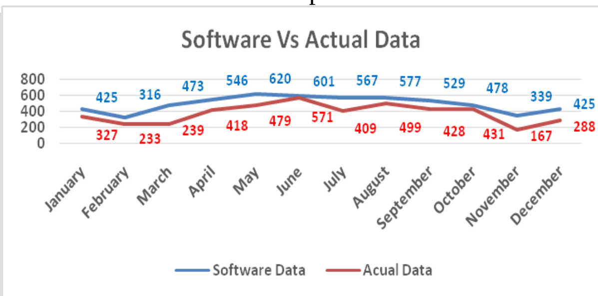

Figure 11: Apartment No. 22 & 30:

Electricity consumption vs. months of the year

Case 7: For Apartment no 23 & 31

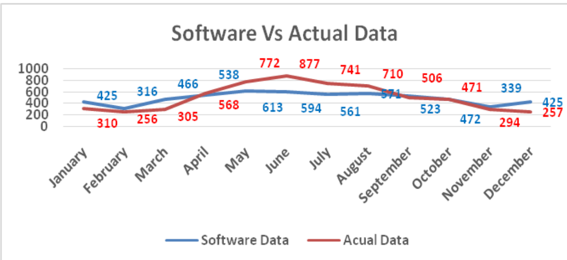

Figure 12: Apartment No.23 & 31:

Case 8: For Apartment no 24 & 32

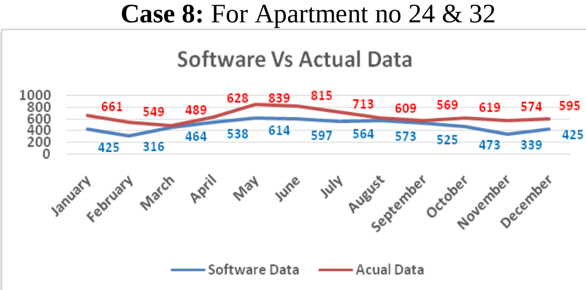

Figure 13: Apartment No.24 & 32:

Electricity consumption vs. months of the year

Similarly, for rest of the seven different orientation of the apartments (in Tables 6,7,8,9,10,11 & 12) with different balcony side, bedroom with toilet side & bedroom with kitchen side have been modeled in the said software and the actual electricity consumption along with the modeled electrical energy requirements are plotted in the graphs that follow the tables. The heating, cooling, appliances, and lighting loads are also plotted month wise *(* Fig. 6,7,8,9,10,11, 12 & 13)

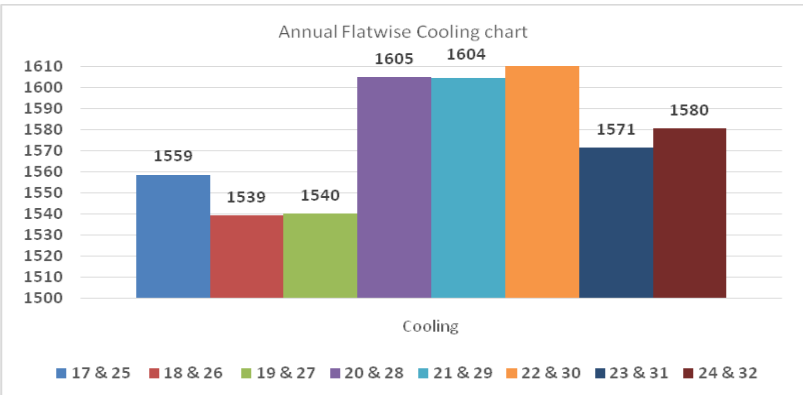

Figure 14: Cooling Energy vs. Existing Apartments

The simulation results showed that energy consumption for cooling accounts for about 20% to 30% of the total energy consumption which is in agreement with results from studies in similar climates and function as shown by Cheung (2005) [23], Ponniera *et al.* (2012) [24] and Sabouri *et al.* (2011) [25]. In this paper, the effects of mentioned orientation efficiency factors on the cooling load and cooling energy consumption are evaluated for each apartment. Two variables were selected for this evaluation, namely monthly cooling energy and mean range of cooling energy deviation. Annual cooling energy is defined as total energy consumed by the cooling system to maintain the required thermal conditions of the space. Mean range of cooling energy deviation means is defined as the maximum amount of heat that needs to be removed from the conditioned space in any single hour over the year in order to maintain the set point temperature. For each orientation of apartment measure, the analysis indicates there is change in the cooling energy consumption and the mean cooling range load.

Table 6. Cooling Load Energy Consumption & Deviation from average of Apartments : Block 2: Professional Apartments :

Name	17 & 25	18 & 26	19 & 27	20 & 28	21 & 29	22 & 30	23 & 31	24 & 32
Cooling	1559	1539	1540	1605	1604	1624	1571	1580
Name	**17 & 25**	**18 & 26**	**19 & 27**	**20 & 28**	**21 & 29**	**22 & 30**	**23 & 31**	**24 & 32**
Deviations	-1.22%	-2.44%	-2.38%	1.70%	1.67%	2.91%	-0.41%	0.17%

From Table No.6 it is observed that the maximum cooling loads are required for the apartments 22 & 30 whose Balcony faces the SE side, the bedroom along with toilet faces the SW side and the bedroom with kitchen lies in the NE side has the requirement of largest cooling energy loads while the minimum is required by Apartment no. 18 & 26 which has balcony side in the NW, bedroom with toilet side is in the NE side and the bedroom with kitchen side in SW side. The Table No.13 also points out that for the above type of building , with longer side of apartments 18 & 26 facing north and south, is appropriate as it affords maximum solar heat gain in winter and less in summer for all places in India [26]. It is also seen that the total solar heat on the building is the same for orientation for 17 & 25 and 18 & 26. But if the site considerations require a choice between these two, at places latitude 22°48'38"N, orientation for 17 & 25 should be preferred and orientation 18 & 26. This is so, because, the total solar load per unit area in summer on the north western wall decreases and that on the south western wall increases. It would, therefore, be advantageous to face only the smaller surface of the building to greater solar load in the summer afternoons, when the air temperature, also, is higher.

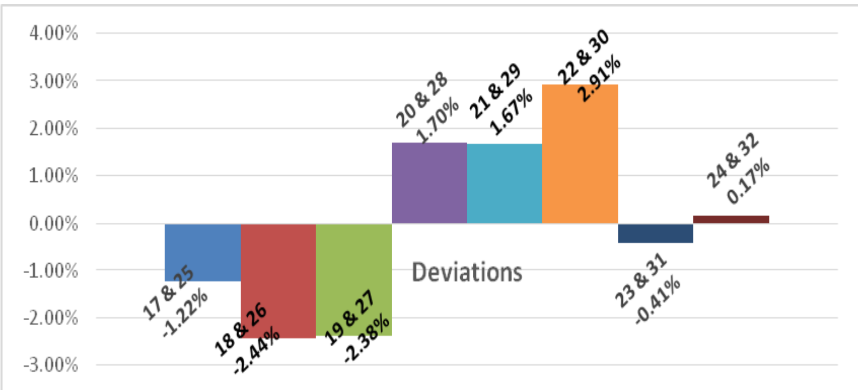

Figure 15: Mean range of cooling energy deviation vs. orientation of existing apartments :Deviation Chart from Average Cooling .

Hence the best alternative for Lowrise multifamily apartments in composite climate can be achieved through changing the orientation of individual apartments and optimize the operational energy of the apartments.

6.2 Implications Of The Results: At present, residential buildings have poor energy performance levels with increased trend in householder consumption level in India. With the current trends, the potential for intervening with design in order to improve building energy efficiency is substantial, whereby relatively basic measures can deliver relatively dramatic improvements [27] thereby putting forward the requirements for examining the benefits of passive design. This is particularly highlighted by the short term cooling energy required arguments presented in Figure 14 where the mean deviation for cooling values achieved for eight classified orientations, shows that there is a difference of 5.35 % (+ 2.91% & -2.44% = 5.35%). Figure 15 takes note of the Mean range of cooling energy deviation vs. orientation of Existing Apartments which gives us the clear picture of deviation from Average Cooling. It is to be noted that for built up area per floor more than 500 m^2 higher thermal performance standards are more difficult to meet, while smaller apartment buildings are more flexible in terms of performance at given orientation, and can more readily be adjusted to perform to higher energy efficiency standards. Apart from the fact that the passive design interventions investigated could potentially be supplemented with further, more sophisticated measures [28], this study supports the conclusion that passive solar energy efficient design can provide an important and low cost step towards reducing cooling energy required for low rise apartment buildings.

VII. Conclusions

With the given trends, there is a need to get involved in the designing of low rise multifamily residential apartment buildings, particularly in composite climates in India, which are a major consumer of electric energy with air-conditioning systems for cooling accounting for a large proportion of total energy consumption. The pressing demands of implementing energy efficient building codes alone cannot lead to the necessary control of energy consumption and there is a need to examine the benefits of early decision support for operational Energy Assessment in apartments. This paper shows the results of operational cooling energy performance over a period of a year in a multifamily residential apartment with similar wall window ratio, cooling energy required varies with the position/ orientation [29] of the residential unit. This study's intent was to highlight on the expected reduction in annual electrical energy consumed by different apartments in a single block with changed orientation, where the main factor is window wall ratio (WWR) and weather conditions [30]. Findings showed that apartments retain their better performance across a wider range of orientations and have better chances of energy efficiency compliance. A known fact states the argument against increasing energy efficiency standards is that they lead to an increase in costs of construction, thus impacting the buyers who then prefer non energy efficient apartments to the ones with energy efficiency. Hence, intervention of the orientation factor at the predesign stage provide more compact designs which are cost effectively adaptable and therefore can be provided at relatively lower cost. The study paves way for formulation of a tool in early design stages [31] which can be utilized in the stage of preliminary design where rough estimation involves in terms of building design, indoor environment, comport and energy issue.

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