An analysis of usage of passive materials for sustainable and innovative construction process

(*A Technique using of passive material in Chennai Residential Apartments for Sustainability and Energy Conservation*)

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Key words
Passive material, passive design, energy consumption, carbon reduction, carbon emission, tropical climate.

Abstract

This paper discusses the importance and approaches of thermal control, carbon emission and carbon reduction in Chennai city at various positions with regard to orientation of high-rise structure. This case study tries to distinguish the relationship between real energy use information and housing design data by changing the passive materials. A number of apartments were randomly chosen as a sample building for the study, which introduces a method to use substantial energy consumption information to estimate the additional energy use related to climatic factors. The factors governing the building temperature and discuss about the Power usage, Carbon emission factor, Carbon footprints, Carbon reduction from the old and new residential houses. This report is almost a case study of Chennai where current construction practices as a normal brick's concrete way of building. In this research suggesting that with certain changes of using passive materials like prefabricated concrete wall, e glass and insular tiles, etc., that owner will be capable to recoup the increased investment within a decade via reduced energy bills with the added benefit of improved comfort. To study heat transfer and the temperature distribution through passive materials can be done by analyzing and stimulating possible economical designs. This work identifies relationships between the increase in mean daily energy consumption information and a trend of building design data of the sample houses and establishes the starting point feasibility for further work for developing passive energy design guides for establishing energy efficiency.

Introduction

In India the Ministry of Power estimate about 35 to 40 percent of the total electricity consumed in Residential apartments in India is wasted, because of improper design parameters of buildings, which results in an annual energy related financial loss of nearly 1.7 billion Rupee. Energy is the major factor required to achieve thermal comfort. India takes in different climatic conditions ranging from extremely hot conditions to severely cold conditions (Thirumaran and Subhashini, 2014). Energy availability has been trimmed down and people have to protect themselves from these extremities of the climate in a lifelike manner. The energy consumption in residential buildings is quite high and is expected to further growth because of improving standards of life and increase in the population. Air Conditioning use has increasingly permeated the market during the utmost few years and greatly contributes to the gain in energy consumption (Bhavsar and Bhatt, 2014). There has been a drastic gain in the role of air conditioning system for cooling the residential buildings all-round the globe. The last two decades have seen a serious energy crisis in developing rural areas especially during summer season, primarily due to cooling load demands of residential towers. Increasing use of energy has contributed to environmental

pollution resulting in global warming and ozone layer depletion. Passive cooling systems utilize non-mechanical methods to keep a comfortable indoor temperature and are a key element in mitigating the impact of buildings on the surroundings. Passive cooling techniques can cut the peak cooling load in buildings, so cutting down the size of the air conditioning equipment and the full point for which it is generally required (Arif and Acta, 2012).In the South Indian state of Tamil Nadu serves one of the highest consumption of electricity, whose average consumption per day is more than 300 million units. Tamil Nadu power supply has increased from 200 million units in 2011 to approximately 315 MU per day in 2017.Only at that place is considered the huge power shortage of more than 3000 MW in 2011. This state has surplus power now, but the demand is increasing every year by 6%. In this state the Chennai city consumes more than 44% percentage of force with regard to the entire electricity consumed by the nation. In Chennai maximum power use is caused by high rise residential buildings due to huge population (Abrav, 2016).

Chennai Residential Building Construction Standards

When Considering the Chennai as Smart city it must be developed with certain necessary components such as smart infrastructure, smart building and materials, smart city services, smart energy management, smart waste management and smart water management has to be involved. Creating smart environment is ultimate goal for smart city which incorporates Energy efficiency in building, intelligent lightning, smart grids, irrigation remote control, renewable power and district heating and cooling has to be provided. The normal Chennai housing construction is done mostly using bricks and reinforced concrete. This Reinforcement concrete acts as a composite material, which occupies an important place in the modern construction of different types of structures due to its several advantages. Due to its flexibility in form and superiority in public presentation, it has replaced, to a great extent, the earlier materials like rock, lumber and so forth with the rapid growth of urban population in India, reinforced concrete has become a material of choice for residential constructions(Bhavsar and Bhatt, 2014). The typical residential wall construction has been built by brick walls, which carries a huge load and less construction cost. The ceiling of the building structure is built using reinforced concrete following the Indian Standard code IS 456:2000: Code of Practice for Plain and Reinforced Concrete. For high rise building considering the Criteria for Earthquake Resistant Design of Structures follows Indian Standard code IS 1893 (Part-1): 2002.

1.2 Chennai Climatic Condition

In India the warm and humid zone covers the coastal regions of the metropolis. Some urban centers that come below this zone are Mumbai, Chennai and Kolkata. In this paper the Chennai climatic condition has been analyzed to know the reason behind huge power consumption. Chennai is located on the southeast coast of India in the northeast of Tamil Nadu which is on a flat coastal plain known as Eastern coastal plains. Its average elevation is around 6.7 meters which is 22feet and its highest point is 60 meters which 200 feet. The East Coast Beach runs around 92 Km along the shoreline of the entire city. In Chennai the high humidity encourages abundant vegetation in these regions. The diffuse fraction of solar radiation is rather high due to cloud cover, and the radiation can be intense on clear days. Hence, the marginal variation in temperature is quite less. In summertime, the temperatures can hit as high as 34 – 42 ^{o}C during the day and 26 – 32 ^{o}C at night. In wintertime, the upper limit temperature is between 30 to 36 ^{o}C during the daytime and 25 to 30 ^{o}C at night. Although the temperatures are not excessive, the high humidity causes discomfort. An important feature of this city is the relative humidity, which is generally really high, approximately 65 – 85% throughout the year, Precipitation (Rainfall) is likewise high, being nearly 1100 millimeter per year, or even more (Bhavsar and Bhatt, 2014).Hence, the provision for quick drain of water is essential in this zone. The twist is mostly from single or two prevailing directions with speeds ranging from extremely depressed to very high. Wind is desirable in this climate, as it can cause sensible cooling of the body. The principal design criteria in the warm and humid region are to cut heat gain by providing passive materials and promote heat loss by maximizing cross ventilation. Dissipation of humidity is also indispensable to reduce discomfort (Thirumaran and Subhashini, 2014).

2.0 Literature Review

2.1 Statement of Problems

A problem statement is a clear concise description of the issues that needs to be described by a problem-solving researcher. From the detailed study of various literature reviews the key problem statement has been identified, which includes a vision, issue statement, and the methods used to solve the problem. It is used to center and focus the research at the beginning; keeps the researcher on track during the entire research, and it helps to validate an effort delivered an outcome that solves the problem statement. In this research the key problem statement taken from the overall literature review as follows

Rising Energy demand [High Electricity consumption]
Finding the suitable passive materials
Changes in Building Design [Passive design]
Increase of carbon emission
High cost of the building Materials [Installation of Energy efficiency material]

2.2 Sampling for Site Selection

In this research the quality of use of the passive materials in residential buildings at various locations in Chennai city. In addition, because of zone situation, the importance of improvement of living condition, too much populations and residential buildings is much more than other zones in this city. The satellite image below shows, field study of this research at various locations of residential houses in Chennai as shown in figure 1.

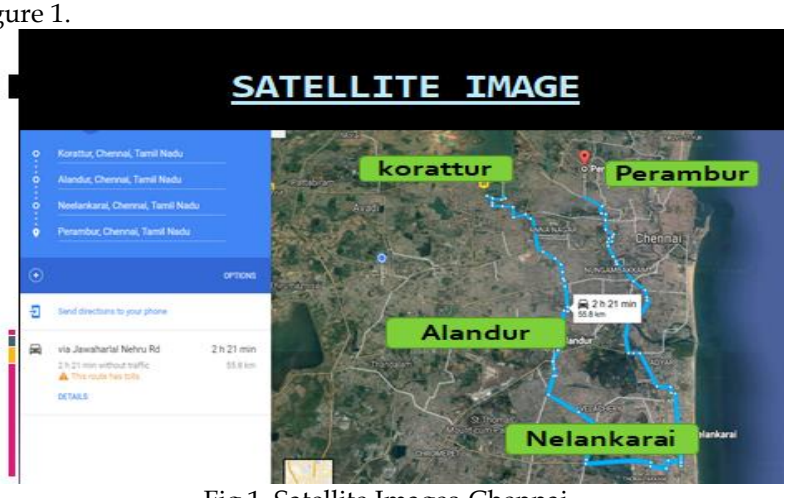

Fig 1. Satellite Images-Chennai

In this paper the four sites have been selected according to its area and the place of the area which it located. On each site a residential apartment is selected in four different parts of Chennai city. Site location at each zone of Chennai that represented the north, south, east and west directions can be named as H1, H2, H3 and H4. The site plan and the images of alandur, perambur, korattur, nelankarai follows

Alandur is located at the South of Chennai with latitude of 12°59'50.95"N and a longitude of 80°12'2.29"E Considering this site which located in Central part of Chennai city, which is away from the sea shore and this site is huge densely populated along with less forest and vegetation zone.

Nelankarai is located at East of Chennai with latitude 12.949282 longitude of 80.255013. This site is located on southern part of the Chennai region where this site is next to seashore, which causes decrease in temperature do the lots of moisture in air and sea breeze. This site is surrounded by huge number fvegetations and open land, since the population is keeps increasing for last 10 years.

Perambur, located at the North of Chennai with latitude of 13° 6' 57.6648'' N and a longitude of 80° 13' 54.0012'' E. This site is located northern part of the region where the site is filled with industry and oil factories. This site not much densely populated as compared to other three sites. But this site is surrounded by huge amount oil and gas industries cause's lots of carbon dioxide in the air.

Korattur is located at West of Chennai with latitude 13.1021499 and longitude of 80.1784312. This site is located on western part of the region where the site is away from seashore, which causes increase in temperature. This site is surrounded by huge number of manufacturing industries and densely populated.

In this site is surrounded by huge amount of Automobile industries cause's lots of carbon dioxide in the air.

2.3 Feasible Passive Materials Identified from Literatures

2.3.1 Pre-Cast Concrete Blocks

Considering the Chennai walls constructions for residential housing walls are mostly constructed by masonry bricks which emits more carbon dioxide. After having the detailed study and characteristics of the passive materials the precast concrete is selected for the housing construction based on the tropical climate. In this paper the brick wall has been replaced by Precast Concrete blocks to achieve the energy efficiency and reduction of carbon. This precast concrete block is primarily used as a building material in the construction of walls and emits less carbon dioxide compared to masonry wall. It is sometimes called a concrete masonry unit (CMU) (Mardina and Riffat, 2015). This is a lightweight concrete wall compared to brick wall, butthe cost of construction is little high. The character of this pre-cast concrete blocks has one or more hollow cavity, and their sides may be cast smooth or with a design. Concrete blocks are stacked one at a time and held together with fresh concrete, mortar to form the desired length and height of the wall which reduce the transfer of heat from outdoor surface to indoor (Henry and Nowak, 2015).

2.3.2 Low E Glass

In Chennai housings single glazed window is used almost all the residential housing, which allows the sunlight to pass through and stores more heat inside the structure. Since for reducing the temperature and reflect the heat and light the single glazed glass window has been replaced with Low E Glass in this research by conducting various passive material study. This Low emissivity refers to a surface condition that emits low radiant thermal energy (heat); also, low e coatings are microscopically thin and transparent metal coatings. They minimize the amount of ultraviolet (UV) and infrared (IR) rays that can pass through window glass without compromising the transmission of visible light (Beebe, 2007). This E Glass also has special features which cool inside room in the summer and warm in winter. Improve the energy efficiency of your house. Reduce the amount of energy you use and more effective than single glazing or standard double glazing (Mardina and Riffat, 2015).

2.3.3 Insula Tiles

Thermal insulation of the terrace, concrete slab is vital for imparting comfort to the inhabitants as compared to other potential elements such as wall, window/door openings etc. Since the upper roof surface is exposed for the longest duration directly to almost intense perpendicular solar heat radiation. For weathering roof top, the clay tiles are insulated which result in reduction of accumulation of heat on the roof and its transmission into the rooms below, helps lower the temperatures in the rooms significantly to a certain extent. This also reduces the period of use of cooling devices such as coolers and air conditioners, thus saving in energy costs (Gang and Bing, 2010). So instead of clay tiles placed on the weathering roof the insular tiles are placed as in above figure which reflects more heat than existing clay materials. This insular heat insulation tiles made from PCM (Phase Change Material) Technology by using micro encapsulated PCM's, which is leak proof. It cools inside room in the summertime and warm in wintertime, which brings down the dead load of the building and reduces the electricity bill fulfilling the BIS Values (Ramin and Fazad, 2014).

3. Research Methodology

In the methodology process data gained during this research was compiled using mixed research methods, which is appropriate for this type of research method. This approach was implemented through a survey questionnaire. This instrument was developed as the best means to capture data from large quantities of professionals in companies with a focus on alternative passive material to replace the existing material for energy conservation. The steps which helps to, and frame the survey questionnaire are outlined below and summarized as follows,

To develop a literature review to determine the basic ideas to carry out research methodologies.

To develop a survey questions directed towards energy saving housing construction professionals that would provide information to answer the research question.

To select a database and develop a subject set using the database for passive design.

To develop pilot study on the survey among professionals and engineers for process, understanding, and complexity of information collected.

To study the survey through SPSS software using email addresses gained through passive design.

Finally carry out the survey closure and method of data analysis.

3.1 Analysis using Software

Auto desk Revit is a building information modeling software used by structural engineers and contractors to design a building and structure and its elements in 3D, annotate the model with 2D drafting elements, and access building information from the building model's database (Autodesk Manual, 2017).By using this Revit software the climatic condition, temperature, energy efficiency and carbon emission of each residential apartment can be broken down. This software specially used for this research which aids to perk up the floors and walls with U values and makes the exact results in giving each house. The U values for External walls, floors, window glass and roof use the British standard code values (Mariska, 2013). Building Assumptions for H1, H2, H3 & H4

Table 2. Building Envelop Parameters List – (British Standard Code)

Building Structure - Element	Description Values	U value W/m2 K
External Walls	252 mm Brick + 19 mm Plaster	1.42
External floors Type 1	110 mm Concrete Slab, 8 mm Screed, 6 mm timber	1.87
External floors Type 2	110 mm Concrete Slab, Insulation (R = 0.16 m2 K/W), 6 mm Screed, 6 mm timber	1.46
External window glass	6 mm Single Glazing, SHGC: 0.8	5.67
Roof	27 mm Slate Tile + 6 mm Bitumen Felt + 24 Air Cavity + 22 mm Plaster	2.78

3.2 Passive& Existing Materials U Value

Before the stimulation the live project study has been done by studying and taking the reading of temperature and carbon emission study for the live project with the existing construction materials. By using the Revit software, each Apartment has been taken in which the entire area was selected and drawn with the exact dimension from the plan. Once the drawing has been done on the software, the material of the existing construction and passive materials data has been entered in the system. Run the analysis and stimulation of the house plan with existing material and passive material using U Value or thermal transmittance. The U value for the Existing materials and passive materials as per the standards by British standard codes are given below on table 3

Table 3. Materials U Value

SL. No	Current Material	U value W/m2 K	Passive Material	U value W/m2 K
1.	Brick Wall	0.52	Pre-Cast Concrete Wall	0.26
2.	Normal Standard Insulating Glass	0.49	Low E Glass	0.24
3.	Clay Tile	0.44	Insula Tile	0.36

4. Finding & Results

The various live analytical studies on the existing building material which is compare with the stimulation study after replacing the passive materials on these study site houses. The study has conducted over energy consumption of each houses, carbon reduction and indoor temperature with relates to before and after replacement of passive materials.

4.1 Power usage in each house

In each house the various electrical appliance data usage has been collected from the real house scenario and these data which helps to be entered in the energy analysis software. The software gives the requirement in electricity for each house with respect to the size of the house, location, climate and

temperature is verified on the site location with present electricity monthly bill which is more or less similar in Chennai city. Each house usage of different electrical equipments' and electrical appliance has been taken into the account and the time period for the working of each appliance has been taken. Based on the electricity bill and using stimulation the requirement of power consumption for each house per day has been calculated and displayed on the Table 4.

Table 4. Power usage in each house.

Types of houses	Specification	Usage of electrical products	Requirements of power in KWh
h1	2BHK	Fan:4 AC: 1; F/WM: 1; Lights: 4	2.6
h2	2BHK	Fan:4 AC: 1F/WM: 1Lights: 4	2.2
h3	2BHK	Fan:4 AC: 1F/WM: 1Lights: 4	3.1
h4	2BHK	Fan:4 AC: 1F/WM: 1Lights: 4	2.7

4.2 Indoor Temperature Before and After Using Passive Materials

Table 5. Indoor Temperature with Current and passive materials

Indoor temperature	Before adding material		After adding material	
	Summer	Winter	Summer	Winter
ALANDUR H1	35.11	28.61	28.24	26.11
NELANKARAI H2	36.11	27.11	27.70	24.44
PERAMBUR H3	39.11	29.66	32.92	27.44
KORATTUR H4	38.51	30.11	31.81	28.36

In the table 5 the temperature for indoor room has been observed at an average rate per year on doing the stimulation using the revit software with the passive materials. There is an average of 7 to 8-degree difference when comparing the existing materials with passive materials in these residential houses. For the existing materials the temperature taken for each month and calculate as an average of entire year, this has been verified with the real housing projects on various site locations. Since each house is in same city but tends to have difference in the indoor temperature compared to one another. These temperature differences for each house are due to the various factors like site geographic locations, population density, vegetations, industrial zone and the distance between the seashores which is mentioned on site study.

4.3 Calculations of carbon emission for various usages of electricity

A carbon footprint is defined as the total amount of greenhouse gases produced to directly and indirectly support human activities, usually expressed in equivalent tons of carbon dioxide (CO2) (Mariska, 2013). Carbon Emissions is caused by the use of electricity by using electric lighting, electric appliance and electric equipments. The energy production for Chennai city is around 85% through Thermal powerhouse, the burning of fossil fuel such as coal which affects the carbon footprint. These carbon emissions are reduced by installing the passive materials which makes the energy consumption less, in turn reduce the carbon emission. Stimulation Analysis of carbon emission is done with respect to U value (thermal coefficient) of the passive materials used in the residential building. It is found that there is huge difference between carbon emission by using the existing material and passive materials. Here the H2 site considered to have more carbon emission due to location around the industrial zone and away from the seashore. This suggest that orientation and location of housing constructed on wind directions.

Table 6: Carbon Emission Assessment

Type of houses	Power required in each house (Kwh)	Before using passive Materials (CO2) in Kg	After using passive Materials (CO2) in Kg
H1	2.6	4137	2284
H2	2.2	3849	2102.2
H3	3.1	4796	2821.4
H4	2.7	4294	2508.6

4.4 Monthly Electricity Consumption in KWh

The measurement of power consumption for the real housing building site has been taken with existing materials. On doing the stimulation analysis, it is observed that there is gradual change in the power consumption after replacing passive material. There is gradual difference of 2 to 3 kWh energy consumption when compared to exiting material and passive material installations. The monthly electricity consumption for the individual housing before and after replacing the passive materials is as follows.

Table 8. Monthly Power Consumptions

	BEFORE Changing Materials	AFTER Changing Material
H1	2.6	1.8
H2	2.2	1.4
H3	3.1	2.3
H4	2.7	1.8

From the above Table 8 the electricity is reduced when the three selected passive materials are implemented for housing. The before and after represents the energy analysis is carried out with existing materials (Before) and replacing the existing materials with passive materials. This energy consumption difference can cause the reduction of cost in electricity bill which gives the benefits for the owners and consumers by paying fewer monthly bills for less power usage.

4.5 Research Observation and Discussion

The Chennai city is taken for the research study because of the tropical climate and energy demand increase every year by 14% due to the growing population increase in housing construction. So, in this research for energy conservation and carbon reduction is major key problems has been identified from various literature review, field survey and questionnaire survey by various construction professional. There is lots of research work carried on passive design and passive material for achieving energy efficiency for colder region by previous researchers. But there is a gap in previous research contribution, which there is not suitable passive design or feasible selection for particular passive material selection for residential houses at tropical climate zone have not identified.

Based on these gaps from literature review and field survey in Chennai the solution needs to be found out, which is related to passive design or passive material for tropical climate as the passive material solutions given to colder climatic zones. In this research there are three passive materials has been selected for replacing the existing materials on residential housing sector. The three feasible passive materials have been found to replace the existing materials. The three passive materials such as precast concrete for wall structure, E glass for windows and Insula tiles for roof surface to replace the materials like masonry wall, Single glazed window and clay tiles which commonly used for Chennai housing constructions.In this research the Chennai city is identified because of the climatic condition, huge energy demand and high population growth. So, based on the above factors and hot and humid climatic zone on Chennai city the suitable passive material is identified for the construction and undergoes detailed comparison and stimulation analysis with existing materials as follows.

The energy analysis result observation shows that when the ordinary window glass is replaced with low e glass which gives considerable difference in energy saving is identified, also when the low e glass is used there is a slight temperature difference inside the room has been achieved. This is due to the fact that e glass doesn't allow UV ray and heat inside the room surface, which makes the room cooler than outdoor.For the housing wall structure the existing material like masonry brick wall structure has been replaced by the passive material like precast wall structure. The energy analysis is done for precast concrete wall which gives a massive difference in temperature inside the room surface. This is because of the precast concrete, which won't transfer much heat from outer surface and reduce lots of carbon emission than masonry brick walls.

Finally, the passive materials like insula tiles used on the top of the roof surface replacing the clay wall existing material. By replacing the Insula tiles after doing the energy analysis, it shows that there is slight difference in temperature and much heat is reduced inside the room temperature. The Insula tiles which has properties to reflect the sunlight and don't observe the heat due to white color, also these tiles

won't transfer much heat inside the room temperature. Overall by replacing these three passive materials, on doing the energy analysis there is considerable amount of temperature difference around 8 degree C in summer and 2 degree C in winter period for the entire four individual houses in Chennai city. The energy requirement of residential houses can be fulfilled by applying the concept of energy efficient smart building with passive materials.

5. Discussion and Conclusion

In the past several decades, many literatures have emerged on the topic of Passive material techniques used in building to achieve energy saving for colder regions by western world. There is huge gap and limitation for the passive material solution for the tropical climate regions. This research paper is focused on Passive material application situations in residential building all over the Chennai city. This study includes passive materials major applications in residential building, passive material application areas and application types in tropical climatic regions, passive material thermal co-efficient properties suitable for building and application effects of passive material integrated in residential building. According to the several literature aspects and limitations, some new findings can be obtained as follows

There is scarcely any study, experimental or numerical, that verifies the evaluation of passive material in real indoor conditions. Therefore, more studies focusing on real full-scale buildings and real operation conditions should be carried out to prove the authenticity and reliability of current research. Based on this different individual housing projects work have been studied in the Chennai city at various places.

Passive material application areas are mainly concentrated into four parts of Chennai city they are Tambaram, Redhills, Sripermbathur and Kannathur. There is a difference in temperature for these entire regions even its falls on same city because of the orientation, location at Industrial and residential zone and increase in population. Also, there is various data collection techniques have been adopted for the selection of houses and passive materials. In these housing the various data has been collected such as Wind speed, temperature at indoor and outdoor, orientation, area and dimension of the houses, orientation, energy consumption, electric appliance usage, population growth at particular site study and finally last 3 decades rainfall and temperature has been studied. Also, the best passive material and their application found for air temperature inside room is a reduction of 8 degree C at an average for the entire housing site for the tropical region. For average peak temperature variation, an increase of more than 15% in temperature has already been achieved by most researches for colder region using the PCM (Phase change materials) or passive materials.

In this research due to the temperature reduction power usage also gradually reduced which makes the owner to pay less electricity bills. The cost of the energy consumption is reduced by around 40 % by using the passive materials than the previous bills. Finally, the carbon reduction is achieved almost 45% as shown by energy analysis by carbon foot print a stimulation method, which helps the environmentally friendly and. By this research it is suggested that still more temperature and carbon reduction can be made effective depends on the orientation and location of site construction using passive design and framing suitable guidelines for residential housings in this Chennai region.

6. Limitations & Directions of Future Work

The size of the sample was not too large – 3 different professionals are selected as participants from nine construction firm do to short time. A bigger sample would probably increase the reliability of the research.

Qualitative research is not permitting the measurement of the examined key issues and problems.

The analysis of the role of the data management software the promotion of software tool SPSS as an outsourced destination may be influenced by factors which were not brief detailed in this research.

In some cases, participants may refuse to speak against their working firms, so some reliable data may not be available.

Functions of residential buildings in Chennai city are dynamic in nature, which is unique (Size and height) compared to one another.

Less number of information is provided by building contractors to the researcher due to lack of knowledge.

Building owner and contractor unfamiliarity with the information required by researcher and more ready to share the information's because of new concepts & techniques which they never come across.

Building contractor's oversight leads to data entry error in the questionnaire submission process.

The direction of the future Study can focus on this research study will make to the broad literature or set of broad research problems upon completion. In this activity it will draft the Significance of the Study or research by determining, how this entire research work benefit other and how other researchers will be benefited or learn from this study made

Further research can be strengthened legal and regulatory framework and mechanisms to enforce the legislation for improving the energy efficiency of the building sector with the focus on new residential buildings by using passive materials.

The direction of further study enhances the capacity of the Chennai city to implement this new passive design features which helps effectively enforce new energy efficiency standards and norms with the focus on new residential buildings and existing buildings.

Energy and cost saving potential of new energy-efficient measures in at least four new residential buildings located at four different directions in Chennai city. This can be taken further steps to implement the guidelines for passive design for the construction of residential housings in tropical climate.

Documented, disseminated and residential project results providing a basis of further future research replications of new passive construction under tropical climate.

References

Abrar, M. D. 2016. Power cut off and Power Blackout in India a Major threat- An Overview. International Journal of Advancements in Research & Technology. 5(7): 8-16.

Arif, M. and Acta, K. 2012. An Overview of Passive Cooling Techniques in Buildings: Design Concepts and Architectural Interventions. Journal of Civil Engineering & Architecture. 55(1): 133-149.

Auto Desk Manual, 2017. www.autodesk.in/products/structural-analysis-revit/overview.

Beebe, P. 2007. Glazing Design for Energy Savings in Sustainable Construction prepared for ENGRC 350: Engineering Communications Oscar Echevarria GPR.

Bhavsar, M. J., Choksi, K. N., Bhatt, S. K. and Shah, S. K. 2014. Comparative Study of typical RCC Building using Indian Standards and Euro Standards under seismic forces. International Journal of Scientific and Research Publications. 4(12): 1-4.

Bull, J. and Judit, K. 2000. Life Cycle cost and carbon footprint of energy efficient refurbishments to 20th century UK school building. International Journal of Sustainable built Environment. 3(6): 1-17.

Gang, H. and Bing, L. 2010. Simulation and Energy Analysis of Thermal Environment of unassisted Passive Solar house. International Journal of Smart house. 10(6): 27-38.

Hanel, S. 2015 Tile roofs are very popular in LasVegas. Las Vegas Review Journal. 3(8): 34-48

Henry, N. and Nowak, L. 2015. The impact of different solar passive systems on energy saving in public buildings and occupants thermal and visual comfort. Journal of Building Physics. 1(4): 18-23.

Mardiana, A. and Riffat, S. B. 2015. Building Energy Consumption and carbon dioxide emissions threat to climate change. Journal of Earth Science climate change. 3(5): 234-245.

Mariska, M. J. 2013. Energy Payback time and Carbon footprint of Commercial Photovoltaic systems. Journal of Solar Energy Materials and Solar Cells. 119(14): 296-305.

Ramin, V. and Fazad, H. 2014. Evaluate Performance of Precast Concrete wall to wall connection. ICCEN-Science Direct. 9(4): 285-290.

Thirumaran, K. and Subhashini, S. 2014. Energy Efficient Passive Design Strategies for Building in Madurai. American Journal of Sustainable Cities and Society, 1(3).

U-value- Heat loss, thermal mass and online

calculators. 2016.https://www.thenbs.com/knowledge/what-is-a-u-value-heat-thermal-mass-and online loss calculators-explained

Weather Statistics for Chennai, Tamil Nadu, India.

https://www.yr.no/place/India/ Tamil_Nadu/Chennai/statistics.html