DESIGN STRATEGIES FOR REDUCTION OF INDOOR MOISTURE IN RESIDENTIAL BUILDINGS IN ENUGU, NIGERIA

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ABSTRACT

There is a lack in understanding of the indoor climate of residential buildings in Enugu. This stemmed from the abandonment of healthy building practices of their forebears to modern residential buildings with its attendant air-tighted building envelopes. The situation is worsened by high humidity, resident's attachment to preparation/cooking of their traditional delicacies which take long hours and their method of bathing/washing within these air-tighted building envelopes. The assumption that one residential building prototype could provide the best indoor environmental conditions may not be feasible. The study is to determine the relative humidity values in residential buildings in Enugu and to introduce the need to utilize design options as an approach to indoor relative humidity strategy in hot humid regions. Extech DCO 1001 building Physics instrument was used for measurements in these indoor spaces. Scholars' suggestions on methods to ascertain the quantity of indoor water vapour generation by various family sizes were also discussed. The findings showed that the relative humidity of these buildings is the same irrespective of building type. The study believes that urgent attention is required in design approaches of these buildings to be healthier, environmentally conducive to the occupants, building materials/components and sustainable.

Keywords: Indoor residential environment, health, relative humidity, sustainable design strategies

INTRODUCTION

Almost every pollution problem that we face has a root basis. Human activities like respiration, cooking, cleaning and bathing contribute to increased moisture indoor of buildings and ultimately indoor contaminants (Burberry, 1979; Toe et. al., 2011). This led Geros, (2006) to assert that every building has a number of potential sources of indoor air contaminants.

In hot-humid climates, failure to properly consider moisture balances and the attendant latent loads can lead to discomfort or moisture related problems in residential buildings. The situation is made worse by the high humidity, high temperature and high precipitation characterized by the climatic region over the study area as well as their attachment to traditional food delicacies, its preparation together with the method of bathing/washing of the building occupants. These contributed to elevated indoor humidity levels and impairment of health/death to the residents.

According to Burberry, (1979) the sources of internal moisture production include respiration and perspiration which come directly from human occupants, and their magnitude depends on the number of occupants and their activity levels. Occupant water usage during activities such as cooking activities, bathing, and washing also produces substantial amounts of indoor moisture, and the result of occupant activities and the quantities of moisture generated by these activities vary

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widely. Plants, pets, unvented combustion, and other things (e.g. aquariums) common in homes also produce moisture in significant amounts. In new homes, moisture problems often occur in the first couple of years due to construction from sources such as drying concrete, materials that were wetted during construction (e.g., due to rain), or high moisture content lumber.

Design is the creation of a representational relationship between people and products, services and systems encountered in everyday human experience. This creation is grounded in a process; the process is a formal approach towards solving any given problems.

Part of the design process is to distinguish between classes of consequences such as lack of comfort, loss of life or health in buildings. These consequences call for differentiation of the safety levels, where loss of life or health, being the most serious, must be given the needed attention. Hence, the study focused on the occupant-related moisture generated from the Kitchen and Toilet with a view to finding ways for ameliorating the discomfort and health challenges in residential buildings. Because increased moisture in buildings is known to contribute to the growth of biological contaminants and exacerbation of so many health issues in residential buildings.

Design strategy therefore is therefore put to place to achieve a goal. It simply refers to the conceptual underpinning for the creative work. Many Scholarly works; American society of heating, refrigeration and Air-conditioning Engineers, 1999: Hadlich & Grismund, (1999) have identified that diluting the intensity of the pollutant sources is the first line of defense, reduction or eliminating it has been widely accepted as the best line of defense. So a program of source control shall be integrated into the design process with the intent of reduction of biological contaminants and spread in residential buildings.

Insights

American society of heating, refrigeration, and air-conditioning Engineers (ASHRAE), (1999) assert that relative humidity that is too high or too low can be problematic to one, his health and comfort. Burberry (1979); Cummings et.al (1991) assert that severity of water in its free liquid varies from the comparative minor inconvenience of condensation upon windows, through black mould forming on internal surfaces to decay of finishing and structural materials/failures, and ultimately poor indoor air quality.

Nicol, (2004); Toe et. al., (2011) are of the opinion that the incidences of black mould, allergens and other problems related to excessively high indoor relative humidity is extremely important because it has recently been linked to known biological contaminants that are causing significant health problems. And to, effects on occupants such as asthma, allergic symptoms and airway infections (Bornehag et. al, 2004).

Moyer (2001); Cummings et.al (1991) suggest that multiple incidences of building failure, discomfort, and poor indoor air quality have been linked to elevated interior humidity levels. High indoor humidity levels (RH>60%) were identified as contributing factors in material degradation and collapse, indoor thermal discomfort, and mold growth (Moyer 2001). Mathews et. al, (1986) opine that high indoor relative humidity can lead to elevations in formaldehyde concentrations in indoor environment.

Kubota et.al (2011) in their study contend that 40-60% as a range of indoor relative humidity that promote optimum health of the occupants, but

many building science and health professionals believe that the range perhaps should be slightly lower (say 30%-50%) to avoid the growth of these biological contaminants and associated health problems. These studies buttress the need for effective management of indoor moisture in residential buildings.

Several sources of information on estimating the magnitude of internal moisture generation rates were examined to determine some reasonable estimates for the magnitude of occupant-related moisture sources as documented by Sherman H., et. al., (2007); Hutcheon 1960), NRCan report (Quirouette 1983), (Hansen 1984), (ASHRAE 2001), Christian (1993), (ASTM 1994), ASHRAE 160, The National Institute of Standards and Technology (Emmerich et. al. 2005). From the documentations, the quantum of indoor moisture generated from the kitchen and toilet can be deduced. A position, which will no doubt, lead to increased growth of biological contaminants and exacerbation of ill-health of building occupants within the study area.

With tighter building envelopes, ventilation rates in new houses have been found to be much lower than historically measured values (Murray and Burnmaster, 1995) hence there is wider acceptance of the need for mechanical ventilation as recommended by the American Society of Heating, Refrigeration, and Air Conditioning Engineers in ASHRAE standard 62-1989 and its current revision 62.2 (ASHRAE 1999). Mechanical ventilation systems have the potential of improving indoor air quality by removing contaminants and reducing indoor humidity. In the study area sustenance of this active means of humidity reduction strategy may not be guaranteed due to incessant power outages and perennial scarcity of fuel as was observed by the studies of Laolu, (2015).

Natural ventilation is a traditional, well-accepted passive ventilating/cooling technique in hot-humid climate. According to Cohen, (1997); Cardinale et.al., 2003; Priyadarsini et al., (2004), natural ventilation does not need mechanical energy to operate, and it has low costs but using passive natural ventilation to exclude this free liquid in indoors of residential buildings may not be easy with tight building envelope because studies have shown that the Passive natural ventilation model covers narrow ranges of moderate climatic conditions and is not applicable to buildings in hot humid environments (Humphreys and Nicol, 2002). Supporting this opinion was komolafe, (1988) in his affirmation of the low wind speed characteristic of the study area.

Following the suggestion of Burberry (1979), that water in its free liquid form must be totally excluded from the interiors of buildings, and its presence as vapour in the air, or as moisture content of building materials, must be controlled to within acceptable limits, the study focuses on residential building arche-types found in hot-humid Enugu, the effects of excess moisture problems and associated biological contaminants inside these homes with a view to sourcing on how best to mitigating in the issue. Experts believe that excessive natural ventilation in hot humid climates have deleterious effect of raising the indoor relative humidity levels (Hodgson et.al., 2005). Thus the strong need for appropriate reduction of indoor moisture using sound and sustainable design strategies becomes very imperative now.

The comparative studies of indoor relative humidity in residential buildings have been studied by Moyer, et.al., (2004); Mohd, et. al., (2012) and documented in scientific literature in similar study area but none has been

directed towards mitigating the effects of high humidity using passive design strategies.

Study Area

The study focused on the residential building typologies in the study area. Enugu lies in the tropical region of Nigeria with coordinate's ranges as N6.20^0 to 6.30' and 7^0.25 to 7. 30'E. It has a hot-humid climate characterized by two main seasons (Dry and Rainy). It experiences constant high temperatures and relative humidity as well as its low wind speed through out the year. The temperature ranges from 23-27^{0}C and maximum 30-34^{0}C, with the mean relative humidity value of 84%. The rainy season is from April to November, and dry season is from November to March.

Materials and Methods

The Objective (Use of Instrument to test) and Survey methods were the analytical tool used in this study.

a. Selection criteria of the case study residential buildings

Convenience sampling technique was employed because experimentation (use of instruments to test) was conducted on all subjects from across the building prototypes (population) in Enugu. The technique was chosen because the purpose of an experiment was to determine if two or more groups differ because of effects of an independent variable. If the independent has an effect, it should occur with any subjects as long as the groups are equivalent and have common characteristics. As well is that Convenience sampling does not limit the importance of an experiment.

The selection criteria for the observation include period of occupation (buildings occupied for at least twelve months to have operated for a full seasonal cycle), type of dwelling, materials of construction, floor–ceiling height and type of fenestration. Based on the criteria, a sample size of 15 no. buildings for the investigation was derived. For proportionate distribution of the buildings from the subsisting residential buildings in the study area. Bowley, (1926) formular as was employed in Ogbuene, (2015) was used to find the most appropriate distribution employed in Ogbuene, (2015) and shown in the Table 1.0.0 below.

Table 1.0.0: Distribution of selected Buildings in Enugu.

S/No	Prototype	Total	No. of buildings selected	Approximate Values
1.	Flat	69593	2	2
2.	Traditional building	28237	0.66	1
3.	Single Maisonette	309980	7.2	7
4.	Single Maisonette with garage	154990	3.6	4
5.	Semi-detached Maisonette	28282	0.66	1
6.	Semi-detached Maisonette with garage	14141	0.33	0
7.	Bungalow with garage	32403	0.76	1

Source: Author's field study, 2015.

Data Collection and Analysis

The objective of the experimental design was that the field survey should be conducted under various indoor climate conditions and spans over a period of at least one full year. This was to provide an accurate and increased representation of the population under investigations. Objective assessment was employed using Extech DCO 1001 building Physics equipment to measure Indoor relative humidity, indoor temperature and Carbon dioxide quality concurrently. The equipment was placed on a stool about 1.0m above the ground to record the indoor air variables.

Analysis of variance (ANOVA) was used to establish that there was no comparative difference in indoor relative humidity amongst the various residential buildings in the study area. The result of Analysis of variance (ANOVA) was shown in table 2.0.0 below.

Table 2.0.0: ANOVA of difference in relative humidity amongst residential buildings

		Sum of Squares	df	Mean Square	F	P value
Relatives humidity	Between Groups	33701.248	6	5616.875	0.469	0.826
	Within Groups	407250.512	34	11977.956		
	Total	440951.760	40			

Source: Author's SPSS ANOVA 2015

With a p value of 0.826 which is greater than 0.05 level of significance. The difference observed is due to chance and retrofitting required in the old building construction. And a program of pollutant source control shall be integrated into the design process for new constructions and remodeling building projects. Thus, the strong integration of the kitchen and toilet shall be dropped and replaced with complete isolation because they were the major sources of moisture in buildings. The spaces should be equipped with the hood over fire places, chimney and appropriate window sizes and location, for easy collection of the contaminants and exhausting to the atmospheric sink. All these are with the intent of preventing, diluting the resultant contaminants from spreading to other spaces of the building.

CONCLUSION.

It should be noted that indoor moisture problems have not been particularly well documented by scholars in study areas. Hence, from the case studies, it was observe that one type of indoor moisture problem exists in almost all instances. Thus indoor moisture problems need to be taken more seriously and should not to be regarded, as more of an aesthetic nuisance on walls of buildings.

Most of the indoor moisture problems are associated to excessively high indoor relative humidity caused by complete absence of relative humidity control. Hence, it is imperative to look for sustainable means through which passive design strategies are to be used in order to achieve design of healthy residential buildings in the study area.

The current analysis and the data from this investigation offered valuable information on indoor relative humidity effects on building materials and occupants comfort/well being. It has always been assumed that the indoor relative humidity of some building typologies are better than some others with respect to keeping the building components free of damage and interior biological growth, but the explained analysis/result suggest otherwise.

Because residential buildings in the study area are exposed to higher

humidity levels all year round, the urgent need now is to change the current norms for building design and construction technology to embody appropriate means of ensuring safety and promoting health through maintenance of appropriate indoor relative humidity through sound design practices/ strategies that have been proven to work as suggested by Bonnefoy X., (2007);

- Strong space integration of Kitchen and toilets in residential buildings within the study area should be discouraged as well as provision of windows/exhaust means that allow for maximum escape of vaporized air in the interior of residential buildings.
- Design building envelopes/materials that allow for leakages of vaporized air and water within the kitchen and toilet spaces. Studies of Sherman M., Matson N., (2002) suggest that increase in air leakages of any building can improve the escape of vaporized air indoors of residential buildings.
- Application of appropriate design measures that reduce rising damp in foundation of buildings in the study area.
- Specify the most benign materials that suit the building's performance requirements of indoor moisture and employ compatible methods of attachment.

Thus, more effort must be made to communicate and educate building users and their owners in terms of achieving better and more workable relative humidity levels. This will result in healthy design approach that will be sustainable and beneficiary to all in the study area.

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