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# CONTRIBUTION OF CONDENSATION TO DAMPNESS ON EXTERNAL SURFACES OF WALLS: A CASE STUDY OF BORNO AND YOBE STATES IN NORTH EASTERN NIGERIA

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## ABSTRACT
*Series of efforts were made from various quotas over the decades to curtail dampness on external surfaces of walls and yet the menace has continued unabated, particularly in Nigeria. This is because 'underground moisture' from rain and other sources of water is erroneously believed to be the only cause of the menace. This study provides a lasting solution to the problem by acknowledging 'persistent condensation' as another cause of dampness on external surfaces of walls. It investigates where the problem lies in the context of 'persistent condensation': Is it with the type of coating used on external surfaces of walls or with construction professionals? Structured questionnaires were used in sourcing field data and Chi-Square was the statistical tool utilised in analysis. Results in the study indicate that, the use of tex-cote coating and tiles can alleviate dampness on external surfaces of walls. Further analysis however, has exonerated construction professionals from possessing insufficient knowledge on the general causes of dampness in buildings, but it failed to spare them from possessing sufficient knowledge on the mechanism of 'persistent condensation'. Recommendations include among others, the general use of tex-cote coating and tiles on surfaces prone to condensation and keeping construction professionals abreast on the sources and causes of condensation on external surfaces of walls by organizing periodic workshops and seminars.*

**KEYWORDS:** *Atmospheric moisture, Clear-sky radiation, Condensation, Dampness, External surfaces of walls*

## INTRODUCTION
Condensation is the process by which a gas changes its state to liquid. In the realm of building and construction however, the term 'condensation' may refer to the conversion of water vapour in the air to liquid water on the surfaces of structural elements. This wetting mechanism occurs when a moist air comes in contact with surfaces that are at or below the dew point temperature of the air (Rafferty, 2022; Duncan, 2021).

Condensation is a commonly seen phenomenon. It can be observed on surfaces of canned drinks taken out of the fridge and left in the open. It can be seen on bath room mirrors during showers, or on window glasses in the morning, especially during raining seasons (Duncan, 2021; Susan, 2020). Just as condensation takes place on indoor surfaces, it also occurs outside the building. The water seen dropping from the roof in the morning, especially during raining season even when it does not rain, is as a result of condensation that took place on the roof the previous night. The water droplets or frost normally observed on grasses in the morning, especially during raining season even when it does not rain, are all due to condensation that took place the previous night (Ronald, 2024; Broan, 2018). Outdoor condensation occurs on any surface which is left exposed to the atmosphere in the night. This implies that even structural elements, such as floors and walls that are left exposed to the atmosphere are not spared from condensation in the night (William, 2021; Banjo, 2021). Condensation that takes place on surfaces is referred to as 'Surface Condensation'. Surface condensation appears as a film of moisture or as beads of water on the surface and it is always very obvious on harder and impervious surfaces. An absorbent surface may not show condensation at first, but it will show as the condensation persists (McMullan, 2022).

Condensation that persists for a long time, particularly on absorbent surfaces, will eventually cause dampness (Xue *et al*, 2022) and, if left untreated on building facades, may lead to serious visual nuisance as it is the case all over urban centers in Nigeria (Ayokunle *et al,* 2023; Zakkariyya *et al*, 2020). In fact, the problem of dampness on external surfaces of building facades has remained unabated for decades in Nigeria because 'underground moisture' from rain and other sources of water is erroneously believed as the only cause of the problem (Ayokunle *et al,* 2023; Nwankwo, 1999); Zakkariyya *et al,* 2020; Joseph, 2021; Okoli & Kehinde, 2002; Sani *et al*,2022; Ayokunle *et al,* 2023). This study therefore provides a lasting solution to the problem by treasuring 'persistent condensation' as another cause of dampness on external surfaces of walls.

Therefore, the aim of the study is to find lasting solution to the problem of dampness on external surfaces of buildings in Borno and Yobe states, Nigeria and this is expected to be accomplished through review of all previously identified causes of the menace and acknowledging 'persistent condensation' as another cause of dampness on external surfaces of buildings. To this end, the study is to conduct series of empirical investigation in the context of 'Persistent Condensation on External Surfaces' of buildings, analyse all results obtained from the investigation, establish the actual causes of the menace, and recommend lasting solutions to the problem of dampness on external surfaces of buildings in the two states.

## LITERATURE REVIEW

### Steam, Water Vapour, Condensation and Evaporation

Steam and mist are not water vapour, rather, they are suspended droplets of water liquid. Water vapour or moisture, which is invisible, is also naturally formed above liquid water. This process is called evaporation and it occurs because some liquid molecules gain enough energy from chance collision with other molecules, to escape from the liquid surface and become vapour molecules (McMullan, 2022; Rafferty, 2022; Vitro Architectural Glass, 2024). Therefore, if the air space above a liquid is enclosed then evaporated vapour molecules will collect in the space and as they collect, some molecules continually return (condense) to the liquid state and eventually the number of molecules evaporating become equal to the number of molecules condensing. At this moment, the air in the space is said to be saturated (figure 1). This means, the space contains the maximum amount of water vapour possible at that temperature. The water vapour has reached its 'Dew Point' and therefore, any additional vapour into the space at that temperature will be condensed into liquid state (Bertley, 2020; McMullan, 2022; Rafferty, 2022). The pressure exerted on the walls of the space at that moment is called Saturated Vapour Pressure (SVP).

The situation, however, will be different with increased in temperature on the liquid. At that higher temperature, even though more liquid molecules will evaporate from the liquid into the space thereby increasing the moisture content of the space, the space now acquires a higher saturation point giving rise to higher dew point and hence higher SVP. In other words, increased temperature on liquid releases more moisture and increases both the dew point and SVP of the air above it (Bertley, 2020; McMullan, 2022; Rafferty, 2022).

Conversely, if an unsaturated sample of moist air is cooled then the sample will, at a certain temperature, become saturated. If the sample is further cooled below this dew point temperature, then some of the water vapour must condense to liquid state. This equally implies that, if moist air is in contact with a surface and the temperature of the surface happens to drop below the dew point temperature of the air, condensation will inevitably occur on the surface (Bertley, 2020; McMullan, 2022; Rafferty, 2022). Therefore, the general requirements for any condensation to occur are moist air (also called moisture or humidity) and change in temperature (cold air or cold surface).

**Problems associated with Condensation**

Condensation can lead to quite a number of problems. These problems could be mild in nature or much more severe depending on the persistent and duration of the condensation. However, some of the potential dangers posed by persistent condensation according to Bertley,2020; Duncan, 2021, are:

(i) Mould growth,
(ii) Stain on walls, windows and doors,
(iii) Damages to electrical appliances,
(iv) Corrosion of metals, and
(v) Wood rot

**Sources of Condensation**

While sources of condensation on and within objects in a constructed structure are mainly showering and bathing, laundry, cooking, breathing, air conditioning (Joseph, 2021; Xue *et al,* 2022), and pattern of use of the building, the major sources of condensation on surfaces of the structure are as follows:

(i) **The Atmosphere**.

The atmosphere contains about 5 per cent water vapour by weight and yet the condensation effect produced by this relatively small percentage of vapour on constructed structures is considerably alarming. It is however understood that, most of the moisture in the atmosphere is as a result of evaporation of water molecules from the sea, which is believed to cover about two-third of the mother earth's surface (Teichol, 2018; Rafferty, 2022; McMullan, 2022).

(ii) **Thermal Bridge**

When a material of high conductivity is made to pass completely through a structural element, such as wall, floor, roof, etc, then the thermal insulation of that element is said to be 'Bridged', that is, the insulation of the elements is lowered at that points of bridging (Maxwell, 2020; McMullan, 2022).

Figure 2 is a window/door lintel that serves as 'Bridge' under a wall and shows how heat flows from the wall across the bridge to its exterior side, thereby cooling the interior side and consequently giving rise to internal surface condensation (McMullan, 2022).

Although heat gain and heat loss in buildings are not within the direct beam light of this research, figure 3 gives an idea of how 'Thermal Bridging' in buildings can lead to both internal and external surface condensation. As shown in figure 3, McMullan (2022) claimed that; "The path of the heat flow has to curve to the outside air at the edge of the floor. Heat losses through the floor are therefore highest near the exposed edges of the floor, and heat losses are lowest near the center of the floor……"

At the ground floor, the ground itself serves as an insulator to the flow of heat from the floor, thereby enhancing the flow of heat toward the exterior edge of the floor.

(iii) **Clear Sky Radiation**

The transfer of heat from the sun through space to the earth is called Radiation. In radiation, generally, black surfaces have the highest absorption and emission of radiant heat and conversely, shiny silver surfaces have the lowest absorption and emission of radiant heat (McMullan, 2022).

Clear Sky radiation is a mechanism which can cause the temperature of some structural elements, such as wall, roof, floor, etc, to fall significantly below the temperature of the surrounding air. At night time a building emits radiant heat to its surrounding as shown in figure 3, and the rate of this heat loss from exterior surfaces of structural elements would increase if the night sky is clear and cloudless (McMullan, 2022). To buttress the occurrence of increased emission of heat from exterior surfaces during clear and cloudless night-sky, McMullan (2022) convincing said; "This radiant 'suck' occurs because a clear sky is closer to a black body than is a cloudy sky and the clear sky therefore acts as a better absorber of radiant heat."

In the night, the clear sky will continuously absorb heat from the structural element via the element's exterior surface until the temperature of the surface is lowered below the dew point temperature of the surrounding air, giving rise to condensation on the surface concerned (McMullan, 2022). Therefore, the dampness we see on external wall fences are also partly as a result of persistent condensation due to clear-sky radiation. As shown in figure 4, the wall fence bridges the heat equilibrium of the ground, giving rise to heat 'suck' which accumulates at the bottom of the fence just above the ground and, consequently, this heat is absorbed during clear cloudless night until the temperature at the bottom of the fence is lowered below the dew point temperature of the surrounding air, giving rise to condensation at the bottom of the fence. Another portion of the heat also accumulates at the top-most end of the fence. These two points of heat concentration become one with fences that are short in height and, during clear cloudless night, the entire height of the fence will be covered with condensation. McMullan (2022) said, it is the same radiant mechanism that causes dew or ground frost to occur on surfaces such as grasses and stones during a clear starry night.

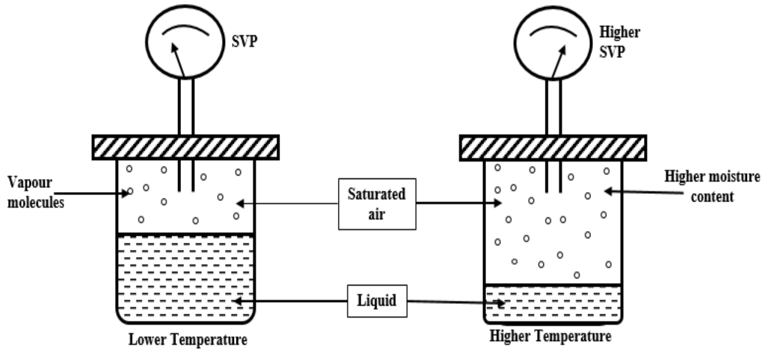


**Figure 1: Saturated air**
Source: McMullan (2022)

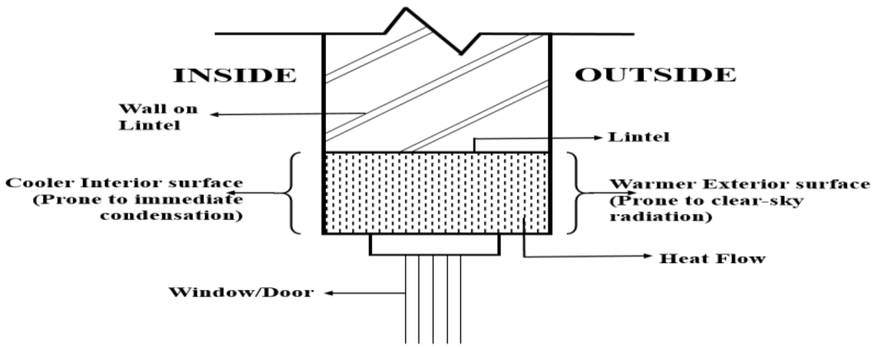


**Figure 2: Lintel/bridging over a window/door**
Source: McMullan (2022) and Maxwell (2020)

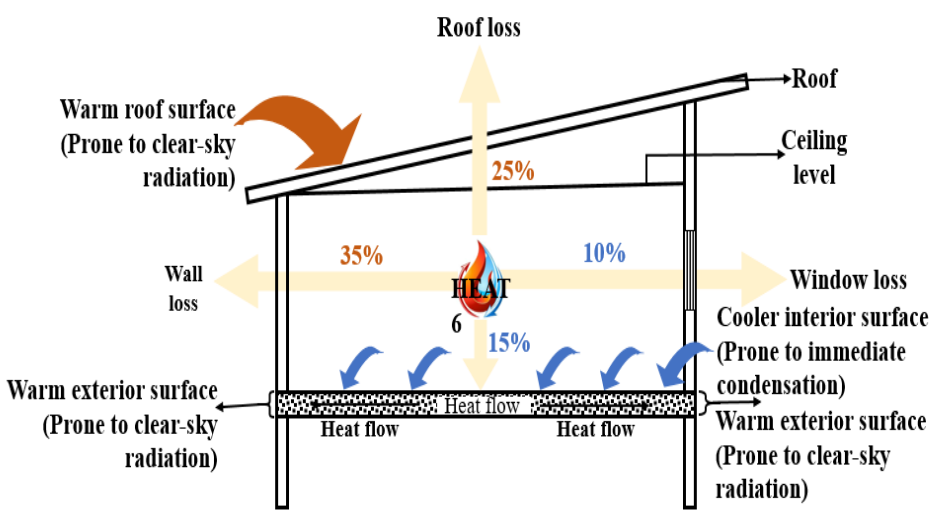


**Figure 3: Heat loss in an uninsulated building**
Source: McMullan (2022)

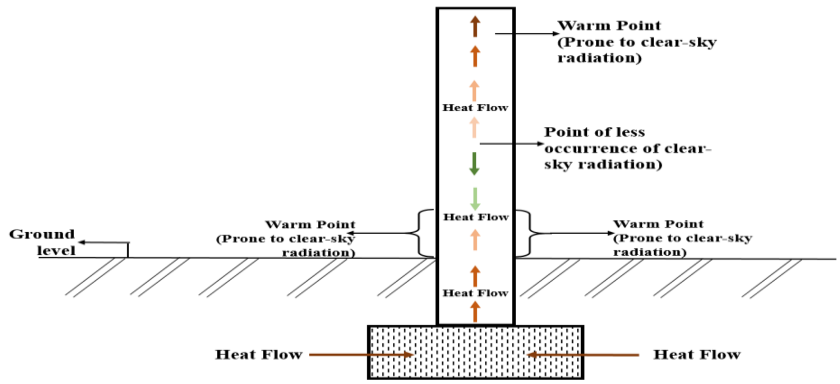


**Figure 4: External Wall Fencing**
Source: McMullan (2022) and Maxwell (2020)

**The Long-time effect of condensation**

Condensation that persists on surfaces would eventually lead to dampness, but not every dampness is due to condensation. Since condensation can take place on both indoor and outdoor surfaces, it means some of the dampness seen on external surfaces could be partly due to persistent condensation. And yet, it is quite disheartening to observe that, the subject area of Condensation on External Surfaces (CES) has lost its bearing in the leagues of literature. Most literatures on condensation appeared to be concerned with Condensation on Internal Surfaces (CIS) at the expense of CES and portraying CIS as the only aspect of Surface Condensation in existence (Broan, 2018; Giovanni, 2018; Ronald, 2021; Chris, 2020a and 2020b). However, there is that league of literature on condensation which paid scanty attention to CES with emphasis on the principal factors responsible for its formation, such as Atmospheric Moisture, Clear-Sky Radiation and Thermal Bridging and, consequently, failed to cover the subject matter in details (Maxwell, 2020); McMullan, 2022; Pelin *et al*, 2024). There is also that school of literature which tends to treat dampness on external surfaces wholly on its own but, unfortunately, failed to reckon with CES as one of the factors responsible for its formation (Zakkariyya *et al,* 2020; Stanley *et al* (2020); Ayokunle *et al,* 2023). This paper therefore covers the subject of dampness due to Persistent Condensation on External Surfaces (PCES) of building structures in full.

In addition, even though quite a number of literature over the decades, such as Nwankwo (1999), Okoli & Kehinde (2002), Aelenei & Henriques (2008), Stanley *et al* (2020), Joseph (2021), Sani *et al* (2022), Ayokunle *et al,* (2023) and Pelin *et al* (2024), tried to proffer solutions to the problem of dampness on external surfaces of buildings, unfortunately, all proffered solutions were based on the premise that 'underground moisture' from rain and other sources of water are responsible for the menace, failing to treasure 'persistent condensation' as another cause of dampness on external surfaces. This most probably explains why the menace continued unabated, particularly in Nigeria. This work is designed to bridge the study gap by acknowledging 'persistent condensation' as another cause of dampness to empirically establish solutions to dampness on external surfaces of walls in Nigeria.

**The problem of dampness and condensation in Nigeria**

Every community in Nigeria is replete with eyesore dampness and discoloration (Alake *et al,* 2022; Sani *et al,* 2022; Stanley *et al,* 2020; Zakkariyya *et al,* 2020; Ayokunle *et al,* 2023), mostly due to Persistent Condensation on External Surfaces (PCES) of building structures, transforming the entire environ in the country to become a visual nuisance. Therefore, the research questions are:

1. Are construction professionals in the country really acquitted with the actual sources and causes of Condensation on External surfaces (CES)?
2. If construction professionals are acquitted with the actual sources and causes of CES, what measures have they taken to remedy the problem of PCES of buildings and how can the measures be improved?
3. If construction professionals are not acquitted with the actual sources and causes of CES, how can the problem of PCES of buildings be remedied?
4. Is there any relationship between intensity of dampness and the type of coating used on external surfaces of walls?
5. If there is any relationship between intensity of dampness and the type of coating used on external surfaces of walls, what is the ranking of these coatings in withstanding dampness due PCES?

However, the study viewed the solutions to the above research questions in the context of two sets of hypotheses as will be discussed further in the methodology section.

**METHODOLOGY**

In consideration of the present unprecedentedly vicious economic and security situation in the country, only urban centers in Borno and Yobe states were used for collating field data in the study. Notwithstanding, all established concept of the study can equally be applied to other urban centres in the country with little or no modifications.

**Data Collection**

The study area for the work was broken into two strata, viz (1) State Capitals and (2) Local Government Headquarters. The first stratum has Maiduguri and Damaturu, the capital cities of Borno and Yobe states respectively, whilst local government headquarters in the second stratum were Machina, Nguru, Gashu'a, Potiskum, Geidam, Biu, Konduga, Bama and Benesheikh. Data for the work were sourced through structured questionnaires. The target respondents in the study were (1) Residents and (2) Construction Professionals.

**Participants of the Study**

The residents contacted for the study were those with first-hand experience of dampness on external surfaces of buildings, whereas the construction professionals were Builders, Architects, Quantity Surveyors, Civil Engineers and other construction professionals who were full-time practitioners within the survey area.

The distribution of questionnaires to residents in each locality was dependent on the size of the city concerned. However, to afford completeness of result for the study, extreme care was exercised to shun those residences that were built, renovated or rehabilitated within 12 months before the study.

In an effort to enhance quality of data for the study, those residents that cannot read and write were engaged in face-to-face dialogue to explain what was actually required from the questionnaires.

On construction professionals however, both Edward (2020) and Eurostat Statistical Explained (2021) claimed that, the concentration of professional service providers resident within an area is dependent, to a large extent, on the urbanisation of the city in focus. Therefore, the number of construction professionals contacted for data collection in the study was also dependent on the size of the cities under review.

Notwithstanding, adopting Robert's (2024) classification of urban centres which gave cognisance to both population and boundary size of cities, the study area was categorised into (1) Towns, (2) Cities, and (3) Metropolitan Cities. Nonetheless, considering the closeness in urbanisation of the first two categories (Towns and Cities), particularly with regards to the study area, a ratio of 1 : 1 : 3 (towns : cities : metropolitan cities) was adopted in the distribution of questionnaires to both residents and construction professionals.

**Determination of Intensity of Dampness**

The study classified 'intensity of dampness' as 'high', 'medium', 'low' and 'none' based on how offensively dark the dampness appears on the surface. Those dampness that are very dark and highly offensive to the eyes are considered as 'high', dampness that are very dark but are not so offensive to the eyes are referred to as 'medium', dampness that are moderately dark and not offensive to the eyes are seen as 'low', and it is referred to as 'none' when there is no darkness at all or the darkness is slight and very light.

**Data Analysis**

The analysis of field data is designed to resolve the research questions of the study in the context of two set of hypotheses as follows:

Set one: **Intensity of Dampness**

To investigate if there is any difference in intensity of dampness and the type of coating used on external surfaces of walls, thus:

**Null hypothesis:** There is no significant difference in intensity of dampness between the types of coating used on external surfaces of walls. Ho: Uo = U1

Set two: **Construction Professionals**

To ascertain the depth of knowledge of construction professionals on the causes of dampness on external surfaces of walls, thus:

**Null hypothesis:** Construction Professionals do not possess adequate knowledge on the sources and causes of dampness in buildings. Ho: Uo = U1

Both sets of hypotheses were tested at 5% level of significance by utilising Chi-Square as the statistical tool.

Chi-square, symbolically written as $\chi^2$ (Pronounced as Ki-square), is a non-parametric test used to determine if categorical data shows dependency or the two classifications are independent. It is also used in the context of sampling analysis for comparing a variance to a theoretical variance. In the first set of hypotheses, a test is conducted to determine if intensity of dampness is dependent on the type of coating used on walls, whilst the second set of hypotheses tested if the magnitude of 'Persistent Condensation' on external surfaces of buildings is dependent on the level of knowledge of construction professionals.

## PRESENATATION OF RESULTS

**Questionnaire Administration**

A total of 1040 questionnaires were distributed in the field. The residents were administered with 1000 questionnaires, whilst construction professionals were administered with 40. Both sets of questionnaires were administered according to the ratio earlier specified.

**Table 1: Administration and Collation of questionnaires.**

| Category of Locality | Name of Locality | Category of Respondents: Residents: No. of Questionnaires | | | Construction Professionals: No. of Questionnaires | | |
|---|---|---|---|---|---|---|---|
| | | Total No. Admnstred | Total No. Returned | Percentage Returned (%) | Total No. Admnstred | Total No. Returned | Percentage Returned (%) |
| Metropolitan City | Maiduguri | 350 | 279 | 28 | 12 | 10 | 25 |
| | Damaturu | 250 | 220 | 22 | 12 | 8 | 20 |
| City | Nguru | 50 | 40 | 4 | 2 | 2 | 5 |
| | Biu | 50 | 45 | 4 | 2 | 1 | 5 |
| | Potiskum | 50 | 42 | 4 | 2 | 2 | 2.5 |
| | Gashu'a | 50 | 45 | 4 | 2 | 2 | 5 |
| Town | Machina | 40 | 28 | 3 | 1 | 1 | 2.5 |
| | Geidam | 40 | 30 | 3 | 2 | 1 | 2.5 |
| | Benesheikh | 40 | 35 | 4 | 1 | 1 | 2.5 |
| | Konduga | 40 | 30 | 3 | 2 | 1 | 2.5 |
| | Bama | 40 | 37 | 4 | 2 | 1 | 2.5 |
| **TOTAL** | | **1000** | **831** | **83** | **40** | **30** | **75** |

Table 1 shows the administration and collation of questionnaires in respect of the two categories of target respondents.

**Respondents Background Information**

According to CEIC (2024), like much of Nigeria, there is clear distinction in the distribution of buildings between urban and rural areas in Borno and Yobe states. Urban areas such as Maiduguri (Borno's capital) and Damaturu (Yobe's capital) have higher concentration of buildings, suburban cities like Biu in Borno state and Potiskum in Yobe state have lower concentration and, towns and other rural communities in the two states have much lower concentration. Therefore, as shown on Table 1, the classification of concentration of buildings, from highest to the lowest concentration, adopted for Borno and Yobe states in the study are Metropolitan Cities, Cities and Town. In addition, the number of respondents for the study were also selected according to the classification as shown on the Table.

As could be expected at the end of most field activities, not all administered questionnaires in the study were returned. A total of 831 questionnaires were received from the residents and 30 from construction professionals, representing 83% and 40% of the total number of questionnaires administered, respectively. These rates of returned of questionnaires from respondents can be considered sufficient enough for further statistical analysis in view of Moser and Kalton's (2019) testimony, that the result of a statistical data tends to be biased and therefore of little value if its return rate happened to be less than 30-40%.

**General Knowledge on Dampness**

One of the major enquiries made in the questionnaires administered to construction professionals is on determination of the professionals' possession of knowledge on causes of dampness in general as well as those factors responsible for condensation on external surfaces of buildings

**Table 2: Knowledge on general dampness/factors responsible for formation of external condensation.**

| S/No. | Response | General Dampness No. Resp. | General Dampness % Resp. (100) | Thermal bridging No. Resp. | Thermal bridging % Resp. (100) | Clear-Sky Radiation No. Resp. | Clear-Sky Radiation % Resp. (100) | Atmospheric Moisture No. Resp. | Atmospheric Moisture % Resp. (100) | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | No | 1 | 3 | 15 | 50 | 28 | 93 | 28 | 93 | 72 |
| 2 | Yes | 29 | 97 | 15 | 50 | 2 | 7 | 2 | 7 | 48 |
| | **TOTAL** | **30** | | **30** | | **30** | | **30** | | **120** |

Responses received from construction professionals are presented in table 2.

**Perceived relationship between level of dampness and wall coatings**

Residents were investigated on the intensity of dampness on external surfaces of their residences and the type of coating used on the surfaces.

**Table 3: Response on relationship between level of dampness and coating on walls.**

| S/No | Coating on Walls | Level of Dampness High | Medium | Low | None | Total Resp. | % Resp. | Cum % |
|---|---|---|---|---|---|---|---|---|
| 1 | No plaster | 179 | 50 | 22 | 0 | **251** | **30** | **30** |
| 2 | Plastered without coating | 158 | 39 | 21 | 0 | **218** | **26** | **56** |
| 3 | Plastered with emulsion paint | 89 | 19 | 19 | 0 | **217** | **15** | **71** |
| ³ | Plastered with gloss paint | 24 | 4 | 2 | 0 | **30** | **4** | **75** |
| 5 | Plastered with Tyrolean coating | 53 | 22 | 13 | 0 | **88** | **11** | **86** |
| 6 | Plastered with Tex-cote coating | 7 | 4 | 23 | 57 | **91** | **11** | **97** |
| 7 | Plastered and tiled | 0 | 0 | 0 | 26 | **26** | **3** | **100** |
| | **TOTAL** | **510** | **138** | **100** | **83** | **831** | **100** | |
| **TOTAL PERCENTAGE (%)** | | **61** | **17** | **12** | **10** | **100** | | |
| **CUMMULATIVE %** | | **61** | **78** | **90** | **100** | | | |

Responses gathered on the relationship between level of dampness and type of coating on walls (Intensity of Dampness) are presented in table 3.

**Intensity of Dampness**

The process of finding solutions to the research questions begun in subsection 3.3 is partly concluded in this subsection. Results regarding the first set of hypotheses are treated as follows:

(i) **Intensity of Dampness**

Ho: Uo = U1

H1: Uo ≠ U1 (Two-tailed)

**Table 4: Intensity of Dampness on External Surfaces of Walls.**

| S/ No | Coating on Walls | Level of Dampness | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | High | | Medium | | Low | | None | | Total |
| | | Ob fq | Ex fq | Ob fq | Ex fq | Ob fq | Ex fq | Ob fq | Ex fq | |
| 1 | No plaster | 179 | **154.04** | 50 | **41.68** | 22 | **30.21** | 0 | **25.07** | 251 |
| 2 | Plastered without coating | 158 | **133.79** | 39 | **36.20** | 21 | **26.23** | 0 | **21.77** | 218 |
| 3 | Plastered with emulsion paint | 89 | **77.94** | 19 | **21.09** | 19 | **15.28** | 0 | **12.69** | 127 |
| 4 | Plastered with gloss paint | 24 | **18.41** | 4 | **4.98** | 2 | **3.61** | 0 | **3.80** | 30 |
| 5 | Plastered with Tyrolean coating | 53 | **54.01** | 22 | **14.61** | 13 | **10.59** | 0 | **8.79** | 88 |
| 6 | Plastered with Tex-cote coating | 7 | **55.85** | 4 | **15.11** | 23 | **10.95** | 57 | **9.09** | 91 |
| **7** | Plastered and tiled | 0 | **15.96** | 0 | **4.32** | 0 | **3.13** | 26 | **2.60** | 26 |
| | **TOTAL** | 510 | | 138 | | 100 | | 83 | | 831 |

Table 4 shows expected frequencies (Ex fq) against corresponding observed frequencies (Ob fq) of received responses on intensity of dampness on external surfaces of walls (Table 3).

$X^2_{cal}$=$\sum\frac{(OV-EV)2}{EV}$ Where, $OV$ = Observed Frequency and $EV$ = Expected Frequency

Degree of freedom = (7-1) (4-1) = 18 and at 5% level of significant the tabulated Chi-Square ($X^2_{tab}$) = 28.87.

**Table 5: Chi-Square Analysis on Intensity of Dampness on External Surfaces of Walls.**

| Observed Frequency (OV) | Expected Frequency (EV) | OV-EV | (OV-EV)$^2$ | $\frac{(OV-EV)2}{EV}$ | Observed Frequency (OV) | Expected Frequency (EV | OV-EV | (OV-EV)$^2$ | $\frac{(OV-EV)2}{EV}$ |
|---|---|---|---|---|---|---|---|---|---|
| 179 | 154.04 | 24.96 | 623.00 | 4.044 | 22 | 30.21 | -8.21 | 67.40 | 2.231 |
| 158 | 133.79 | 24.21 | 586.124 | 4.381 | 21 | 26.23 | -5.23 | 27.35 | 1.043 |
| 89 | 77.94 | 11.06 | 122.32 | 1.570 | 19 | 15.28 | 3.72 | 13.84 | 0.906 |
| 24 | 18.41 | 5.59 | 31.25 | 1.697 | 2 | 3.61 | -1.61 | 2.59 | 0.718 |
| 53 | 54.01 | -1.01 | 1.02 | 0.019 | 13 | 10.59 | 2.41 | 5.81 | 0.549 |
| 7 | 55.85 | -48.85 | 2386.32 | 42.727 | 23 | 10.95 | 12.05 | 145.20 | 13.261 |
| 0 | 15.96 | -15.96 | 254.72 | 15.960 | 0 | 3.13 | -3.13 | 9.80 | 3.130 |
| 50 | 41.68 | 8.32 | 69.22 | 1.661 | 0 | 25.07 | -25.07 | 628.51 | 25.07 |
| 39 | 36.20 | 2.8 | 7.84 | 0.217 | 0 | 21.77 | -21.77 | 473.93 | 21.77 |
| 19 | 21.09 | -2.09 | 4.37 | 0.207 | 0 | 12.69 | -12.69 | 161.04 | 12.69 |
| 3 | 4.98 | -0.98 | 0.96 | 0.193 | 0 | 3.00 | -3.00 | 9.00 | 3.00 |
| 22 | 14.61 | 7.39 | 54.61 | 3.738 | 0 | 8.79 | -8.79 | 77.26 | 8.79 |
| 3 | 15.11 | -11.11 | 123.43 | 8.170 | 57 | 9.09 | 47.91 | 2295.37 | 252.516 |
| 0 | 4.32 | -4.32 | 18.66 | 4.320 | 26 | 2.60 | 23.40 | 547.56 | 210.600 |

$X^2_{cal}$=$\sum\frac{(OV-EV)2}{EV}$ $X^2_{cal}$=645.178 $X^2_{tab}$=28.87

$X^2_{cal} > X^2_{tab}$

However, analysis as presented in Table 5 shows that the calculated Chi-Square ($X^2_{cal}$) = 645.178. This means $X^2_{cal}$ is greater than$X^2_{tab}$: $X^2_{cal}$>$X^2_{tab}$

Since analysis on intensity of dampness (Table 5) indicates that, the calculated value of Chi-Square (645.178) is greater than the tabulated value (28.87), the null hypothesis is rejected and therefore, the alternative hypothesis is accepted. Hence, we conclude that there is significant difference in the intensity of dampness and the type of coating used on external surfaces of walls. In other words, the intensity of dampness on external surfaces of walls is dependent on the type of coating used on the walls. It is therefore no wonder we observed on Table 3 that, there is no tiled surveyed house which is affected by dampness and, in addition, 57 out of the 91 houses whose walls were coated with tex-cote paint are not affected (in anyway) by dampness. Therefore, the revelation on the table is that, the external surfaces of walls that were not affected by dampness are all either tiled or coated with tex-cote paint. The figures on Table 3 further indicate that the danger of persistent condensation on walls decreases (from the worst affected to the less affected) in the following order:

(1) Walls that are not plastered at all.
(2) Plastered walls without any Coating or Painting.
(3) Plastered walls with Emulsion Paint.
(4) Plastered walls with Gloss Paint.
(5) Plastered walls with Tyrolean coating.
(6) Plastered walls with Tex-cote coating.
(7) Plastered walls with Tile.

**Knowledge of dampness among respondents**

The process of finding solutions to the research questions begun in subsection 3.3 through subsection 4.5 is finally concluded in this subsection. Results regarding the second set of hypotheses are treated as follows:

(i) **Construction Professionals**

Ho: Uo = U1
H1: Uo ≠ U1 (Two-tailed)

**Table 6: Knowledge of Causes of Dampness on External Surfaces of Walls**.

| S/No | Response | Frequency | General Dampness No. Resp. | Thermal Bridging No. Resp. | Clear-Sky Radiation No. Resp. | Atmospheric Moisture No. Resp. | TOTAL |
|---|---|---|---|---|---|---|---|
| 1. | No | Observed | 1 | 15 | 28 | 28 | 72 |
| | | Expected | **18** | **18** | **18** | **18** | |
| 2 | Yes | Observed | 29 | 15 | 2 | 2 | 48 |
| | | Expected | **12** | **12** | **12** | **12** | |
| | TOTAL | | 30 | 30 | 30 | 30 | 120 |

Table 6 gives the expected and observed frequencies of received responses on knowledge of causes of dampness on external surfaces of walls (Table 2).

$X_{cal}^2 = \sum \frac{(OV-EV)2}{EV}$ Where, $OV$= Observed Frequency and $EV$ = Expected Frequency

Degree of freedom = (4-1) (2-1) = 3 and at 5% level of significant the tabulated Chi-Square ($X_{tab}^2$) = 7.81.

**Table 8: Chi-Square analysis on knowledge of causes of dampness on external surfaces of walls.**

| Observed Frequency (OV) | Expected Frequency (EV) | OV-EV | $(OV-EV)^2$ | $\frac{(OV-EV)2}{EV}$ |
|---|---|---|---|---|
| VVV 1 | 18 | -17 | 287 | 16.056 |
| 15 | 18 | -3 | 9 | 0.500 |
| 28 | 18 | 10 | 100 | 5.556 |
| 28 | 18 | 10 | 100 | 5.556 |
| 29 | 12 | 17 | 289 | 24.083 |
| 15 | 12 | 3 | 9 | 0.750 |
| 2 | 12 | -10 | 100 | 8.333 |
| 2 | 12 | -10 | 100 | 8.333 |

$X^2_{cal}=\sum\frac{(OV-EV)2}{EV}$ $X^2_{cal}$ = 69.167

$X^2_{tab}$ = 7.81

$X^2_{cal} > X^2_{tab}$

However, analysis as presented on Table 7 shows that the calculated Chi-Square ($X^2_{cal}$) = 69.167. This means $X^2_{cal}$ is greater than$X^2_{tab}$: $X^2_{cal}$>$X^2_{tab}$

Since analysis on construction professionals (Table 7) indicates that, the calculated Chi-Square (69.167) is greater than the tabulated Chi-Square (7.81), the null hypothesis is rejected and therefore, the alternative hypothesis is accepted. This means, construction professionals would not be said to lack any knowledge on the causes of dampness on external surfaces of walls. This revelation notwithstanding, the data on table 2 is indicative of the fact that most construction professionals do not possess sufficient knowledge on the factors responsible for the formation of Condensation on External Surface (CES).

## DISCUSSION

Results indicate that, the external surfaces of walls that were not affected by dampness are all either tiled or coated with tex-cote paint. As tiles are generally impermeable to liquids, it corroborates McMullan's (2022) claim that condensed water droplets on non-absorbent surface can only drip away from the surface with just a little or no visual consequences. The observed behaviour of tex-cote coating (Table 3) on the other hand, collaborates the claims made by both Terry (2021) and Frank (2021) that, the coating has the ability to (1) insulate heat on warm surfaces from reaching the atmosphere, thereby curtailing the incidence of clear-sky radiation, (2) reflect away radiant heat from the sun, thereby preventing building up of heat on surfaces, and (3) provide considerable level of proof between surfaces and atmospheric moisture.

On construction professionals however, it is understood that, those professionals who exhibited full knowledge of the causes of Condensation on External Surface (CES) are all young graduates of tertiary institutions. This likely explains that, the subject area of Condensation on External Surfaces, hitherto treated with levity, has now started gaining momentum in our institutions of higher learning. This notwithstanding, Aziza (2019) opined that "an uninformed group of people is indeed a lost group" and, therefore, there is the need for all cadres of construction professionals to be fully enlightened on factors responsible for the formation of Condensation on External Surface (CES).

## CONCLUSION AND RECOMMENDATIONS

### Conclusion

The study has revealed that, the intensity of dampness due to persistent condensation on external surfaces of buildings is dependent on the type of coating used on the surface concerned, indicating that there are some types of coatings that are absolutely resistant to dampness due to persistent condensation and that, surfaces of buildings without any coating are most prone to dampness due to persistent condensation. The study has also revealed that, construction professionals within Borno and Yobe states, Nigeria do not possess sufficient knowledge on the actual causes of condensation on external surfaces and as a result, they were unable to manage the menace of dampness due to persistent condensation on external surfaces of buildings. It is therefore concluded that, the two major culprits in the menace of dampness due to persistent condensation on external surfaces of walls in Borno and Yobe states are (1) The type of coatings used on the surfaces and (2) Lack of possession of sufficient knowledge by construction professionals on the causes of External Surface Condensation.

### Recommendations

Dampness and discoloration on external surfaces cannot be said to be solely attributable to condensation as some other causes of dampness might have played their own roles, too. Notwithstanding, condensation plays a major role in dampness on external surfaces in areas like Borno and Yobe states in Nigeria, where the atmospheric moisture is highest in the raining season and surfaces within and around streams of water are most prone to External Surface Condensation because evaporating water molecules from the streams eventually increase the seasonal moisture content of the atmosphere around the surfaces. Therefore, adequate measures should be taken to prevent water from streaming around building structures.

To further alleviate the incidence of External Surface Condensation, residents, governments and indeed construction professionals are hereby encouraged to imbibe the use of tiles and tex-cote coatings, particularly on those portions of building structures that are prone to surface condensation. However, to achieve the desired result on the use of tex-cote coating, the coating should always be mixed and applied to surfaces according to the manufacturer's instructions. In addition, as coatings get obsolete over time, residents are encouraged to imbibe the culture of periodic renovation by repeating their surface coatings after every 5 years or so. Both foreign and local manufacturers of tex-cote paint and tiles are also encouraged to intensify researches in making their products more affordable while maintaining quality standard.

Furthermore, there is the need for construction professionals and the likes to intensify researches on how to curtail the menace of Persistent Condensation on External Surfaces. Tertiary institutions on the other hand, are enjoined to accord the subject of Condensation on External Surfaces the status of major course area. There is also the need for Professional Bodies to keep their members abreast on the subject of Condensation on External Surfaces through periodic workshops and seminars.

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