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A TWO-STAGE APPROACH TO DAMP INVESTIGATION IN A THREE BEDROOM RESIDENTIAL BUILDING IN KUMASI, GHANA

K. Agyekum[1*] and J. Ayarkwa[1]
[1] *Department of Building Technology, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*
*Corresponding author: agyekum.kofi1@gmail.com

Abstract

Buildings are composites of different materials and forms of construction and each has its own specific performance characteristics. Despite the lasting qualities of buildings, they are all susceptible to natural and man-made mechanisms of deterioration, one of which is dampness. This study employed a holistic approach to dampness investigation involving a two stage protocol which sought to identify and document areas in the walls of a three bedroom residential facility severely affected by dampness. The results from the visual inspection showed that blistering of paint, flaking of mortar, cracks, mould growth and surface efflorescence were symptoms identified on the walls of the building. Also, the results from the moisture content measurements (non-destructive tests) showed that though the walls located in all the four orientations experienced dampness, it was very pronounced in the walls located in the western, eastern and southern directions. The results further showed that with the exception of rising dampness, no other source(s) of dampness existed. Further detailed destructive tests are recommended for the confirmation of the source of dampness present and this will help to put in place appropriate intervention mechanisms to address the problem. This study should provide the necessary platform for construction professionals in Ghana and other tropical countries with similar geological settings like Ghana to educate themselves on this common but dangerous problem.

Key words: dampness, residential buildings, walls, moisture content

Introduction

Buildings by their very nature are composites of differing materials and forms of construction each having their own specific performance characteristics (Watts et al., 2001). The demands placed on a building or an element of its construction by occupants and users relate to its location and siting, climatic and environmental conditions, the manner in which it is used, current and past levels of damage, deterioration and decay, etc. (Watts et al., 2001).

Despite the lasting qualities of buildings, all buildings, be it old or modern types of construction are susceptible to natural and man-made mechanisms of deterioration (Noy and Douglas, 2005; Watts et al., 2001; Hollis, 2000; Massari and Massari, 1993). If these buildings are not properly maintained they would not survive in an acceptable state beyond the generation that built them (Watts et al., 2001). Of all defects associated with buildings, moisture or dampness is the most frequent and dangerous, and contributes more than 50% of all known building failures (Halim et al., 2012; Watts et al., 2001).

Dampness can be defined as water penetration through the walls and certain elements of a building (Halim et al., 2012). Dampness can also be defined as an excessive quantity of moisture contained in building materials and components which causes adverse movements or deterioration and results in unacceptable internal environmental conditions (Briffet, 1994). Burkinshaw and Parrett (2004) defined dampness as the amount of moisture content present in a material and can be classified as capillary moisture content, equilibrium moisture content, hygroscopic moisture content, total moisture content and potential moisture content. According to Hollis (2000), dampness is inextricably linked to most building deterioration. A source of water close to a building will also be one of the problems associated with dampness. These problems include symptoms such as dirty spots on the building, biological plants like the growth of fungi, mosses and creeping plants, paint flaking, blistering etc. (Halim et al., 2012). In order to successfully diagnose and make appropriate recommendations for remedial actions, one should understand dampness and its impact on buildings. Accumulation of moisture or dampness in buildings or components of a building leads to physical, biological or chemical deterioration of the building or its materials (Haverinen-Shaughnessy, 2007). Damages to buildings caused by dampness pose serious risks to the performances of those buildings (Oliver, 1997).

The ultimate objective of any dampness study is to identify the lead source of moisture in order to recommend actions to remedy the problem (Halim et al., 2012). According to Hollis (2000), sources of dampness can be classified as rising dampness, penetrating dampness, condensation and pipe leakages. According to Burkinshaw and Parrett (2004), dampness can be classified as air moisture condensation, penetrating dampness, internal plumbing leaks, below ground moisture or building specific sources.

Rising dampness results from the capillary suction of moisture from the ground into porous masonry building materials (Halim and Halim, 2010; Ahmed and Rahman, 2010). Though rising damp is a problem common in older buildings, it is gradually becoming a common issue with modern types of buildings as well (Rirsch, 2010). Penetration damp is the term applied to the penetration of moisture through the fabric of buildings over a period of time and is usually characterized by localized areas of damp or saturated wall/ceiling finishes (Latta, 2005; Oliver, 1988). The simultaneous occurrence of the presence of water, an opening through which water can enter and a physical force to move the water are the three main issues that underpin water penetration through a building enclosure (Beall, 2000). Condensation occurs when water in the air inside a building condenses on a cooler surface (Curtis, 2007). Severe mould growth which create health hazards and damp patches on plastered walls in odd places are some of the symptoms associated with severe condensation (Burns, 2010).

In Ghana, the problem of dampness is pronounced and studies conducted on the health of patients have shown that most respiratory diseases are caused by this problem (Asamoah et al., 2012). In a survey of 5,800 buildings affected by dampness, Agyekum et al. (2013) reported that all the buildings showed one or more signs of rising dampness, penetration damp and condensation. The commonest problem, which is rising dampness, was identified in 5,037 of the buildings (Agyekum et al., 2013). As a step towards addressing this common but dangerous problem, this study identifies a typical residential building suffering from such a problem and adopts a holistic approach to damp surveying involving a two-stage protocol of damp investigation (stages 1 and 2) to uncover some of the secretes behind it. In achieving this aim the study sought to identify the parts of the building severely affected by the problem of dampness using visual observations and non-destructive tests. This should help identify any significant dampness in the walls of the building and decide whether any action needs to be taken to either manage or cure it through stages 3 and 4 investigative approaches.

Study area

The building is located at Deduako, a suburb of the Oforikrom sub-metro which falls under the Kumasi Metropolitan Assembly (Figure 1). The Kumasi Metropolis is the most populous district in the Ashanti Region. It is located in the transitional forest zone and it is about 270km north of the national capital, Accra (www.ghanadistricts.com).

The Metropolis falls within the Wet Semi Equatorial climatic zone (www.ghanadistricts.com). The vegetation of the Metropolis falls within the moist semi-deciduous South-East Ecological Zone.
The area is underlain by a large mass of granitoids known as the Cape Coast and Winneba (G1) rock types (Kesse, 1985). These granitoids are related to the later stages of the Eburnean Orogeny, at or after the end of the Birimian deposition.

These are, at times, well foliated, often magmatic, potash-rich granitoids which come in the form of muscovite biotite granite and granodiorite, porphyroblastic biotitegneisises, aplites and pegmatites. These granitoids are characterised by the presence of many enclaves of schist’s and gneisses. They are generally associated with Birimian metasediments and their internal structures are always concordant with those of their host rocks. The Cape Coast granitoid complex is believed to represent a multiphase intrusion consisting of four separate magmatic pulses. It is believed that the last phase is associated with the upper group of Birimian metasediments (Kesse, 1985).

The site is generally underlain by granite which is a later intrusion into the lower birimian rocks. The soil type found here is mostly residual in nature with covering of weathered argellateous phyllite from the country rock (Kesse, 1985).

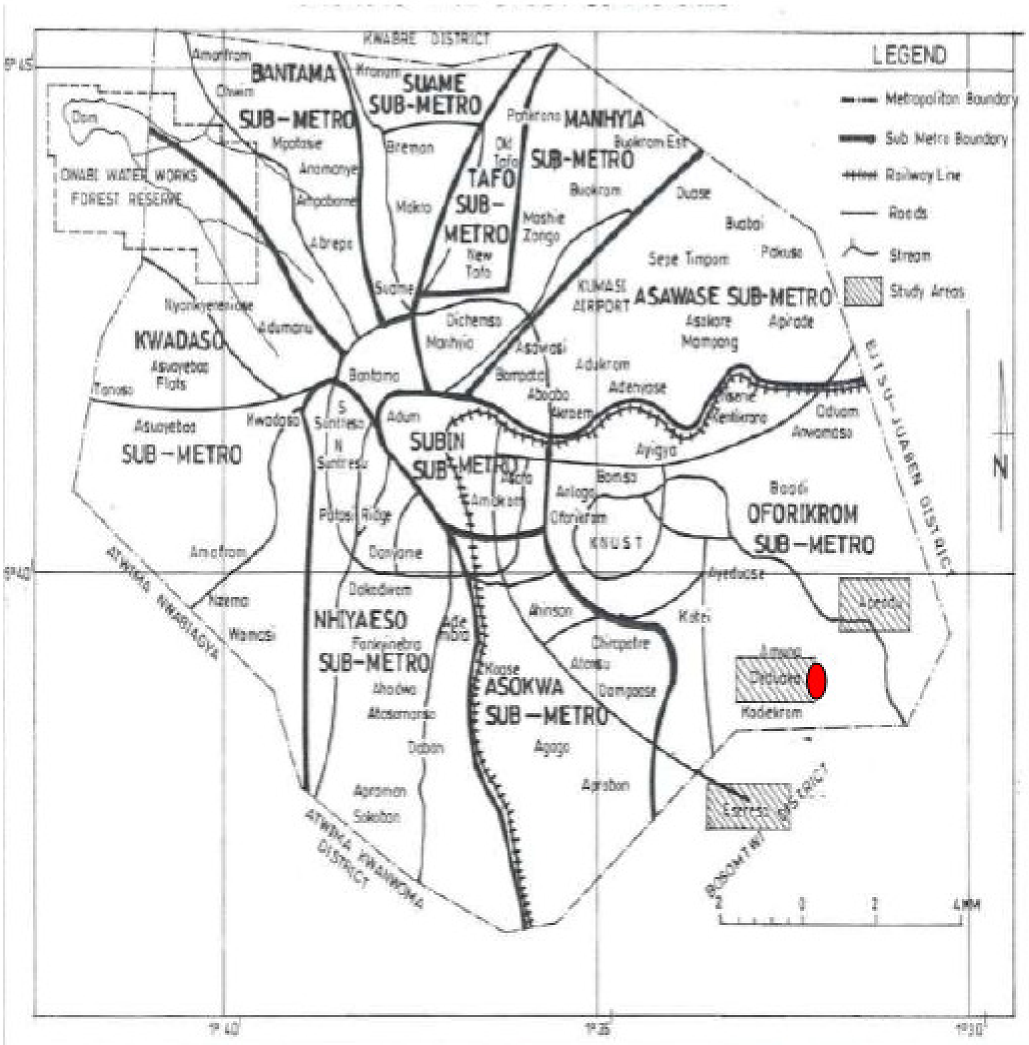


Figure 1: The study location (Deduako, a suburb of oforikrom sub-metro) marked in red (Source KMA, 2011)

Method

This study sought to identify areas in the walls of the building severely affected by dampness through visual observation and non-destructive testing using moisture meter. This should assist in a detailed investigation later and aid in the recommendation of appropriate methods to address the problem. The investigation consisted of a single case study of the building reported to be experiencing severe dampness problems. Literature reports that in an invasive inspection, more can be learned about damp damage in one inspection than in a hundred more cursory surveys (Burkinshaw and Parrett, 2004). This building was chosen because it had been severely affected by dampness and it would provide a basis for further studies to be conducted on buildings located in similar conditions and situations.

There are four major stages or approaches to any dampness investigation, these include: visual inspection; investigations using moisture meters (non-destructive tests); a more detailed investigation (destructive tests) and homing in on the problem (laboratory assessment study) (Halim et al., 2012; Burkinshaw and Parrett, 2004). The study was carried out using visual inspection and moisture meter (stages 1 and 2 approaches). A holistic approach to dampness investigation which involves observing symptoms in relation to the whole building, the site and what can be gathered about the locality was adopted (Burkinshaw and Parrett, 2004).

Stage 1 investigation requires a surveyor to inspect the defect closely and it is the first of the four stages involved in any dampness investigation. This investigation may be subjective and the experience of the personnel involved is very important (Halim et al., 2012). In this stage being able to identify a dampness problem depends on the symptoms of the defect i.e. staining of water, cracking, rotten timber, decay, blisters, etc. (Halim et al., 2012; Burkinshaw and Parrett, 2004). During the diagnosis, knowledge of the behavior of relevant building materials, construction knowledge and knowledge on the use (past, present and future) of the building is highly required. The surveyor needs to record the defect by description, photograph or sketch drawings, etc. (Halim et al., 2012; Burkinshaw and Parrett, 2004).

The stage 2 investigation solely depends on the use of a moisture meter. This technique non-destructively tests materials or elements of a building without causing alterations, damages or destructions to the fabrics of the building under investigation. The moisture meter used in this study was the PCE-MMK1 universal moisture meter; a multi-functional equipment which measures the moisture content, relative humidity, temperatures, etc. of the material under investigation. The measurement of the dampness focused on all the four orientations of the building. Symptoms such as blistering of paint, staining, flaking of mortar, surface efflorescence, etc. helped in the identification of the affected parts.

Checklists were prepared on which readings were recorded. Grids of 300 mm×300 mm were drawn on all the affected walls. Damp walls in the Southern, Western and Eastern orientations extended up to about 900 mm and grids were drawn as shown in Figure 2.

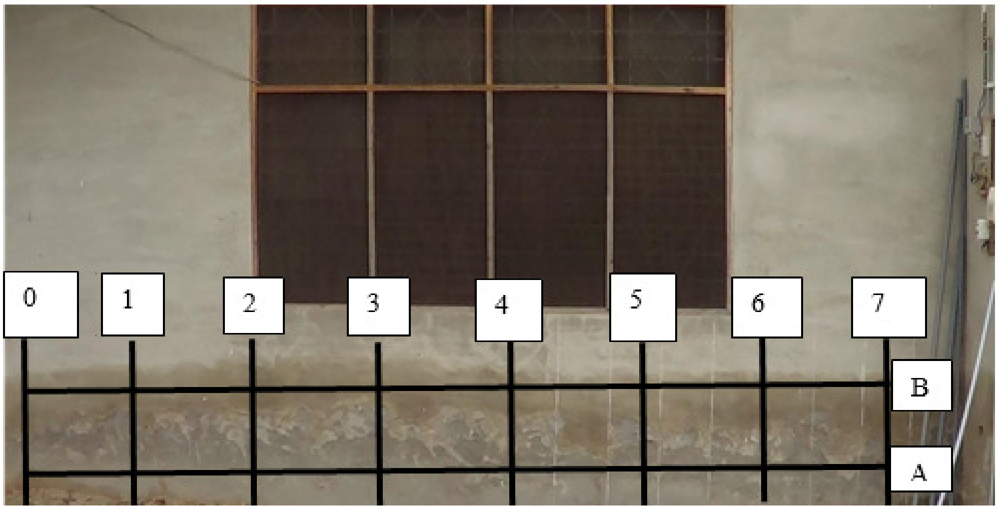


Figure 2: Grid points marked on the wall

For the PCE-MMK1 universal moisture meter maximum moisture content and relative humidity for masonry materials like cement mortar are recorded at 3.0% and 100% respectively. For this study, moisture content and relative humidity readings were interpreted as follows (Halim and Halim, 2010):

1. The wall is considered a very wet zone where the moisture contents recorded are greater than 2.8% and the relative humidity ranges between 22% rH-100% rH;
2. A moist condition is recorded where the moisture content ranges between 1.5% - 2.8% and the relative humidity lies between 18% rH - 21% rH; and
3. A dry condition or level of dampness is recorded where the moisture content is less than 1.5% with relative humidity ranging between 6% rH and 21% rH.

The gridlines were coded using alphabets (for horizontal gridlines) and figures (for vertical grid lines) as shown in Figure 2.

Moisture contents measured on the walls were further presented in coloured contour maps, with the default colours of the legend being formatted to suit the study. Green represents very low moisture contents (between 0% and 1%), yellow intermediate moisture content (between 1% and 2%) and purple represents very high moisture content (above 2%).

Building details

The building under study is a three bedroom detached building that was constructed between the years 2004 and 2010 and occupied in 2013. The site is levelled and about 4 m away from a river source. The area is very rich in sand and was once used as a sand mining location. The construction technology used is the simple artisanship system, the type very common in Ghana (Koranteng and

Abaitey, 2009). The internal and external walls of the building are constructed with sandcrete blocks. The foundation is the pad type with no damp proof course or membrane in place, though the occurrence of dampness is not solely due to the use of DPCs. The floors are made of concrete with tile finish. Hardwood timber skirting boards are used at the bases of the internal walls. The ceilings are of hardwood and the roofs are made of aluminium sheets. The windows are made of glass louvre blades fixed in hardwood frames with hardwood doors. The building is oriented in the east-west direction contrary to the north south directions as suggested by Koranteng and Simons (2011) in warm humid countries like Ghana. The front elevation faces the west, the right elevation faces the south, the back elevation faces the east and the left elevation faces the north. The compound is bare with no paved areas. The survey was conducted between October 2013 and November 2013.

Figure 3: The three bedroom detached building under study

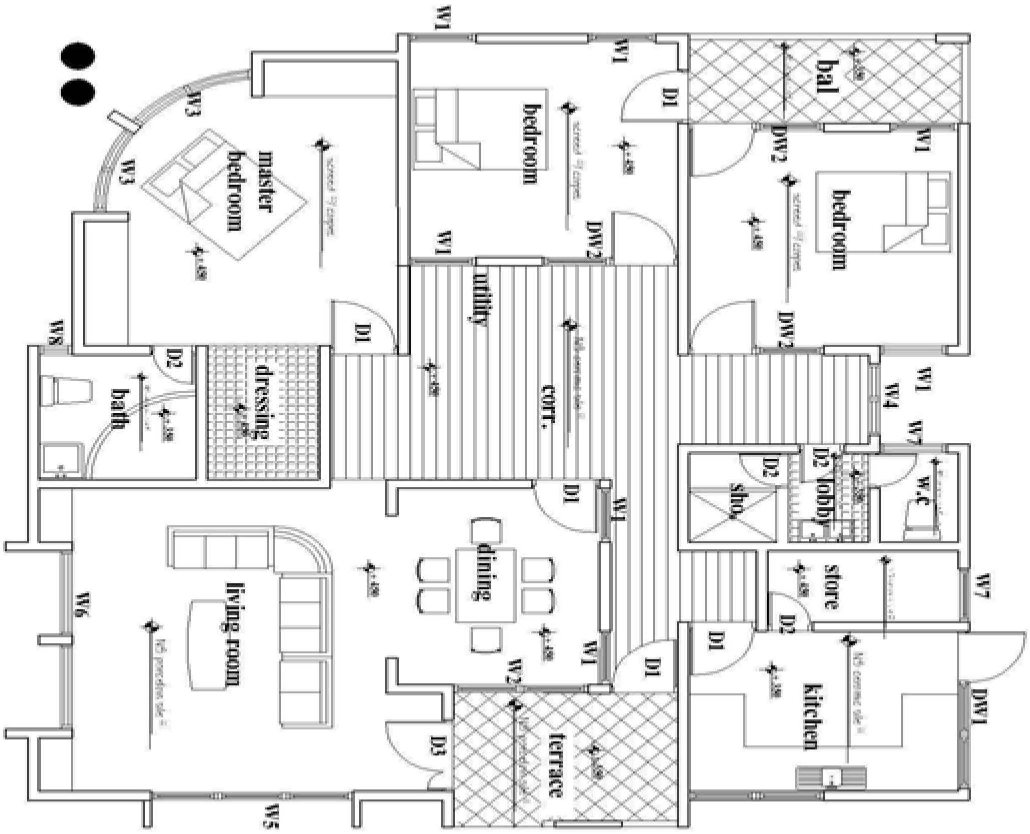


Figure 4: Ground floor plan for building under study

Results

Result from site inspection

The site inspection carried out led to the identification of several symptoms exhibited by the building. These symptoms included cracks in columns (Figure 5a), greenish stains on walls (Figure 5b), blistering of paint (Figure 5c), brownish yellow stains on wall (Figure 5d), flaking of mortar, etc. Dampness on the walls located in the Southern, Western and Northern, orientations reached heights of 900 mm respectively. These symptoms provided a basis for the second stage of the investigation to be conducted. The problem of dampness was very severe in both external and internal walls.

Figure 5a. Crack in column

Figure 5b. Green stain on external wall

Figure 5c. Internal blistering of paint

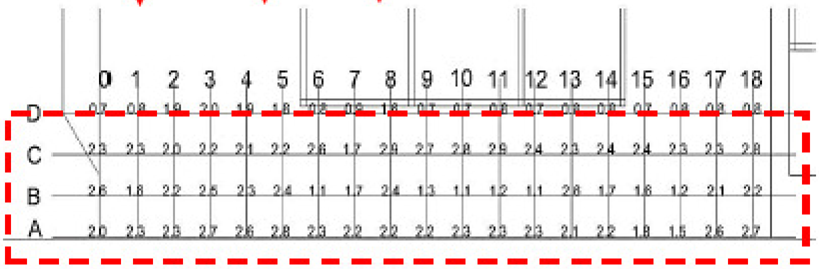
Figure 5d. Brownish-yellow stain on external wall

Moisture content distribution in external walls

Although both internal and external walls were affected, only the external walls were considered in this study. The distribution of moisture contents along and across the faces of the affected external walls are shown in Figures 6 to 8.

Results from the moisture content measurements on the external walls located in the western orientation (Figure 6a) showed that dampness was dominant in the zones highlighted in red (in rectangles). This is because for most of these grid points the moisture contents measured were greater than 2.0, indicating high levels of dampness in those zones.

Figure 6a. Moisture contents on walls in the western orientation



	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
D	0.7	0.8	1.9	2.0	1.9	1.8	0.8	0.8	1.8	0.7	0.7	0.8	0.7	0.8	0.8	0.7	0.8	0.8	0.8
C	2.3	2.3	2.0	2.2	2.1	2.2	2.6	1.7	2.9	2.7	2.8	2.9	2.4	2.3	2.4	2.4	2.3	2.3	2.8
B	2.6	1.8	2.2	2.5	2.3	2.4	1.1	1.7	2.4	1.3	1.1	1.2	1.1	2.8	1.7	1.8	1.2	2.1	2.2
A	2.0	2.3	2.3	2.7	2.6	2.8	2.3	2.2	2.2	2.2	2.3	2.3	2.3	2.1	2.2	1.8	1.5	2.6	2.7

Figure 6b. Enlarged 300mm×300mm grids showing moisture contents on walls in western orientation

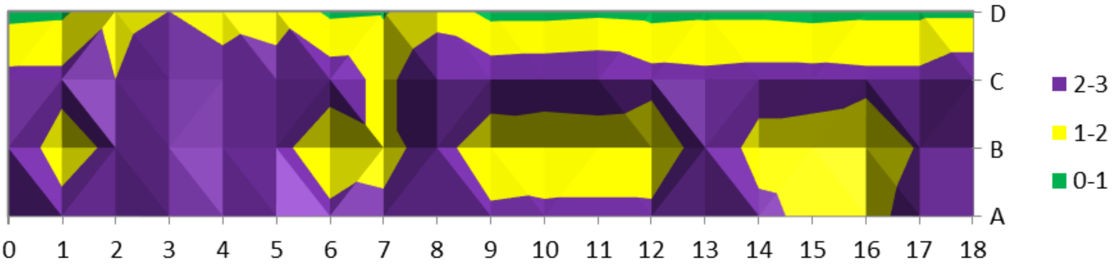


Figure 6c. Contour map showing the distribution of moisture contents along and across the external wall of the western orientation.

Figure 6c is a coloured contour map which shows areas in the walls of the western orientation severely affected by dampness. From Figure 6c it can be seen that all across and along the walls of the western orientation dampness was present and severe (yellow and purple colours). However, the dampness was very dominant in the zones that can be seen in purple because for most of those zones the moisture contents measured were greater than 2.0, indicating high levels of dampness. Furthermore, grid points A2-A5 through to C2-C5 were severely affected (As the purple colour stretched all along and across those grid points).

Figure 7a. Walls in the southern orientation showing signs of dampness

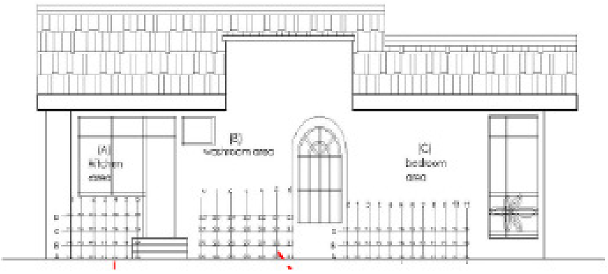


Figure 7b. Readings taken on the walls in the southern orientation

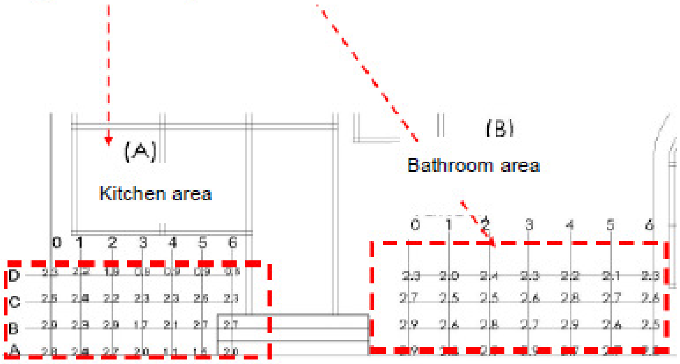


Figure 7c. Moisture content distribution on walls of kitchen and bathroom in the southern orientation

Among all the affected walls, moisture content measurements on the external walls of the building in the southern orientation were unusually higher. Figures 7b and 7c show the moisture contents recorded on the walls of the kitchen and the bathroom. The damp zones are marked with the rectangles shown. These are the two wettest areas in the house and normally have lots of plumbing works. Although the very high moisture contents recorded could be due to plumbing leakage in the walls, further detailed work conducted in these two areas did not show any such leakage.

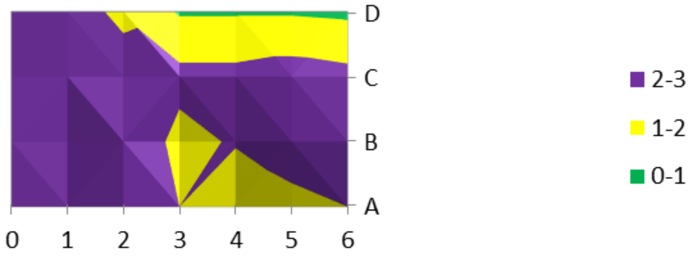


Figure 7ci. Contour map showing the distribution of moisture contents along and across the kitchen wall located in the southern orientation

The contour map in Figure 7ci shows the areas with severe dampness (indicated in yellow and purple). The contour map shows the damp zones where the moisture contents recorded are greater. Those zones (areas shaded in purple) were greatly identified between grid points A0-A3, B0-B3 and C0-C3.

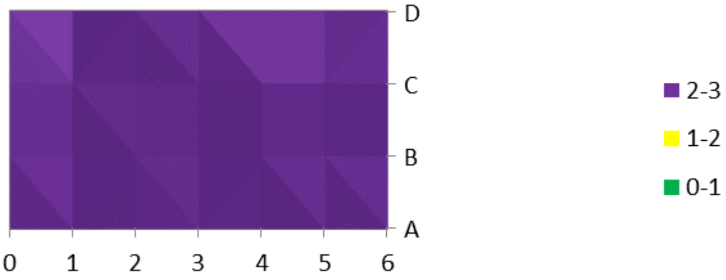
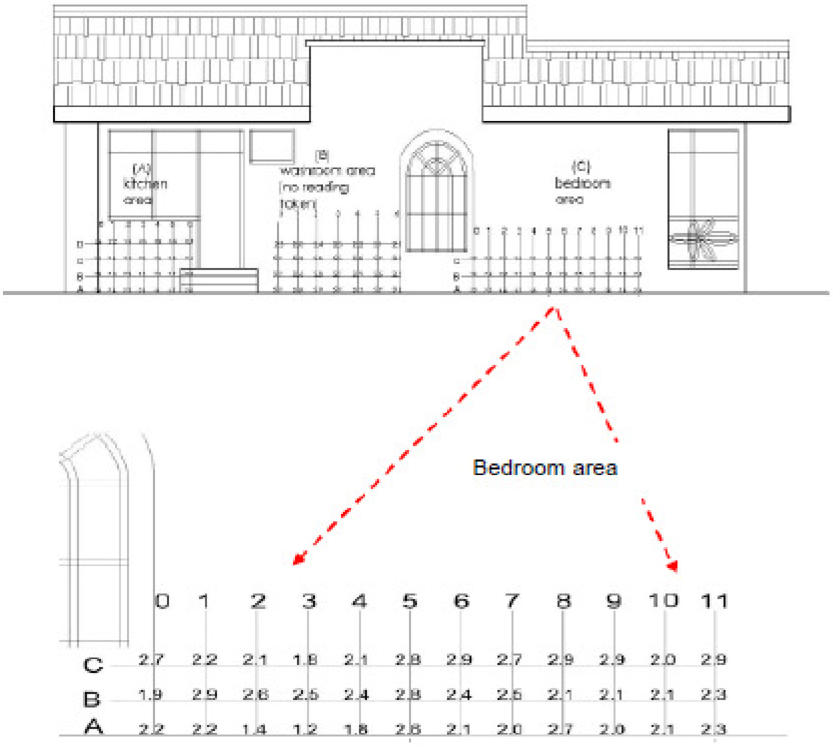


Figure 7cii. Contour map showing the distribution of moisture contents along and across the bathroom wall located in the southern orientation

For the walls of the bathroom located in the southern orientation dampness was so dominant that readings from the moisture meter taken on the entire wall were greater than 2%. The contour map (Figure 7cii) gives a clear picture of the problem in the walls of the bathroom. The purple colour shows the areas in the entire bathroom walls which showed significant level of dampness (damp zones).



	0	1	2	3	4	5	6	7	8	9	10	11
C	2.7	2.2	2.1	1.8	2.1	2.8	2.9	2.7	2.9	2.9	2.0	2.9
B	1.9	2.9	2.6	2.5	2.4	2.8	2.4	2.5	2.1	2.1	2.1	2.3
A	2.2	2.2	1.4	1.2	1.8	2.6	2.1	2.0	2.7	2.0	2.1	2.3

Figure 7d. Moisture content distribution on bedroom walls in the southern orientation

Because the southern orientation of the building was closer to the water body, there could be the possibility of water rising in the walls because of the high water table. This point is buttressed by Figure 7d where the moisture contents recorded on the walls of the bedroom also seemed unusually high, compared to those from the kitchen and bathrooms.

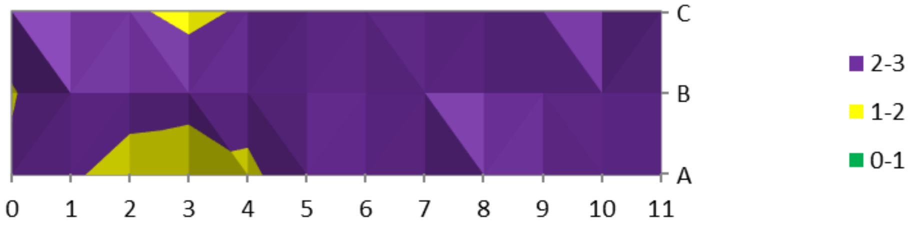


Figure 7di. Contour map showing the distribution of moisture contents along and across the bedroom wall located in the southern orientation

Figure 8a. Eastern orientation showing signs of dampness

	0	1	2	3	4	5	6	7	8	9	10	11	12	13
D	2.9	1.3	1.1	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.0
C	2.4	2.7	2.9	2.7	2.8	2.8	2.7	2.8	2.8	2.7	2.8	2.4	1.8	1.6
B	2.8	2.3	2.8	2.9	2.7	2.9	2.9	2.9	2.6	2.1	2.9	2.5	2.3	1.9
A	2.6	1.9	1.6	2.0	1.9	2.5	2.0	1.4	2.4	2.7	1.8	2.2	2.8	2.3

Figure 8b. 300mm×300mm grids showing moisture contents on the eastern orientation

Results from the moisture content measurements on the external walls of the eastern orientation (back elevation) indicated higher moisture contents on the walls of the bedroom. Figure 8b shows readings taken from the moisture meter on each grid. Grid lines A0-A11, B0-B11, C0-C11 and D0 were identified as the severely affected zones. Though there existed some low level of dampness on some of the grids (A8), dampness recorded in majority of the zones were between 1.5 and 2, an indication of the severity of the problem.

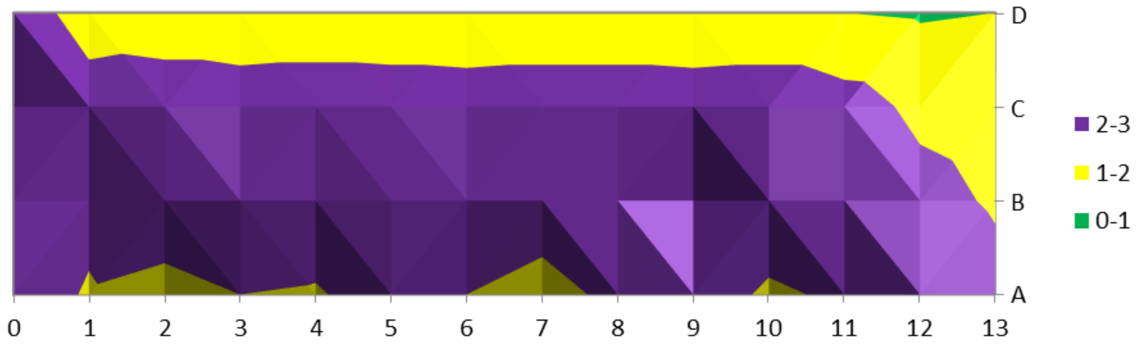


Figure 8c. Contour map showing the distribution of moisture contents along and across the bedroom wall located in the eastern orientation

Moisture contents recorded on the walls of the building showed that the walls oriented in the southern, eastern and western directions showed various levels of dampness. However, the dampness was very severe among the walls oriented in the eastern direction, and were identified as areas where further investigations should be conducted.

Diagnosis

The site inspection revealed a lot of interesting issues on the building. Blistering of paint, flaking of plaster and render, surface efflorescence, green algae (eastern orientation) and cracks in the column located at the balcony area were among the symptoms identified. Along all the external and internal walls, dampness extended to heights of about 900 mm. On the compound where the building is located, it was realized that a portion of the soil found in the area had changed colour to brownish yellow and this indicated the presence of ions in the soil (Burkinshaw, 2010). This colour was identified on the surfaces of the walls located in the western and eastern orientations. These symptoms identified in the walls point to the possibility of rising dampness. Rising dampness results from the capillary suction of moisture from the ground into porous masonry building materials (Halim and Halim, 2010; Ahmed and Rahman, 2010). Among the visible symptoms of rising damp is dampness on the lower parts of walls, sometimes up to 1.5 m in horizontal bands (Rirsch, 2010). Rising damp may also present itself as salty brownish yellow patches of plaster or décor just above the height of skirting boards (Burkinshaw, 2010). Other sources also list blistering of paint, surface efflorescence, flaking of mortar, etc. to be part of the symptoms associated with rising dampness (Halim and Halim, 2010).

A closer examination of the whole building revealed no symptoms of other sources of dampness (condensation, plumbing leakages and water penetration). The bathroom and kitchen areas which are normally the wettest in buildings and are susceptible to plumbing leakages were leakage free. A more detailed study conducted in these areas revealed no leakages. These were also supported by the fact that the moisture contents in the walls of the bedroom located in the same orientation were also very high as in the case of the kitchen and the bathrooms.

Prognosis

The building is situated in an area which is closer to a water body and which has lots of ions present in the soil (Burkinshaw, 2010). These facts mean that appropriate interventions should be put in place for the occupants to keep staying in the building. In a similar study by Burkinshaw and Parrett (2004), moulds were identified to be demoralizing because they could cause health problems. The ions present in the soil have that tendency of corroding the steel rods in the concrete should they be in contact (Burkinshaw and Parrett, 2004). The paint blistering in the living room is not pleasant and the flaking of render and mortar outside will gradually deteriorate the building. It would not be practical to redecorate the building before remedial measures are put in place. This is because once the root cause is still present, the problem will keep on persisting. It is important if the necessary interventions are put in place to trace and remedy the moisture at its root before any other remedial measures are put in place.

Conclusions

This study sought to identify and document areas in a three bedroom residential building severely affected by dampness. The complete building was sick because every part of it experienced dampness in one way or the other. Both internal and external walls of the building were severely affected by dampness. Visually, symptoms such as blistering of paint, flaking of mortar, cracks, mould growth and surface efflorescence were identified on the walls of the building. These symptoms point to the possibility of rising damp. Areas in the walls severely affected by the problem have been identified with the help of the moisture meter. The foundation was constructed with no damp proof course in place and this could have affected the way water had risen in the walls, though the occurrence of dampness is not solely due to the use of DPCs. Notwithstanding these findings, there is still a clear case of poor construction methods, inappropriate technology, non-involvement of construction professionals during the construction process, etc. which contributed to this problem and a further study is recommended in this area. Although these symptoms are very clear for any surveyor to judge, it is still important to conduct further studies using the stages 3 and 4 approaches (detailed laboratory investigations) to identify the lead source of the problem and the possible ions that could be present. This will provide a clear evidence of the true cause of the problem which could lead to the recommendation of appropriate interventions.

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