A METHODOLOGY FOR DIAGNOSING DAMP IN A TROPICAL BUILDING

Agyekum, K.[1], Ayarkwa, J.[2] and Salgin, B[3].

[1, 2]*Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*
[3]*Erciyes University, Faculty of Architecture, Department of Architecture, Kayseri/Turkey*
agyekum.kofi1@gmail.com; ayarkwajosh@yahoo.com; bsalgin@gmail.com

Abstract

As the most frequently reported cause of building defects, dampness has for many years received attention worldwide. It is a major problem associated with many buildings, and contributes more than 50% of all known building failures worldwide. In a tropical region like Ghana, dampness is a very common problem among many residential buildings. However, there is no detailed information on the problem, let alone diagnosing it. It has therefore become necessary to conduct studies on the problem, and provide the necessary information for people in academia and the construction sector to become aware of this common but deadly problem in buildings. This paper adopts the principles involved in the diagnosis of damp (visual inspection, investigation using moisture meter, a more detailed investigation, and laboratory assessment study) as outlined and accepted internationally, and applies those principles to a real life scenario in a tropical country like Ghana. A typical case is selected (a six-bedroom residential building), and the principles are applied to diagnose the presence of dampness or otherwise. The findings revealed that the proper application of the principles can effectively help to diagnose the presence of dampness in buildings. This study does not only present theories behind dampness and its causes, it offers detailed and practical advices on how to effectively investigate and report on dampness issues using modern equipment and gadgets.

Keywords: Dampness, four-stage-approach, residential buildings, Ghana

Introduction

Water is one of the most dangerous enemies of porous building materials. There are many ways in which water penetrates the pores of building materials (Karagiannis et al., 2016). Water in buildings may originate from driving rains, condensation, rain water splash back, capillary rise of water, among others (Karagiannis et al., 2016; Karoglou et al., 2005). According to Karagiannis et al. (2016), there is always some amount of bound water present in building materials. This bound water, if in the right amount, does not affect the durability of such materials in any way. However, where the moisture content of a material exceeds a certain percentage, the deterioration effect of moisture may be triggered, and this may lead to physical, chemical and biological problems in the material (Karagliannis et al., 2016; Moropoulou et al., 2014). It is therefore very important that one gains knowledge in the movement of water within building materials to be able to control some of these problems.

Dampness in buildings is a very delicate issue, and if care is not taken, it may be misdiagnosed. Some of the reasons why dampness is often misdiagnosed include the following (Burkinshaw and Parrett, 2004): one-off snapshot pre-purchase surveys; solely relying on readings from electrical moisture meters when such equipment has been designed to detect the absence of moisture; lack of permission from landlords for surveyors to undertake minor puncturing of walls, among others.

Proper diagnosis of damp in buildings has always been an issue among building surveyors. Adequate information is available, but scattered throughout literature. The work by Burkinshaw and Parrett in 2004 took the understanding of damp diagnosis to a new level. From the work 'diagnosing damp', Burkinshaw and Parrett (2004) demonstrated how inspection of damp problems begins with visual examinations and ends with a more detailed laboratory diagnosis of the problem. Theoretically, there is adequate information on laid down procedures involving a step-by-step approach to the diagnosis of damp problems. However, there is inadequate information available when it comes to the application of the priciples to real life scenarios, especially in Africa. This paper therefore adopts the principles involved in the diagnosis of damp as outlined and accepted internationally but scattered, and applies those principles to a real life scenario in a tropical country like Ghana. A typical case is selected (a six-bedroom residential building), and the principles are applied to diagnose the presence of dampness or otherwise.

The paper is structured into three sections. The first section provides a brief introduction to the study. It is then followed by a detailed literature review on the theory behind damp investigations. The final section shows how the principles of damp investigation was applied to investigate dampness in a typical residential building, and the key findings that were obtained are also presented. It is very important for readers to note that the key findings presented are not very detailed. This is because much emphasis has been laid on how surveyors within the tropical part of the world, typically Africa and Ghana could apply the principles of damp investigation in a real life scenario to get results.

Literature Review

The theory behind diagnosing damp in buildings

This section of the paper discusses literature on dampness in general. It discusses the general principles of damp investigation and approaches to damp investigation. The section also describes the surveying equipment and tests for conducting such investigations.

Dampness in buildings

Dampness can be defined as water penetration through the walls and certain elements of a building (Halim et al., 2012). It 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. Dampness is the most frequent and main problem in buildings and contributes more than 50% of all known building failures (Halim et al., 2012; Trotman, 2004). According to Hollis (2000), it is inextricably linked to most building deteriorations. Dampness may be associated with symptoms such as dirty spots on the affected building, biological growth of plants like 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.

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 damp, penetrating damp, condensation and pipe leakages. Burkinshaw and Parrett (2004) also classified the sources of dampness to include air moisture condensation, penetrating damp, internal plumbing leaks, below ground moisture or building specific sources.

Principles of dampness investigation

The most important 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). During the course of a damp investigation, the sense of sight, touch, taste, smell and hearing as well as communication and analytical skills need to be utilized (Burkinshaw and Parrett, 2004). Physical agilities such as climbing ladders, peering under floorboards or squeezing into corners need to be demonstrated by the surveyor. The investigator needs to be proficient with a range of specialist equipment, like those for conducting tests, or taking samples for testing at a laboratory (Burkinshaw and Parrett, 2004).

To deal effectively with the problem of dampness, an organized system of investigative procedures should be undertaken to confirm all the sources of dampness and to ensure that the recommended remedial works are appropriate (Carrilion, 2001). According to Smith (1986), such a system must begin with the identification and recognition of symptoms or signs associated with dampness. A professional who carries out any form of building inspection should be aware of already existing data. The selection of an effective remedy for any form of dampness must start with a correct diagnosis of the cause (Carillion, 2001). There are four major stages to any dampness investigation. These are visual investigations, non-destructive testing, destructive testing and laboratory assessment study (Halim et al., 2012; Burkinshaw and Parrett, 2004).

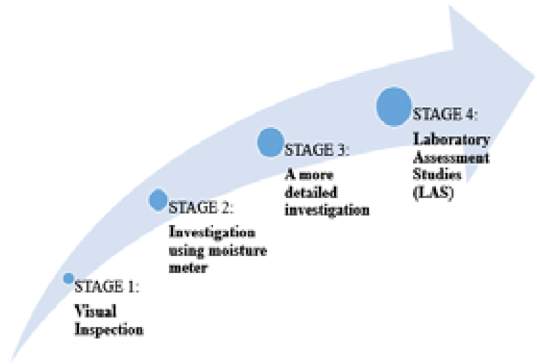

Figure 1. Four stage approach to dampness investigation

(Source: Halim et al., 2012; Burkinshaw and Parrett, 2004)

A specialist damp investigator will take quite a number of equipment to site and in most cases would follow the investigation to whatever stage necessary to identify the cause of a dampness problem (Hamid and Ngah, 2010; Burkinshaw and Parrett, 2004). In practice, however, surveyors do not firmly stick to these four stages. At times parts of a property (sometimes just one room or part of a room) exhibit symptoms of a dampness problem for which there is no obvious cause. When this happens, the investigation may be intensified from stage 2 to stage 3 and sometimes from stage 3 to stage 4 as the surveyor seeks to identify the cause (Hamid and Ngah, 2010; Burkinshaw and Parrett, 2004).

Stage 1 which is the visual investigation stage requires the surveyor to inspect the defect closely. It acts as a basis for further investigation and confirmation of the defect assessed (Halim et al., 2012; Burkinshaw and Parrett, 2004). This stage is principally based on experience and skill of the personnel involved. The ability to identify any problem of dampness depends on several symptoms such as staining of water, cracking, rotten timber, decay, blisters, etc. Knowledge of the behaviour of relevant building materials, construction knowledge and knowledge of the use (past, present and future) of the building is very well required. The surveyor needs to record the defect by description, measurement, photograph or sketch drawing. The difficulty associated with this stage is that the surveyor may need to adopt a more scientific approach to diagnosis if the symptoms are complex or conflict with other available information (Halim et al., 2012; Burkinshaw and Parrett, 2004).

During the stage 2 investigation (the non-destructive testing stage), the moisture meter is the most widely used instrument for the diagnosis of dampness in buildings (Halim et al., 2012). The moisture meter is used to inspect materials or elements of construction in place without causing modifications, damages or destruction to the fabric of the building (Halim et al., 2012; Burkinshaw and Parrett, 2004). In a stage 2 investigation, the surveyor is advised to establish an efficient work pattern. This speeds up surveying and reduces the risk of missing potential problems (Burkinshaw and Parrett, 2004). No walls or surfaces should be ignored but it is sensible to spend more time in the likely damp zones that the visual inspection has highlighted. Readings should be taken around external openings or where potential penetrating damp positions have been noted (Burkinshaw and Parrett, 2004).

The destructive testing stage (stage 3) offers a specific set of measurements or data in response to a known or suspected dampness conditions (Halim et al., 2012; Burkinshaw and Parrett, 2004). This assessment requires the assembly of techniques that may be used to inspect or observe materials or elements of construction in place. It also involves causing modifications, damages or destruction to the fabric of the building. The tools and techniques used at this stage include drilling of samples (mortar, bricks/blocks), salt test, carbide meter, electronic-thermo hygrometer and mechanical hygrometer (Halim et al., 2012; Burkinshaw and Parrett, 2004). Oven drying method which is the most precise method of determining the moisture content of materials involves taking samples, weighing the samples and drying the samples to constant weight in an oven at a suitable temperature (100°C) and then re-weighing. Dampness is expressed by the weight loss achieved through drying as a percentage of the oven dry weight of the material being examined (Halim et al., 2012; Trotman, 2007; Burkinshaw and Parrett, 2004).

The final stage, which is the laboratory assessment study stage, may apply to a whole building or to the further investigation of a damp zone identified from a Stage 2 or 3 investigation (Halim et al., 2012; Burkinshaw and Parrett, 2004). A stage 4 investigation is usually carried out in the context of a specialist dampness investigation and the surveyor spends a lot of time to concentrate on dampness issues. The thinking process will be aimed at diagnosing the problem of dampness. Several equipment is required to carry out the investigation in this stage (Halim et al., 2012; Burkinshaw and Parrett, 2004). During this stage, destructive tests and examinations that require opening up are conducted. More emphasis is placed on the sampling which aims at confirming moisture conditions within structural elements by drilling out masonry samples (Burkinshaw and Parrett, 2004). The decision on where samples should be drilled depends on the purpose of the investigation conducted and prevailing site conditions (Burkinshaw and Parrett, 2004). A typical investigation could first involve sampling at various positions laterally to confirm a damp zone, then by vertical sampling where damp patches extend upwards. A typical stage 4 investigation of an average-sized house with very average moisture conditions could involve drilling 10-12 holes (Burkinshaw and Parrett, 2004).

Surveying equipment and tests for dampness investigation

As a leading cause of building deterioration, high moisture levels can cause decay, warping or corrosion of materials (Halim et al., 2012; Ahmad and Abdul Rahman, 2010; Riley and Cotgrave, 2005). High humidity may result in mould, mildew or staining, and paint may peel or blister as a result of too much moisture (Halim et al., 2012; Ahmad and Abdul Rahman, 2010; Riley and Cotgrave, 2005). Although moisture problems are so persuasive and detrimental, there are limited understanding of the causes and conditions leading to the various problems. To critically investigate and analyse the causes of such problems, various instruments and methods can be used. These methods and instruments include the determination of the moisture content of materials and drilling for samples in masonry walls.

The moisture content of a material is the ratio of the mass of moisture within a given volume to the dry mass of the same volume, multiplied by 100 percent (Trotman, 2007). Moisture content can also be expressed as a volume fraction, which is the volume of moisture contained within a volume of dry material, in which case the density of the material must be known to convert it to a mass percentage.

According to Sandrolini and Franzoni (2006), the first step to identifying the actual source of moisture in damp buildings is to measure the moisture content. There are wide ranges of techniques either destructive or non-destructive and direct or indirect for investigating moisture contents in buildings (Sandrolini and Franzoni, 2006). The indirect methods of measuring dampness in buildings include the infra-red thermography and moisture meters (Electrical resistance meters, electrical capacitance meters, Radar and microwave techniques, Neutron scattering techniques).

In the Carbide meter method, some moisture could be lost during the drilling of the samples, crushing, handling and weighing (Harriman, 1995) and this could lead to under estimation of moisture content by 2-3% wt% (Alfano et al., 1999). According to Sandrolini and Franzoni (2006), the gravimetric method which can be undertaken both on site (Portable thermo-balances) or in the laboratory (oven drying) usually on material samples taken by mechanical drilling at a fixed depth in the building faces, could be affected by errors in sampling and handling of samples (Sandrolini and Franzoni, 2006). Figure 2 is a picture of the calcium carbide meter used to measure moisture contents in buildings.

Figure 2. Calcium Carbide meter/ speedy tester used to measure moisture contents of samples

(Source: Jet Materials, 2013)

In drilling for samples in masonry walls, it is necessary to use sampling or meters to determine the source of any dampness in buildings (Trotman, 2007). According to Burkinshaw and Parrett (2004), sampling is the extraction of masonry materials (bricks, blocks, mortar, plaster, etc.) from or within a wall, usually by cold drilling (to between 10 mm and 80 mm depth). The basis for the drilling method is to drill out damp masonry or mortar and measure moisture content and hygroscopic moisture content.

Walls may contain considerable quantities of hygroscopic salts. As a result of that, hygroscopicity should be measured to see whether the walls could have absorbed the quantity of water found in the samples from the atmosphere. On site moisture content can be established by using a carbide meter, or a commercial piece of equipment where the damp drillings and carbide are mixed in a pressure vessel (Trotman, 2007; Trotman et al., 2004; Burkinshaw and Parrett, 2004). A gauge measures the pressure generated and the calibration is directly related to the moisture content (See Figure 2). If several samples are taken, it is more convenient to test in the laboratory to establish both moisture content and hygroscopic moisture content (Trotman et al., 2004).

Samples can be collected through the entire depth of a masonry wall. Trotman et al. (2004) noted that "in particularly thick walls, drilling at 25 mm or 50 mm increments can create a moisture content profile through the depth of the wall. Drilling is stopped 5-10 mm short of the inner face of each leaf to prevent penetrating the cavity and losing the dust sample". This staged drilling technique can be achieved by marking along the length of the drill or by using a depth gauge attachment (Trotman et al., 2004).

The main disadvantage of the drilling method is that it is semi-destructive, and requires at least a series of 9 mm holes, or if the wall is plastered, a chase cut out to locate the mortar joints. In practice, building owners are usually content for samples to be taken so that a definitive diagnosis can be made (Trotman et al., 2004; Burkinshaw and Parrett, 2004).

Among the equipment needed to drill the samples are: electric drill (hammer-action, variable speed)-corded with extension lead, or cordless drill with spare batteries/charger; sharp tungsten carbide drill bits, 6, 10 and 16 mm diameter and of suitable length; containers for samples (eg. 35 mm camera film cases) with self-adhesive labels; plastic resealable sample bags; dustpan/brush/cleaning equipment; metal detector; sharp 65 mm bolster, claw hammer; small piece of card for collecting dust; carbide meter, with fresh powder; small piece of hardboard to collect debris and facilities clearing up; making good materials (if required); safety equipment-goggles, gloves, face mask, etc. (Hamid and Ngah, 2010; Burkinshaw and Parrett, 2004; Trotman et al., 2004).

Massari and Massari (1993) suggested typical drilling patterns used in the collection of samples from brick masonry. In a brick wall for instance, the brick acts as a short-cut between one mortar layer and another. This invasion as shown in Figure 3 will follow the shortest route (A) or (B) when the material is more absorbent than the mortar; it follows the longest route (C) and makes little progress when the material is anti-capillary (Massari and Massari, 1993).

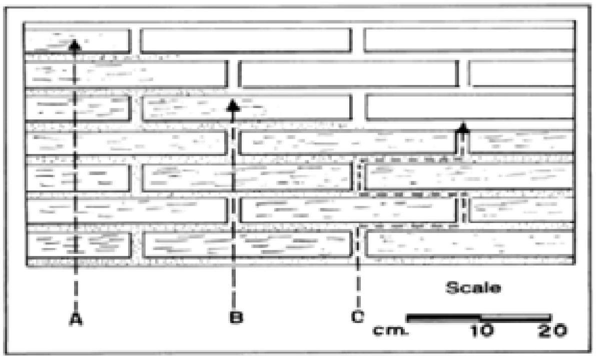

Figure 3. Possible routes of moisture in a masonry wall

(Source: Massari and Massari, 1993)

When this happens, remarkable heights of humidity resulting from the

characteristic of the brick course are reached in the shortest possible time.

According to Trotman *et al.* (2004), the drilling technique is generally used on masonry materials such as brick, stone, concrete block work walling, etc. It is better to drill into the mortar because the bricks /blocks will have lower moisture content (Trotman et al., 2004). Also, the drilling of mortar samples is important because they are the dominant paths through which damp rises in walls of buildings (Rirsch and Zhang, 2010). It is always advisable to collect the samples in a stoppage bottle for subsequent laboratory tests. If the carbide meter is to be used for the testing, about 2 to 6 grams of the sample should be sufficient. Successive samples should be taken up the height of the wall and a graph of moisture content against height should be plotted (Trotman et al., 2004). Figure 4 also shows how mortar or brick/block samples are drilled and collected.

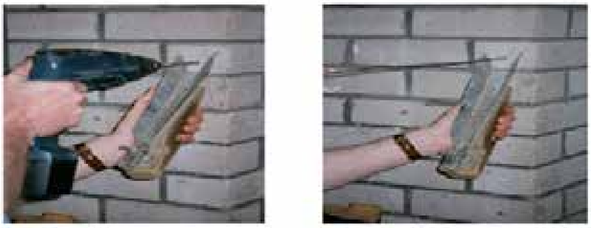

Figure 4. Drilling of brick samples from an affected wall

(Sources: Trotman, 2007; Trotman et al., 2004)

Research Methodology

With permission from the building owner, the study adopted a holistic approach to dampness surveying involving the four-stage protocol of damp investigation to diagnose dampness in the building. This 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, 2012).

The four main approaches to dampness investigation include visual inspections, investigations using moisture meters (i.e. non-destructive tests), a more detailed investigation (i.e. destructive tests) and homing in on the problem (i.e. laboratory assessment study) (Halim and Hamid, 2012; Burkishaw and Parrett, 2004). The methods applied in diagnosing the dampness in the building is discussed under the various approaches. Figure 5 shows the 3-D plan description of the building under investigation.

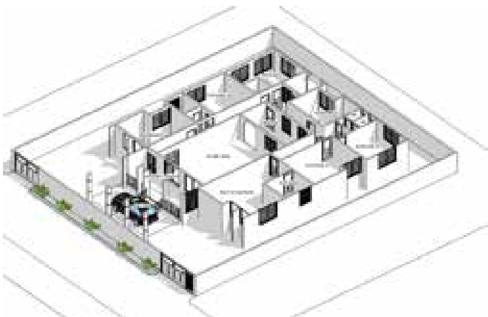

Figure 5. 3-D *plan of the building under investigation*

Stage 1-Visual inspection

The visual inspection was conducted through the observation of the surrounding area, checking of the damp zones and physically identifying the causes of the dampness based on the symptoms identified from the building. Furthermore, examinations of the exteriors of the building from street level and from higher access (roofing, rain water gutters, etc.) were carried out for any obvious defects. Also, the interior parts of the building were examined to determine areas affected by dampness. Figure 6a shows some of the defects which were identified on the affected areas of the building. Figure 6b shows the areal views of the building in the eastern and western orientations.

Figure 6a. *Some of the affected areas of the building identified during the visual inspection*

Figure 6b. *Areal views of the eastern and western orientations of the building*

*Red lines indicate the height of the damp front (maximum height to which the water had risen)

Stage 2- Investigation using moisture meter (Non-destructive testing)

The non-destructive testing on the building was carried out to identify the problematic areas. Moisture content measurements were taken on the walls of the building which showed symptoms such as blistering of paints, peeling of paints, staining, mould growth, etc. Grids of 300 mm × 300 mm were drawn on the surfaces of affected walls and moisture contents were recorded.

The PCE-MMK1 universal moisture meter (Figure 7) was used to measure moisture contents in the sandcrete block walls of the building. This is a multi-functional equipment that can read moisture content, temperature and the relative humidity of the affected walls. Checklists were prepared to record readings. The readings were important in identifying areas within the wall zones where the problem was very severe for further investigation to be conducted.

Figure 7. PCE-MMK1 Moisture meter kit used in the study

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. Moisture content and relative humidity readings were interpreted (Halim and Halim, 2010) as:

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; 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 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 18% rH.

For the building under study, since the walls in all orientations had been affected by dampness, grids of 300 mm×300 mm were drawn on all the walls using a tape measure and light wooden batten. On the faces of the suspected damp walls, a tape measure was laid along the walls and at right angles to this, a light wooden batten was used to mark some values. These markings created grids against which moisture meter readings could be plotted. Damp walls in the various orientations extended from about 600 mm to 900 mm depending on how high the water had risen, and grids were drawn as shown in Figure 8. The gridlines were coded using alphabets (for horizontal gridlines) and figures (for vertical grid lines).

Figure 8. *Measuring and drawing the grids using the tape measure and light wooden batten*

Stages 3 and 4- Destructive testing and laboratory assessment studies

The stage 2 investigations enabled the problematic areas to be identified, leading to the stages 3 and 4 investigations. The stages 3 and 4 approaches employed in this study involved destructively sampling mortar from the problematic areas by adopting approaches used in previous studies (Burkinshaw, 2012; Ahmad and Abdul Rahman, 2010; Hamid and Ngah, 2010; Burkinshaw and Parrett, 2004; Borelli, 1999). These samples were sent to the laboratory for further investigations to be carried out. Primary data were obtained from laboratory tests conducted on the mortar samples.

Sampling of mortar from the building

The walls of the building were constructed using sandcrete blocks. The sandcrete blocks were bonded together with 150 mm thick mortar. Mortar samples were collected because studies have confirmed that mortar is the dominant path through which damp rises in walls of buildings (Burkinshaw, 2010; Rirsch and Zhang, 2010). The mortar samples were obtained from the building studied in the pattern 'B' as shown in Figure 3.

Figure 9. Sampling of mortar

The equipment and materials used to obtain the mortar samples from the building included cordless drills, sharp tungsten carbide drill bits, 35 mm camera film cases for holding samples, plastic resealable sample bags, sharp 65 mm bolster, small piece of card for collecting dust, PCE MMK1 universal moisture meter with deep probes, rule, note pad and labels.

Three different types of mortar samples were taken at 300 mm height intervals up to the height of visible damp (i.e 300 mm, 600 mm, 900 mm) to provide information about water soluble salts distributions in the walls (Burkinshaw and Parrett, 2004). An extra sample was collected about 1.5 m above the height of visible damp to act as a control. In all, twelve (12) different samples of mortar (including control samples), three at each height were drilled at depths of 0-25 mm, 25-50 mm and 50-75 mm into the affected walls of the building. Mortar samples collected at depths of between 10 mm and 80 mm is recommended (Burkinshaw, 2012).

Figure 10. Equipment for the sampling

Analyzing the moisture and salt contents of the mortar samples

Samples of mortar from the building were sent to the Geotechnical Laboratory at the Building and Road Research Institute (BRRI) of the Council for Scientific and Industrial Research, Kumasi (CSIR) where tests were conducted in accordance with BS 1377 (1990). Laboratory tests conducted on the mortar samples included the moisture content test (BS 1377, 1990). The moisture content (MC) was determined by the oven-dry method. The amount of moisture in the samples was determined and expressed as a percentage of its dry mass. The moisture content was determined by taking about 50 grams each of the soil and mortar into moisture cans and the masses were measured (M1). The samples were then oven dried and measured again (M2). The moisture content was determined as follows:

$$MC = \frac{M1 - M2}{M2} \times 100\%$$

Samples of the mortar were further sent to the Chemical Laboratory of the Department of Chemistry at the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana, for chemical tests. The chemical tests performed on the mortar samples were carried out in accordance with BS 4551(2005).

Equipment used in the analysis of the salt included Ion Chromatography (Metrohm 861 Advanced Compact IC), mechanical shaker, 100 ml measuring cylinder, satorious extend analytical balance, centrifuge tubes (15 ml and 50 ml), wash bottles and volumetric flasks (2000 ml, 1000 ml, 100 ml) (ASTM D4327, 2011; ASTM D6919, 2009; Seubert et al., 2002).

Figure 11. *Stages involved in testing for the presence of salts in the samples*

Findings and Discussion

Key findings from the principles used in the study are presented to include the following:

The investigation revealed that there were combinations of several sources of dampness. These included plumbing leakages, rising dampness, condensation, among others.

The visual inspection (Stage 1) revealed that dampness in the walls of the building was associated with symptoms such as cracks in walls, blistering of paint, flaking of plaster, surface efflorescence and stains on walls. Symptoms such as surface efflorescence, damp base of walls up to 1.5 m in horizontal band, among others, closely related to rising dampness were identified.

The non-destructive tests (Stage 2), conducted with the universal moisture meter identified dampness to be pronounced in both the external and internal walls oriented in the western direction. Plumbing leakages were identified in the bathrooms located within this orientation, and could have contributed to the severity of the dampness. Furthermore, dampness was pronounced in the internal walls of bedroom 1 (located in the western orientation) than the other bedrooms. All the destructive tests conducted in the bathrooms located within the building revealed that dampness in most of the internal walls were due to plumbing leakages. However, on the exterior walls of the buildings, rising dampness was very predominant.

Further analysis from the Stages 3 and 4 investigations revealed that the main salts that were predominant in the mortar samples from the building were magnesium sulphate (MgSO4), magnesium chloride (MgCl2), sodium sulphate (Na2SO4) and sodium chloride (NaCl). The results further revealed that although all these salts identified in the study could be damaging, Na2SO4, MgSO4 and MgCl2 are more destructive and can result in more extensive decay in the walls of the building studied (Lopez Arce et al., 2009; De Clercq, 2008; Young, 2008; Zsembery, 2001).

Conclusion

Dampness is most frequently reported as the main cause of building defects around the world. If residential properties are to be carefully surveyed regularly, many problems will be identified before they become very severe. Unfortunately, most houses are often inspected by construction professionals when the problem has become sufficiently advanced to be noticed by the occupier. Adopting the proper methodology will assist surveyors to properly diagnose the problem of dampness. This paper sought to adopt the principles involved in the diagnosis of damp as outlined and accepted internationally, and applies those principles to a real life scenario in a tropical country like Ghana. A typical case was selected (a six-bedroom residential building), and the principles were applied to diagnose the presence of dampness or otherwise in the building. Diagnosing the true cause of dampness plays a significant role in providing lasting solutions to the problem. The lessons from this study supersedes the case presented. The study has shown that it is possible to apply the four-stage approach to damp investigation to accurately diagnose damp in a typical tropical building. This study does not only present theories behind dampness and its causes, it offers detailed and practical advices on how to effectively investigate and report on dampness issues using modern equipment and gadgets.

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