International Journal of Energy and Environmental Research
Vol.6, No.3, pp.1-18, September 2018
Published by European Centre for Research Training and Development UK (www.eajournals.org)

APPROPRIATE CONSTRUCTION TECHNOLOGIES TO CONTROL THE EFFECTS OF WET CONDITIONS IN WETLANDS IN BUILDING INDUSTRY IN KUMASI METROPOLIS

Timothy Adu Gyamfi[1] Moses Amo[2], Samuel Osae[1] Atta Agyeman Junior[2] and Isaac Yaw Manu[2]

[1]Faculty of Built and Natural Environment Department of Building Technology, Koforidua Technical University.
[2]Mphil Construction Technology, Department of Construction and Wood Technology, University of Education, Winneba-Ghana

ABSTRACT: *There is increasing pressure on all-natural resources including wetlands which numerous building and construction activities, such as religious structures, residential facilities and service stations are being constructed without due consideration to effects of wet conditions and the buffer range at which physical development must be restrained. This study explores the appropriate construction technologies to control the effects of wet conditions on buildings in wetlands in Kumasi Metropolis. The study adopted a cross-sectional survey design with a mixed method approach. 120 respondents were randomly selected from a population of 450 developers for the study. The research used questionnaire to collect data. SPSS were used to analyse the data collected. The study reveals that wet conditions contributed to eight (8) defects to buildings and nine (9) appropriate technologies that could be used to control effect of wet conditions. Also, it was found that developers used all the nine technologies. Finally, the results show an increasing trend of the use of proper technologies in recent times. The study strongly recommends that city authority should strengthen the departments/agencies that take charge of supervision on building construction activities with appropriate logistics to enable them discharge their duties effectively.*

KEYWORDS: Construction Technologies, Building, Construction, Wetland, Wet Conditions, Kumasi Metropolis.

INTRODUCTION

Wetlands offer tremendous ecological benefits to the health of the environment. They help to filter and remove pollutants such as sediments and toxic substances from the ecosystem (Anku, 2006). Wetlands collect and store the excess storm water that runs off uplands as well as the waters from flooding rivers. This helps to provide temporary storage areas for surplus water that may cause destruction to lives and properties (Mitsch & Gosselink, 2000). They provide recreational opportunities, tourism, food production and medicinal purposes. Verhoeven, et al. (2006) proposed that, wetlands must be protected because they support high levels of plant and animal diversity which support the economy of a country. The ecological set up of wetlands provides beauty and well-being to the environment.

The construction industry is one of the most important sectors in our system, with significant contribution to both industrial output and overall Gross Domestic Product (GPD) in Ghana (Osei, 2013). It plays an essential role in the socio economic development of the country, and has a lot of significance to the achievement of national socio-economic development goals of providing infrastructure, sanctuary and employment (Ofori, 2012). Danso and Manu

ISSN 2055-0197(Print), ISSN 2055-0200(Online)

(2013) emphasized that, all other sectors of the economy depend much on building and construction. This is because every sector of the economy depends on it for their infrastructural needs such as accommodation, offices, hospital, school, road network and other infrastructure of the economy (Osei, 2013).

Building and construction has to support the world of continuing population growth and economic development, at the same time, it must pay heed to the widespread social interest in environmental preservation (Horvath, 2004). The policies governing wetlands in the country seek to conserve and promote the wise use of wetlands. However as to what extent the policies are being implemented is yet to be known. According to Betey and Owusu-Boateng (2013), city authorities find it difficult to protect and conserve wetlands effectively because of the land tenure system of which most of the lands are stool owned instead of the state. Amo etal (2017) found that chiefs mostly allocate wetland to developers.

There is increasing pressure on all natural resources including wetlands (Ghana National Commission for UNESCO, 2010) which were less used for constructional purposes in the olden days. Consequently, numerous settlements and buildings are now being developed on all wetlands in the Kumasi metropolis.). Many of such houses or structures also get flooded each time there was heavy rainfall. This situation could lead to loss of lives and properties (Ghosh, 2014). Despite all these effects, developers are still in the process of putting up structures mostly for religious activities, residential facilities and service stations without due consideration to effects of wet conditions and the buffer range at which physical development must be restrained. These defects and health hazards could be minimised with appropriate use of technology. However, much is not known about the technologies that developers in Ghana apply to control some of the effects of wet conditions on buildings. Agyekum et al. (2013) therefore proposed a study into the strategies of minimising the effects of wet conditions on buildings on wetlands. This study therefore intends to fill these gaps in knowledge by exploring the appropriate construction technologies apply to minimise the effects of wet conditions on buildings on wetlands in the Kumasi Metropolis. This is part of the larger study that focuses on strategies to minimise hazards of construction activities on wetlands: a case study of Kumasi metropolis.

The study aim to explore the appropriate construction technologies that developers apply to control the effects of wet conditions on wetlands on buildings in Kumasi Metropolis. The study seeks to achieve the following objectives; the effect of wet conditions on buildings, determination of construction technologies for controlling effect of wet condition and investigation of construction technologies used by building developers.

Wetlands in Kumasi

Kumasi is located in the transitional forest zone with a land area of about 254km^2. The city is blessed with a number of major rivers and streams. According to (GSS, 2014) Kumasi Metropolis is traversed by major river known as Owabi, and streams like Subin, , Wiwi, Sisai, Nsuben, and Aboabo with various wetlands which add beauty and other ecological functions to the environment. However, as a result of the effects of the urban sprawl and population growth, the natural environment has been altered (KMA, 2006). Abdul-Razak (2012), reports that the major wetland sites of ecological, landscape, economic and social interests are Aboabo, Bantama, Kwadaso, Sisai, Subin, and Wewe.

ISSN 2055-0197(Print), ISSN 2055-0200(Online)

Private developers have encroached upon the green reserves and its environs, and are reclaiming wetlands for the development of private properties (Forkuor, 2010). Some structures have been constructed less than 30m range to the catchment of rivers and streams (Ministry Of Water Resources, Works and Housing [MWRWH], 2011). In addition to this, portions of streams and water courses have been filled up for development facilities. This situation has affected most wetlands in Kumasi and its influences are glare; the water bodies have been greatly polluted from human activity to the extent that some are near extermination (KMA, 2006), there is also an increasing occurrence of floods in the metropolis in recent times and their devastating effects on lives and properties. There are a lot of building facilities springing up on wetlands each day as a result, the wetlands in the metropolis are under serious threat. This is partly attributable to rising land values and weak land administration (Betey and Owusu-Boateng, 2013).

Wetlands Ground Water and its Effects on Buildings

Tularam and Krishna (2009) state that, groundwater refers to all water below the surface of the ground including that in the saturated zone and in deep aquifers. Wetlands contain a lot of ground water almost throughout the year. Braddock (2007), emphasized that, hydrology is the primary factor determining the existence of wetlands. Although, water may not be seen on the surface of the wetlands all year round but it does not mean there is no ground water present. The water table of the wetlands is always near the surface of the ground. As a result, wetlands maintain considerably certain amount of ground water always (Ramsar Convention Secretariat, 2006). This situation no matter how the ground is filled for the purpose of construction activities will have some effects on the building (Russell, Green, and Rumpf, 2010). This is because water has the capacity of moving from one place to another through capillary attraction.

The walls and other concrete component of the building have the ability of constantly absorbing moisture from the ground through capillary attraction (Bakri and Mydin, 2014). Belgrade (1975) cited in Bakri and Mydin (2014), reported that, dampness can be a serious matter, particularly to the building located near water sources. When the water table is high, water can rise up especially during the rainy season through the foundations and the walls. This rising up moisture can exert hydrostatic pressure on the foundations and walls resulting in dampness, leakages and cracks in the foundation of the building.

Effects of wet conditions of the Wetlands on buildings

Buildings on wetlands experience some level of defects in the cause of the usage of the facility. These defects may have short term to long term effects on the structures as well as the occupants. Since wetland areas contain a lot of ground water, buildings on wetlands may experience continual dampness throughout its existence. This situation may result in other structural defects such as cracks, growth of moulds, efflorescence, wood rot and corrosion of metals (Cotgrave, 2005).

Dampness

Structures on wetlands may experience dampness. Dampness may arise as a result of excessive or unwanted moisture contained in the ground where the structure is situated (Cotgrave, 2005). The moisture in the soil has the tendency of rising upwards through the concrete and other block work components of the building. This is because the component of the building placed

ISSN 2055-0197(Print), ISSN 2055-0200(Online)

directly on the ground has the capacity of absorbing moisture through capillary attraction. This means that buildings on wetlands may always be damp especially during the raining season. The wetlands have the capacity of containing excess water or moisture no matter how much in-filling is done. This situation will make the building susceptible to frequent or constant moisture to make the structure always damp. In view of Cotgrave (2005), the existence of dampness in buildings is one of the most damaging failures that can occur in buildings. Dampness in buildings can cause deterioration of buildings by damaging brick/block work, cause decay and disintegration of mortar joints, fungal attack in timber and corrosion of metals as well as stained wall surfaces internally and externally (Agyekum et al., 2013).

According to the National Academy of Sciences (2007), excessive indoor dampness is not by itself a cause of ill health, but it is a determinant of the presence or source of strength of several potentially problematic exposures. The National Academy of Sciences (2007) further explained that, damp indoor environments favour house dust mites and microbial growth, standing water supports cockroach and rodent infestations, and excessive moisture may initiate chemical emissions from building materials and furnishings. It was evident from their findings that dampness and mould may cause wheeze, cough, asthma, shortness of breath, skin problems; with sufficient evidence of an association. Tuula (2012) also reported that, hundreds of studies from different countries have proof evidence of health implication associated with dampness and moulds. According to Tuula (2012), dampness and moulds may result in cough, blocked nose, rhinitis, wheeze, skin irritation, eye irritation, hoarseness, asthma, muscle and joint pain, headache, nausea, neurological problems, difficulties in concentration, fatigue, fever, arthritis, endocrinologic disorders, and cancer. According Ghana Health Service Report (2010), the first four diseases of Top Twenty Causes of Outpatient Morbidity in Ghana for the year 2008 were malaria, 5,041,025; Upper respiratory tract infection, 794,301; Skin Diseases, 422,948; and Diarrhoeal Diseases, 385,737. The prevailing factors of these diseases are associated with indoor damp conditions, poor environmental conditions, and other environmental conditions.

Development of cracks in the structure

When the buildings are always damp, the bonding capacity of the cement-sand component may be weakened or disintegrate themselves (Agyekum et al., 2013). This situation may result in the building developing some level of cracks which may intend weakened the structural component of the building. Cotgrave (2005), emphasized that, dampness may cause damage in brickwork by saturating it, which can cause decay and break up of mortar joints. Cracks may also develop in buildings as a result of unstable condition of the structure or cement-sand component of the building. Excessive moisture or dryness that may be as a result of the various weather conditions may cause series and frequent cracks developing in the building.

Growing of weeds and moulds

Dampness of the structure may also result in growing weeds and moulds at certain areas of the building such as aprons, pavement, window sill, parapet and other areas of the building. This is because moisture supports plant growth and also vegetation grows very well in wetlands, since the wetlands absorb a lot of nutrients (Dordio et al., 2008). Damp structures are susceptible to growing weeds and moulds because air and moisture support plant growth. According to National Academy of Sciences (2007), moulds may cause wheeze, cough, asthma, shortness of breath, skin problems, gastrointestinal problems, fatigue, cancer, reproductive effects. Tuula (2012) also adds that, moulds can hasten the rate of occurrence of

ISSN 2055-0197(Print), ISSN 2055-0200(Online)

asthma and other related diseases. In Ghana, Asamoah, Forson, and Boakye (2012), conducted studies on the health of patients and found out that, most respiratory diseases are caused by indoor dampness.

In addition, as the structure always or frequently become damp, it encourages necessary nutrients that support plant growth to reside on the building (Tuula, 2012). Eventually, weeds and moulds grow on the vulnerable areas of the building or structure. In addition, weeds and moulds may also grow from the cracks that develop in the structure. When cracks develop in the building, necessary nutrients that support plant growth may enter into them and this may encourage plant or weeds to grow in them.

Peeling of plaster or rendering

Plaster or rendering is the external or internal mortar coating or finish respectively, giving to the block work, brickwork or concrete. Peeling of plastering or rendering may occur when there is prolong structural dampness. The bonding capacity of sand and cement component parts of the building may be saturated in the presence of prolong dampness. Bakri and Mydin (2014), report that, prolong dampness can cause damage in brickwork by saturating them, decaying and breaking up of mortar joints. When this happen the plaster or the render may peel off.

Peeling paint

Peeling paint usually occurs on building surfaces, mainly on plastered walls, columns and other areas which are exposed to excessive rain and dampness (Mansor et al., 2012). When buildings become always damp, the bond between the surface of the wall and film of the paint loses thereby making the paint peel off. Bakri and Mydin (2014), report that, one of the main reasons for peeling paint is excessive moisture surrounding the wall. Peeling of paint may result in embarrassment and frustration to the homeowner and this may call for frequent maintenance which may put financial burden on building owner.

Wood Rot

This is a situation whereby the wooden members of the building begin to decay. The main factor of defects of wooden structures in buildings is dampness (Mansor et al., 2012). Moisture from the ground can diffuse through the floor, walls and other concrete components and affect wooden members on direct contact (Homeowners against Deficient Dwellings, 2004). Air and moisture hasten the rate of timber decaying. When the timber members of the building become damp, chemicals and other agents that support decaying quickens and it makes the wood rot (Bakri & Mydin, 2014).

Technologies for Minimising the Effects of Wet Conditions on Buildings

The ground condition to every building is one of the essential components of the building process (Qureshi, Nasir-u-din, Tahir and Ilyas, 2012). This is because the nature of the ground on which the building is constructed has a greater influence on the structural component of the building. According to Threadgold (2007), the soils or rocks which may be present at a site have resulted from the process of nature over a long period of time and have been subjected to an enormous range of influences such as tectonic movements, volcanic activity, deposition, erosion and weathering. These influences have not been produced by any artificially controlled process which therefore be known through site investigations. This will help to employ special construction design on the ground base on its conditions and the nature of building to be built.

ISSN 2055-0197(Print), ISSN 2055-0200(Online)

Hooda, Parveen, Bhupinder, Verma, and Dhiman (2013) stated that, special foundation techniques are required where the soil is problematic such as loose cohesion soil, soils with high water table, saturated fine silt, saturated clays and expansive clays.

Wetlands contain a lot of ground water because the water table is normally higher (Braddock, 2007).

Kreibich and Annegret (2008) opine that, wetlands usually have high groundwater levels which can cause considerable damage to buildings. It is therefore necessary to consider the ground conditions of such areas so that appropriate design and technology of construction can be duly applied. According to Ishak, Chohan, and Ramly (2007), anyone who set out to create buildings in wet areas must also make sure that the structure is designed to have proper drainage systems and water proofing membranes. The wetlands have large amount of topsoil which support plant growth. This type of soil has weak bearing capacity. It is therefore necessary to remove this type of soil and replace with a good quality laterite which may give a reasonably firm ground for the building (Brix, 2003). In addition, rising dampness is one of the damaging defects of buildings (Agyekum et al., 2013). As result, the U.S. EPA (2013) recommends the use of damp proof membrane to control it.

There are numerous ways by which rising dampness can be prevented in buildings. Physical barrier can be created at the base of walls above ground level to prevent rising damp. This can be done by reducing the rate of absorbent area or placing water tight barriers. The rate of absorbent area can be reduced by replacing part of the wall with air pocket to reduce the amount of water absorbed and also increases the rate of evaporation (Torres & Peixoto de Freitas, 2005). Also, watertight material such as damp proof membrane can be inserted into the wall above the ground level (as has been shown in Plates 13-16) to prevent water from migrating to upper levels (Torres & Peixoto de Freitas, 2005). This may consist of flexible impervious materials like bituminous felt and polythene sheets. It can also be made of rigid and semi rigid materials such as mastic asphalt, corrugated sheets of stainless steel, fired bricks, stones, concrete and slate. Grout material which consists of cement slurry and acrylic base chemical can also be used. These materials are laid in walls above or below ground level to control rising dampness through walls. Similarly, the damp proofing materials could be laid over the entire area of the building in the ground floors. This will help control rising dampness from every part of the building (Torres & Peixoto de Freitas, 2005).

In the case of existing buildings, rising dampness can be treated with chemical damp proof solution such as Dryzone damp proof cream (Safeguard Europe Limited, 2007). This can be applied by injecting the cream into drilled holes into the walls at certain intervals to alter the interference between the pores and the rising moisture. This must be done well to ensure that the chemical barrier covers the entire width and length of the affected walls.

Furthermore, ventilated peripheral channels can be created to reduce water contact with porous walls and increase the rate evaporation of absorbed water. This new technique consists of ventilating the base of walls through a natural ventilation process or by installation of hygro-regulated mechanical ventilation device (Guimarãesn and Peixoto de Freitas, 2009). Wall base ventilation increases evaporation, which leads to a reduction in the level achieved by the dampness. This can be effective when the groundwater is lower than the base of the wall.

ISSN 2055-0197(Print), ISSN 2055-0200(Online)

METHODOLOGY

The Study Area

Kumasi is the capital of the Ashanti region, located at North West of Accra, the capital of Ghana. It is situated in a transitional forest zone with an area of about 254km^2 (Adarkwa, 2011). The city is the second most populous in the country as it attracts all sorts of immigrants from all parts of the country with a population of about 1,730,249 (Ghana Statistical Service [GSS], 2015). Gregory (2005) report that, the driving reason for most people migrating from rural areas to urban centres is in search for work and other urban benefits

Research Design: The study employed a cross-sectional survey design utilizing mixed methods. Cross-sectional survey design was used because it specifies the nature of a given phenomenon and reports things the way they are (Cresswell, 2009).

Population: The targeted population identified for the study was developers in the major wetland areas in Kumasi. The population and housing units of the city are distributed among 9 sub metros as shown in table 1:

Table 1: Population and Number of Houses of the Kumasi Metropolis

Sub Metro	Population	No. Houses
Kwadaso	251,215	61,379
Nhyiaeso	134,488	35,354
Subin	174,004	48,678
Asokwa	140,161	36,726
Oforikrom	303,016	75,156
Manhyia	159,668	43,960
Old Tafo	146,024	37,403
Suame	161,199	41,794
Bantama	260,474	66,521
Total	**1,730,249**	**446,971**

(Source: GSS, 2015)

Sample and Sampling Techniques

According to Abdul-Razak (2012), the major wetland sites of ecological, landscape, economic and social interests were at Aboabo, Bantama, Kwadaso, Sisai, Subin, and Wewe. There were wetlands at other areas such as Asuoyeboa and Suntre which were of equal importance to the study. Some of the communities around these rivers are Aboabo, Bantama, Kwadaso Estate, Atonsu, Ahensan, Dakodwom, UST, Oforikrom, Airport Roundabout, Asafo, Asokwa, Breman and Asuoyeboa.

Ten wetland sites of the communities were purposively sampled for the study. The selection was based on literature that, they are the worse affected of floods anytime there is heavy rain fall (Abdul-Razak (2012).The selected areas were Tanoso, Asuoyeboa, Kwadaso Estate, Atonsu 'S' Line, Bantama, Dakodwom, Ahensan fitting area, Anloga Junction, Family Chapel, and Ahodwo-Daaban.

ISSN 2055-0197(Print), ISSN 2055-0200(Online)

These areas were zoned or put into strata and developers (buyer of land for building purposes) outside the buffer range of about 30m from the rivers or streams channel were selected as the population for the study depending on the size of the area which amounted to 450 structures. According to MWRWH (2011), building development must be restricted within a buffer range of about 30m from the channels of rivers or streams. The table 2: Shows sample size of estimated number of structures

Table 2: Estimated Number of Structures and Sample Size

Zone (Description)	Estimated No. of Structures	Sample Size	Respons e
A (Tanoso, off Denkyemuoso road)	50	15	14
B (Asuoyeboa, IPT off Nyankyerenease road)	30	9	9
C (Kwadaso Estate, near Ohwimase)	60	18	17
D (Bantama, between Bantama and Sentreso North)	40	12	10
E (Ahodwo-Daaban, Unity oil area)	40	12	9
F (Ahensan Fitting Area)	60	18	16
G (Atonsu 'S' Line)	60	18	14
H (Anloga Junction)	30	9	8
I (Family Chapel, Susuanso)	40	12	12
J (Dakodwom)	40	12	11
Total	**450**	**135**	**120**

According to Asamoah-Gyimah and Duodu (2007), a sample size of about 10-30% of the population is acceptable for quantitative research. A sample size of 135 which is 30% of the population was chosen for the study.

Questionnaire Administration

Structured and unstructured questionnaires were administered to about 135 developers of the selected study area. Five point likert scales was used for the study. The five point scale was: strongly disagree (1), disagree (2), uncertain (3), agree (4), and strongly agree (5). Developers were randomly sampled from ten wetland sites and structured questionnaire related to the study were administered to solicit information relevant to the study. This gave equal opportunities or chances for each developer in each of the areas to be selected (Creswell, 2012). In all, 120 questionnaires were received indicating 89% responds rate.

Reliability and Validity of Instruments

The questionnaires were pre-validated by competent assessors both in research and on the field of work. This helped to assess the contents and items included in the questionnaire so that it would be able to measure the expected outcome accurately (Creswell, 2012). The questionnaires were pre-tested on the subjects of this research as suggested by Dillman (2005) and Martin et al. (2007). This is because, effective and efficient questionnaires may not emerge fully-fledged. They are normally created or adapted, fashioned and developed to maturity after many trials (Dillman, 2005). After the pre-testing of questionnaire it was revised accordingly

ISSN 2055-0197(Print), ISSN 2055-0200(Online)

based on the feedback received. As a result, all the constructs achieved a reliability and validity standards required by scientific research (Hinton et al., 2004; Creswell, 2012). The factors had a Cronbach's Alpha of 0.815 and KMO value of 0.824.

Data Analysis

The data were then computed and analysed using Statistical Package for Social Sciences (SPSS) Version 20, after the factors had satisfied the validity and reliability test. The data collected were analysed quantitatively and qualitatively using both descriptive and inferential statistics.

Relational analysis was conducted using one-way ANOVA and their statistical significance (Cresswell, 2012). Also, Microsoft Excel were used. The results were presented using distribution tables, percentages means, standard deviations and graphical formats for easy interpretation

RESULT AND DISCUSSIONS

The Effects of Wet Conditions on Buildings

Table 3 shows the effects that may result from wet conditions on building on wetlands in Kumasi. A theoretical mean from a 5 point likert scale was peg at 3 to determine the relevance of the responses. From Table 3, respondents agreed that, their buildings were experiencing dampness (3.5667), the base of concrete walls get saturated (3.4667), their buildings were experiencing peeling of paint (3.4667), their buildings were experiencing cracks (3.4667), their building were experiencing staining of wall covering (3.3833), they were experiencing deterioration of carpet (3.0833), their buildings were experiencing growing of moulds (3.0167) and their building experiencing peeling of plastering works (3.0000). On the other hand, respondents disagreed to occurrence of wood rot (2.9750) and standing water on floor (2.8917). The results indicate that, occurrence of dampness may also result in high levels of other related health problems as indoor dampness is a determinant of the presence of several potentially problematic exposures (National Academy of Sciences, 2007). The occurrence of cracks at any level or on component of the building may be damaging and costly. This is because cracks are very difficult to deal with since it has the tendency of extending perpetually ones it starts. Excessive cracks if unchecked may result in general structural weakness (Agyekum et al., 2013)

ISSN 2055-0197(Print), ISSN 2055-0200(Online)

Table 3: Effects of Wet Conditions on Buildings

Effects	N	Mean	Std. Deviation	Ranking
Dampness (wet floors and walls)	120	3.5667	1.15761	1st
Saturated base of concrete block walls	120	3.4667	1.22942	2nd
Peeling of paint	120	3.4667	1.06063	3rd
Occurrence of cracks	120	3.4667	1.15179	4th
Staining of wall covering	120	3.3833	1.11659	5th
Deterioration of carpet	120	3.0833	1.11207	6th
Growing of molds	120	3.0167	1.15942	7th
Peeling of plastering works	120	3.0000	1.20921	8th
Rotting of wooden members	120	2.9750	1.14100	9th
Standing water on floor	120	2.8917	1.21473	10th
Efflorescence(whitish powder appearing on wall surface)	120	2.7250	1.11493	11th

When Building was constructed and Dampness

Table 4 shows the relationship between the year building was constructed and the occurrence of dampness base on pertinent descriptive statistics and ANOVA results. From Table 4, all the responses for various year groups except after 2015 were rated above the theoretical mean of 3 from the 5 point likert scale items. This means that, the structures that were built before 1990 to 2014 were experiencing dampness. The results indicate that, the structures that were built before 1990 were experiencing dampness in very high levels (4.6316) followed by the structures that were built between 1991 and 1996 (4.3750). Similarly, the structures that were built between 1997 and 2002 (3.6667), between 2003 and 2008 (3.6000), and between 2009 and 2014 (3.1818) were also experiencing some level of dampness. Confirming the differences, the F-value of 21.261 was considered with its significant value of 0.000 which is less than alpha 0.01, leading to the conclusion that there were significant differences in dampness and the year building was constructed at one percent level of significance. The study had reveal that from 2015 to date developers had been using some sort of technologies to reduce the rate of dampness in buildings constructed in wet areas.

Table 4: When Building was constructed and Dampness

Year Group	N	Mean	Std. Deviation	F	Sig.
before 1990	19	4.6316	.49559	21.261	.000
between 1991-1996	24	4.3750	.49454		
between 1997-2002	15	3.6667	.89974		
between 2003-2008	10	3.6000	.84327		
between 2009-2014	22	3.1818	1.00647		
after 2015	30	2.4667	1.07425		
Total	**120**	**3.5667**	**1.15761**		

ISSN 2055-0197(Print), ISSN 2055-0200(Online)

Appropriate construction technologies for controlling the Effects of Wet Conditions on Buildings.

The respondents were asked to rate their level of agreement or strongly agreement and disagreement on the appropriate technologies they deem fit to control wet condition on buildings. A theoretical mean from a 5 point likert scale was peg at 3 to determine the relevance of the responses. The result in table 5 indicates that respondents ranked laying of damp proof membrane as first (1^{st}) position with mean value of 4.467 followed by laying of damp proof course ranked second (2^{nd}) position with mean value of 4.267. Constructing pad foundation was ranked third (3^{rd}) position with mean value of 4.208. Constructing raft foundation was ranked fourth (4^{th}) position with mean value of 4.150. However respondents ranked using 1:2:4 concrete ratios as fifth (5^{th}) position with mean value of 3.633. Laying of subsoil drainage was ranked sixth (6^{th}) position with mean value of 3.550. Use of 1:3 mortar ratios for plastering was ranked seventh (7^{th}) position with mean value of 3.475. Casting of over site concrete was ranked eight (8^{th}) position with mean value of 3.225. Filling to get firm ground was ranked ninth (9^{th}) position with mean value of 3.008. Among the major findings of the study on appropriate technologies for controlling effect of wet conditions are applications of (DPM), (DPC), and sub soil drainage, this finding are similar to findings of Ishak, Chohan, and Ramly (2007), who found that anyone who set out to create buildings in wet areas must also make sure that the structure is designed to have proper drainage systems and water proofing membranes. Again, the study reveals that pad and raft foundations are appropriate technologies for controlling effect of wet conditions and these finding is in line with Hooda, Parveen, Bhupinder, Verma, and Dhiman (2013) they stated that, special foundation techniques are required where the soil is problematic such as loose cohesion soil, soils with high water table, saturated fine silt, saturated clays and expansive clays.

Table 5: Appropriate Technologies

Technologies	**N**	**Mean**	**Std. Deviation**	**Ranking**
Laying of damp proof membrane (dpm)	120	4.467	.59314	1^{st}
Laying of damp proof course (dpc)	120	4.267	.86708	2^{nd}
Constructing pad foundation	120	4.208	1.02814	3^{rd}
Constructing raft foundation	120	4.150	.90424	4^{th}
Using of 1:2:4 concrete ratio	120	3.633	1.04466	5^{th}
Laying sub-soil drainage	120	3.550	1.35876	6^{th}
Use of 1:3 mortar ratio for plastering	120	3.475	1.41399	7^{th}
Casting of over site concrete	120	3.225	1.07267	8^{th}
Filling to get a firm ground	120	3.008	1.01663	9^{th}
Removal of top soil	120	2.183	1.03699	10^{th}
Site investigations	120	2.017	.36630	11^{th}
Valid N (listwise)	120			

ISSN 2055-0197(Print), ISSN 2055-0200(Online)

Technologies Used by Developers to Control the Effects of Wet Conditions on Buildings

This part of the study further investigated into the appropriate technologies developer adopted when building on wetlands. The respondents were asked to answer yes or no to the appropriate technologies they used, from figure 1, 8.3% of the respondents used damp proof membrane (DPM) before casting over site concrete. However 16.7% provide damp proof course (DPC) on the wall. With regard to construction of pad foundation 8.3% of respondent adopted this technology. Again 12.5% of the developers sometimes use raft foundation to prevent dampness in building. Furthermore 10% of the developers adopted 1:2:4 concrete ratio for their concrete works. Also, 7.5% of developers use sub soil drainage to reduce level of water table. 10.8% use 1:3 mortar for plastering. However, more than half of the developers representing 55.8% cast over site concrete before laying super structure work. With regards to filling the land to obtain a firm ground before building, closed to half of the developers (47.5%) do fill the land before building commenced. However 36.7% remove vegetative cover before they commence their building. Finally, 5.8% carry out site investigations before staring their buildings. The result of the study reveals that only small number of developers uses the appropriate technologies, for example 8.3% and 16.7% apply (DPM) and (DPC) respectively. However, the greater number of developers representing 91.7% and 83.3% do not apply (DPM) and (DPC) respectively. Such developers exposed their buildings to defects such as dampness, cracks, growing of weeds and moulds. In view of Cotgrave (2005), the existence of dampness in buildings is one of the most damaging failures that can occur in buildings. Dampness in buildings can cause deterioration of buildings by damaging brick/block work, cause decay and disintegration of mortar joints, fungal attack in timber, developing some level of cracks which may intend weakened the structural component of the building and corrosion of metals as well as stained wall surfaces internally and externally (Agyekum et al., 2013). Damp structures are susceptible to growing weeds and moulds because air and moisture support plant growth. Moulds may cause wheeze, cough, asthma, shortness of breath, skin problems, gastrointestinal problems, fatigue, cancer, reproductive effects National Academy of Sciences (2007). Tuula (2012) also adds that, moulds can hasten the rate of occurrence of asthma and other related diseases. In Ghana, Asamoah, Forson, and Boakye (2012), conducted studies on the health of patients and found out that, most respiratory diseases are caused by indoor dampness. Though more than half of the developers representing 55.8% apply over site concrete on their building works, this could not stop dampness as small number of developers about 10% uses 1:2:4 concrete mix ratio for their concrete work this mean that majority of developers who apply over site concrete do not used 1:2:4 concrete mix which could contribute to reduction of damp prevention.

ISSN 2055-0197(Print), ISSN 2055-0200(Online)

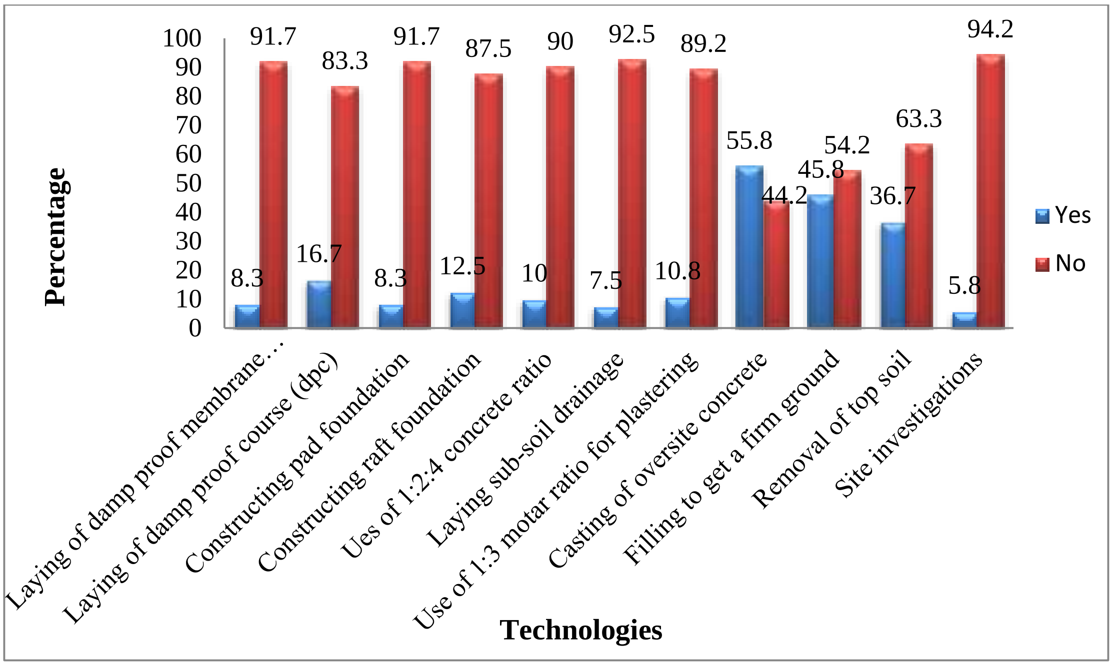

Figure 1: Technologies used by developers to Control the Effects of Wet Conditions on Buildings

When the Building was Built and the Related Technologies

This part of the study further explores the technologies that were used to construct buildings in wetlands before 1990 to 2015. From Figure 2, the results show that developers started using (dpm) from 2009. 2.5% of the respondents used (dpm) between 2009 to 2014, 5.8% used (dpm) after 2015. Also, the study shows that respondents started using (dpc) in 1997. Between 1997 and 2002 recorded 0.8%, between 2003 and 2008 recorded 1.7%, between 2009 and 2014 recorded 2.5% and after 2015 recorded 11.7%. However, the study found that respondents started using pad foundation in wet areas in 2009. Between 2009 and 2014 recorded 1.7%, and after 2015 recorded 6.6%. Again, the results highlighted that respondent started using raft foundation in wet areas in 2009. Between 2009 and 2014 recorded 2.5%, and after 2015 recorded 10%. Moreover, respondents began using 1:2:4 concrete mix ratio in 2003. Between 2003 and 2008 recorded 0.8%, between 2009 and 2014 recorded 1.7% and after 2015 recorded 7.5%. However, respondents began laying sub soil drainage under their building in wet areas in 2003. Between 2003 and 2008 recorded 0.8%, between 2009 and 2014 recorded 1.7% and after 2015 recorded 5%. Intrestinly the study found that respondents began using over site concrete before 1990 with record of 0.8%, but this has increase to 30.2% after 2015. Again, respondents started fill to make up level before 1990 with record of 0.8%, this increased after 2015 with 19.2%. Moreover removal top soil also started before 1990 with record of 1.7%, the uses increased after 2015. However, respondents started site investigation in 2003 with record of 0.8%, this has increase to 21.5 after 2015. The result of the study indicates that, less than quarter of the respondents lay (dpm) and (dpc) example polythene sheets over the entire area of building before casting over site concrete or on the wall. Damp proof membrane (dpm) and damp proof course (dpc) are the most effective way of controlling rising dampness (Torres & Peixoto de Freitas, 2005). It is therefore necessary for developers to consider damp proof membrane if the building is likely to be affected by rising dampness (Ishak, Chohan, & Ramly, 2007). Unfortunately, only a handful of the developers used (dpc) as a strategy of controlling the effects of wet conditions on buildings. This might be the reason why most of the buildings

ISSN 2055-0197(Print), ISSN 2055-0200(Online)

studied were experiencing dampness (Table 3). Furthermore, more than quarter of the respondents cast ground floor concrete or over site concrete before continuing the superstructure. The over site concrete serves as a bridge between the substructure and the superstructure. It also gives a firm base to the superstructure. It also helps to control rising dampness if constructed properly (The Civil Engineer, 2012). It is therefore pathetic for a greater number of the buildings studied to have ignored this important aspect of the building. This means that majority of the buildings may lack the capacity to effectively control rising dampness. Additionally, only a small number of the respondents insert drain tubes at footings level. This technique helps to drain excessive water from the substructure in order to reduce the amount of moisture that can relatively have effect on the building. This may be done in addition to other strategies of controlling the effects of wet conditions on buildings such as damp proof membrane, mostly where there is excessive water in the ground or where the water table is very high. However, the study indicates that, more than one-third of the respondents remove topsoil before they commence their building. The topsoil contains high amount of humus (Brix, 2003). The high amount of humus has the capacity of containing a certain amount of moisture which is can affect the building negatively. It is therefore necessary to remove the topsoil before buildings are commenced. Unfortunately, only a small fraction removed the vegetative cover before commencing their buildings. This situation is likely to contribute to the effects of rising moisture affecting most of the buildings. Only a negligible number of the respondents who are less than quarter carried out site investigations before starting their buildings. Site investigation is very important as it reveals the nature of the soil on which the building is placed (Threadgold, 2007). Upon the knowledge of the nature of the soil, appropriate technology can equally be applied. The small number of the respondents carrying out this activity means that, majority of the developers may not be able to apply appropriate technologies for their buildings.

Also, nearly half of the developers filled their land to obtain a firm ground before buildings were commenced. The wetlands are normally situated on low levels which has very high water tables (Braddock, 2007). It is therefore necessary to fill the land in order to raise the area to a level conducive for buildings. This will help to lower the water table so that its effects on the building will be minimised.

ISSN 2055-0197(Print), ISSN 2055-0200(Online)

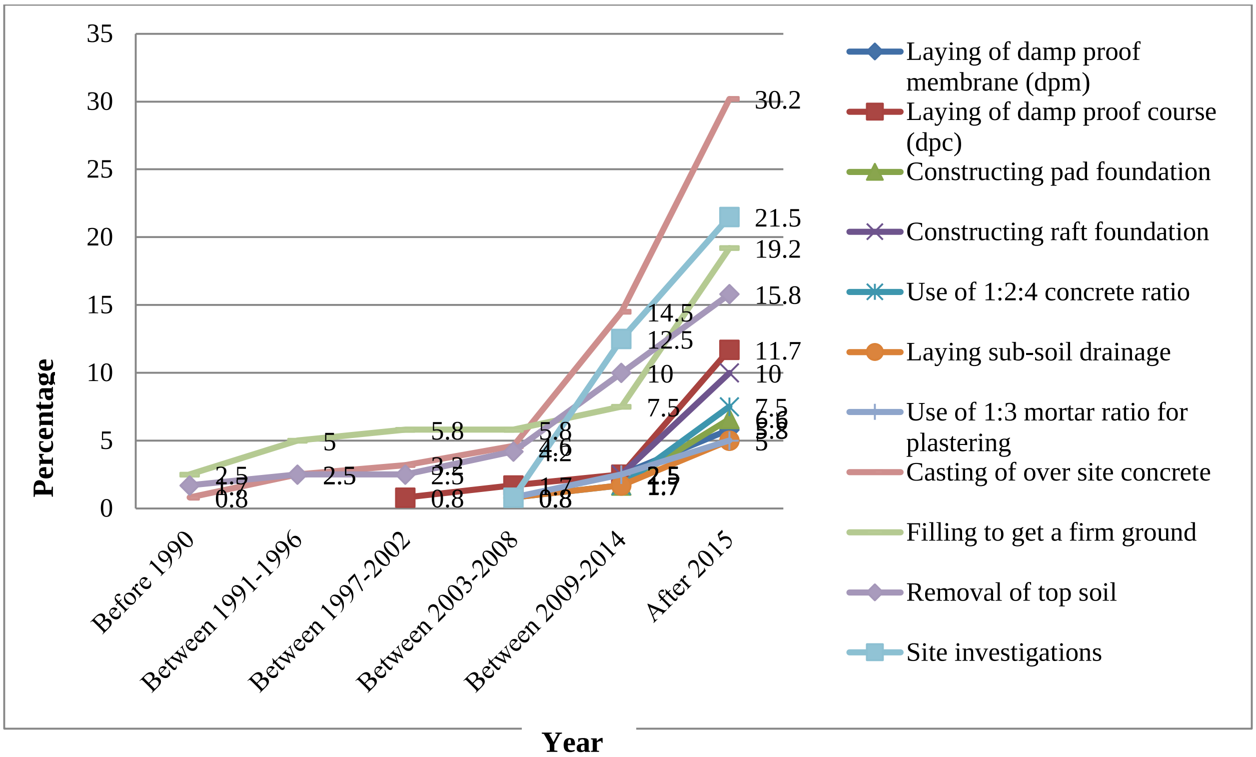

Fig.2 Related Technologies and when the building was built.

CONCLUSION

Building and construction has to support the world of continuing population growth and economic development, at the same time, it must pay heed to the widespread social interest in environmental preservation. This study focus on the appropriate technologies adopted to control the effect of wet conditions in Kumasi metropolis. The following conclusions were drawn based on the major findings of the study. The study reveals that wet conditions contributed to eight defects to buildings such defects are dampness to floors and walls, saturation at the base of concrete walls, peeling of paint, cracking of buildings, staining of wall covering, growing of moulds, peeling of plastering works and deterioration of carpet. Again, the study found nine appropriate technologies that could be used to control effect of wet conditions these includes laying of damp proof membrane, laying of damp proof course, construction of pad foundation, construction of raft foundation, use of 1:2:4 concrete mix ratio, laying of sub soil drainage, casting of over site concrete, use of 1:3 mortar for plastering and filling to make firm level. Moreover, the results of the study shows that developers used all the nine technologies but not on grand scale, since small number of developers have been using some of the technologies.

The results show an increasing trend of the use of proper technologies in recent times. However this trend of increase is minimal as compere to current dispensation where building professionals are abundance in the country and these are capable to apply the appropriate construction technologies. The study strongly recommends that city authority should strengthen the departments/agencies that take charge of supervision on building construction activities with appropriate logistics to enable them discharge their duties effectively. That city authority should start implementing the building regulation to the later in other to check and

ISSN 2055-0197(Print), ISSN 2055-0200(Online)

regulate activities of the developers. Developers should be made aware of the consequences of wet conditions on buildings and strategies that can be used to control or minimised it.

Acknowledgement

To God be the glory great things He has done. We wish to express our sincere gratitude to the Almighty God for seeing ours through this research work. Our profound gratitude goes to Dr. Francis Kofi Bih who provided constructive criticisms, insightful suggestions and valuable time in spite of the heavy demand on this time. We appreciate all who in diverse way contributed to the realization of this work.

REFERENCES

Abdul-Razak, I. (2012). *Assessing the Ecology of Wetlands in Kumasi and the Adaptations of the Communities to Floods.* Retrieved from Kwame Nkrumah University of Science and Technology Dissertation Data Base

Adarkwa, K. K. (2011). The Role of Kumasi in National Development-Kumasi as a Central Place. In Adarkwa K.K. (Ed.), *The Future of the Tree*: *Towards growth and development of Kumasi.* (14-34). Kumasi: UPK.

Agyekum, K., Ayarkwa, J., Koranteng, C. and Adinyira, E. (2013). Preliminary Assessment of Dampness in Walls of Residential Buildings in Four Climatic Zones in Ghana. *Journal of Sustainable Development*, *6*(9), 51-61

Amo, M., Bih, K. F. Agyeman, A. J., Adu, G. T., Mensah, M. (2017) Investigation into the Acquisition and

Anku, K. S. (2006). *Managing Wetlands in Accra, Ghana.* African Regional Workshop Cities, Ecosystems and Biodiversity Nairobi. [PDF document]. Retrieved from http://www.unep.org/urban_environment/PDFs/ManagingAccraWetlands.pdf

Asamoah, A. S., Forson, A. G., and Boakye, D. A. (2012). A review of epidemiological studies of asthma in Ghana. *Ghana Medical Journal*, *46*(2), 23-28.

Asamoah-Gyimah, K. and Duodu, F. (2007). *Introduction to research methods in education.* Winneba: Institute for Educational Development and Extension, University of Education Winneba

Bakri, N. N. O. and Mydin, M. A. O. (2014). General Building Defects: Causes, Symptoms and Remedial Work. *European Journal of Technology and Design*, *3*(1), 4-17

Betey, C. B. and Owusu-Boateng, G. (2013). The Political Ecology of Wetlands in Kumasi, Ghana. *International Journal of Environment and Bioenergy, 7*(2), 108-128

Braddock, T. (2007). Wetlands*: An introduction to ecology, the law, and permitting.* Second Edition. Plymouth, UK: The Scarecrow Press, Inc.

Brix, H. (2003). *Plants Used in Constructed Wetlands and their Functions: 1st International Seminar on the Use of Aquatic Macrophytes for Wastewater Treatment in Constructed Wetlands*. Risskov, Denmark: Lisboa

Burns, R. B. (2000). *Introduction to research methods.* (4th ed.). London: Sage Publications Ltd

Cotgrave, R (2005). *Dampness in buildings* [PowerPoint Slides]. Retrieved from http://www.eng.utoledo.edu/~akumar/IV/PowerPoint/IV8.ppt

Creswell, J. W. (2012). Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research. (4th ed.). Boston: Pearson Education, Inc.

ISSN 2055-0197(Print), ISSN 2055-0200(Online)

Creswell, J. W. (2009). Research *design: Qualitative, quantitative and mixed methods approach.* (3rd ed.). Thousand Oaks, California: Sage Publications Ltd.
Danso, H. & Manu, D. (2013). High Cost of Materials and Land Acquisition Problems in the Construction Industry in Ghana. *International Journal of Research in Engineering & Applied Sciences 3*(3), 18- 33
Development of Wetlands in Built Environment Industry: A Case Study
Dillman, D. A. (2005). Mail and Internet Surveys: The Tailored design Method. Hoboken, New Jersey: John Wileys & Sons Publications.
Dordio, A., Carvalho, A. J. P. & Pinto A. P. (2008). Wetlands: Water Living Filters. In Raymundo E. Russo (Eds.), *Ecology, conservation and restoration*. (15-72). New York: Nova Science Publishers, Inc.
Forkuor, D. (2010). *Land Allocation and its Effects on the Spatial Planning and Development of Kumasi Metropolis.* Retrieved from Kwame Nkrumah University of Science and Technology Dissertation Data Base
Ghana Health Service (2010). *The health sector in Ghana facts and figures*. Accra: Centre for Health Information Management
Ghana National Commission for UNESCO (2010). *Wetlands as models for sustainable development.* Accra, Ghana. Ashong Sheila.
Ghana Statistical Service (2015). *2010 Population & Housing Census: Summary Report of Final Results.* Accra: Sakoa Press Limited
Ghosh, S. N. (2014). Flood Control and Drainage Engineering. (4th ed.). London, UK: Taylor & Francis Group
Guimarães, A. S. & Peixoto de Freitas, V. (2009). Wall base ventilation system as a new technique to treat rising damp in existent buildings. *Journal of Building Appraisal, 5*(2), 187–195
Hinton, P. R., Brownlow, C., McMurray, I. & Cozens, B. (2004). SPSS Explained. New York, NY: Routledge Inc
Homeowners Against Deficient Dwellings (2004). Common defects in new home construction: A list of common defects in new homes experienced by homeowners. Texas: Eureka
Hooda, N., Parveen S., Bhupinder S., Verma, V. & Dhiman, S. (2013). Modern Trends in Construction. *International Journal of Innovative Technology and Exploring Engineering (IJITEE), 3*(3), 80-83
Horvath, A. (2004). *Construction materials and the environment*. Berkeley, California: Annual Review Inc.
in Kumasi Metropolis. International journal of civil Engineering, Construction and Estate
Ishak, S. N. H., Chohan, A. H. & Ramly, A. (2007). Implications of design deficiency on building maintenance at post-occupational stage. *Journal of Building Appraisal, 3*(2), 115-124
Kreibich, H. & Annegret, H. T. (2008). Assessment of Damage Caused by High Groundwater Inundation. *Water Resources Research, 44*, 1-14
Kumasi Metropolitan Assembly (2006). Physical characteristics of Kumasi. Retrieved from http://www.kma.ghanadistricts.gov.gh/?arrow=atd&_=6&sa=5475
Management vol.5, No 4, pp. 1-21.
Mansor, R., Mydin, M. A. O., Ismail, M. and Harun W. M. W. (2012). Categorization of General Problems and Defects in Historical Building. *1*, 127-136
Martin, E., Childs, J. H., DeMaio, T., Hill, J., Reiser, C., Gerber, E., Kathleen S. and Dillman, D. (2007). Guidelines for Designing Questionnaires for Administration in Different Modes. Washington, DC: U.S. Census Bureau

Ministry Of Water Resources, Works and Housing (2011). Riparian Buffer Zone Policy for Managing Freshwater Bodies in Ghana. Accra: Government of Ghana

Mitsch, W. J. & Gosselink, J. G. (2000). The Value of Wetlands: Importance of Scale and Landscape Setting. *Ecological Economics, 35*, 25-33.

Ofori, G. (2012). *Developing the construction industry in Ghana*: *The case for a central agency*. Singapore: National University of Singapore

Osei, V. (2013). The Construction Industry and its Linkages to the Ghanaian Economy-Polices to Improve the Sector's Performance. Published by European Centre for Research Training and Development UK. *International Journal of Development and Economic Sustainability*. *1*(1), 56-72.

Qureshi, L. A., Nasir-u-din, Tahir S. &Ilyas S. M. (2012). Effect of different soil conditions on static analysis & design of high rise buildings. *14th International Conference on Computing in Civil Building Engineering*. Moscow, Russia

Ramsar Convention Secretariat (2006). The Ramsar Convention Manual: A Guide to the Convention on Wetlands. (4th ed.) Gland, Switzerland: Ramsar Convention Secretariat

Russell, G., Green, R. & Rumpf, C. (2010). Managing the Groundwater Impacts of Construction in Sydney NSW. [PDF Document]. Retrieved from http://www.groundwater2010.com/documents/4HGregRussell.pdf

Safeguard Europe Limited (2007). Rising Damp and its Control: A guide to identifying the various forms of dampness encountered in buildings and control of rising damp through remedial action. United Kingdom: Safeguard Europe Ltd. Retrieved from http://www.safeguardeurope.com/pdf_datasheets/rising_damp_book.pdf

Sithole, A. & Goredema, B. (2013). Building in Wetlands to Meet the Housing Demand and Urban Growth in Harare. *International Journal of Humanities and Social Science, 3*(8), 193-201

The National Academy of Sciences (2007). *Damp Indoor Spaces and Health.* Washington, Dc: The National Academies Press

Threadgold, L. (2007). Site Investigation within the Development process. *Journal of Geotechniques, 28*(3), 1-11

Torres, M. I. M., & Peixoto de Freitas, V. (2005). Treatment of rising damp in historical buildings: wall base ventilation. *Building and Environment, 42,* 424 - 435

Tularam, G. A. & Krishna, M. (2009). Long Term Consequences of Groundwater Pumping in Australia: A Review of Impacts around the Globe. *Journal of Applied Sciences in Environmental Sanitation, 4*(2), 151-166.

Tuula, P. (2012). *Indoor air problems – exposure and health effects*. [PDF document]. Retrieved from http://www.helsinki.fi/henvi/yvv/esitykset/Putus2012.pdf

U.S. EPA (2013). Moisture Control Guidance for Building Design, Construction and Maintenance. Washington, DC: Office of Radiation and Indoor Air

Verhoeven, J. T. A., Beltman, B., Bobbink, R., & Whigham, D. F. (2006). Wetland Functioning in a Changing World: Implications for Natural Resources Management. In J. T. A. Verhoeven, B. Beltman, R. Bobbink, & D. F. Whigham (Eds). *Wetlands and Natural Resource Management*. (1-12): Berlin Heidelberg, Germany: Springer-Verlag

ISSN 2055-0197(Print), ISSN 2055-0200(Online)