International Conference of Science, Engineering & Environmental Technology (ICONSEET), 2(21): 161-167, 2017
ISSN 0794-9650

www.repcomseet.com

Assessment of the Effect of Underground Water on Civil Engineering Structures (A Case Study of Gaa-Odota, Ilorin)

K.O. Olorunfemi, E. O. Ibiwoye , and D.J. Adeleke.
Department of Civil Engineering, Institute of Technology
Kwara State Polytechnic, P.M.B 1375, Ilorin, Kwara State, Nigeria
E-mail: olorunfemikenny@gmail.com

Abstract- This research was carried out to assess the effect of underground water on civil engineering structures; buildings, roads and hydraulic structures and to provide possible solutions to problems emanating from the effect at Gaa-Odota Ilorin. Site visitation, aerial photographs and laboratory tests of underground water was carried out at lower Niger River Basin Authority Ilorin to determine the physio-chemical composition of underground water in the study area. All civil engineering structures assessed experienced the impact of underground water especially those that is very close to the river. The effect of underground water observed on buildings are water saturated wall, deep cracks in walls, discoloration of walls, wall plastering and paint film flaked off. Defects on roads and hydraulic structures; potholes on road pavement, edge cracks on road pavement, failure of road culvert, collapse of lined drainage The study reveals that retention of water is great enemy to civil engineering structures and chemical attack on structures can affect the durability of structures. The use of damp proof membrane, geotechnical test, introduction of drain pipes, land filling with aggregates and addition of sulfate resisting Portland cement into concrete are recommended in order to prevent civil engineering structures in the study area against deterioration and damages done by underground water.

Keywords; Bacteriological, Civil Engineering Structures, Cement, Cracks, Underground Water.

1. Introduction

Underground water is the water present beneath the earth surface in soil pore space and fracture of rock formation (Wikipedia). The top of underground water is called water table. Between the water table and the land surface is the unsaturated zone. In the unsaturated zone, moisture moves downward to the water table to recharge the ground water. The water table can be very close to the surface or very deep (up to hundred feet). The effect of underground water in civil engineering structures is a consequence of an action that underground water brought to civil engineering structures. Civil engineering is a professional engineering discipline that deals with the design, construction of naturally built environments including works like roads, bridges, canals, dams, culverts, drainages and buildings (Wikipedia). Structure is a series of connected interrelated elements that form together a system that can resist a series of external load effects applied to it, which includes its own self weight and provide adequate rigidity (Jack and Russell,2016), (Chudle and Greeno, 2004)

James (1985) in his study reported that the intended performance of hydraulic structures built on soluble rocks or soil foundation may depend upon the rate of dissolution caused by water seeping through joints, fissures or granular zones. Also changes in the composition of pore fluid in contact with clay minerals can lead to changes in permeability. George (1992) concluded that rising ground water has caused costly damages to structures and services in many urban areas of the Middle East reiterating the principal cause as artificial groundwater recharge from potable supplies, sewer systems and irrigation returns which may greatly exceed both the natural rate of recharge and capacity of the natural substructure and surface drainage systems to receive them. Much damage has occurred because the potential for rising groundwater were not recognized prior to development and the effect of a higher water table not often considered. Buildings, foundations, walls and floors can deteriorate by excessive rising of underground water. Underground water can cause efflorescence, peeling of Paint, foundation weakness, cracking of wall in building.

Jennifer et.al (2007) reported that pH can determine how well concrete holds up over time. Given that the constituents of concrete are Portland cement, aggregate and water. It is the pH of cement that is a critical component. For cement to effectively holds the various component, it should have pH of 11. The problem is that Portland cement does not resist many acidic compound well. In road works, if the concrete pH is between 9 and 11, the surface can withstand salting in winter and variable weather conditions. If the pH is between 7and 9, concrete starts to break down, as the pH falls below 6.5, it deteriorates and became porous.

Aquifers generally refers to any geological formation containing or conducting groundwater, especially one that supplies the water for well, spring or lake. An aquifer is a body of rock or soil that yields water for human use. Most aquifers are water-saturated layers of rock or loose sediment. The total amount of empty pore space in the rock material, called its porosity, determine the amount of groundwater the aquifer can hold. Materials like sand and gravel have high porosity and can absorb a high amount of water. Aquifers must have high permeability in addition to high porosity. Permeability is the ability of the rock or other material to allow water to pass through it. The pore space in permeable materials is interconnected throughout the rock sediment, allowing groundwater to move freely through it. Some high porosity materials like mud and clay have very low permeability. They soak up and hold water, but do not release it easily to other groundwater points, so they are not good aquifer materials. Sandstone, limestone, fractured granite, glacial sediment and gravel are example of material that make good aquifer, (Bish and Gates, 1994).

Water below the ground may be considered sub-surface water. The section through the ground from the land surface to the rocks forms the geological basement of the water profile. From the land surface and the level at which pore spaces are saturated, the water profile is rarely and incompletely wetted, with many air-filled voids, (Bish and Gates, 1994). Water passing through this zone may be referred to as vadose zone water. In the part of the profile extending from the land surface to the geological basement, water is found within pore spaces, in the soils or rock. Fetter (1985) explained that within the geological basement, water is usually only present as part of the chemical make of the rock itself, and not within voids or pores. Therefore, water in the subsurface are recognized as part of the water profile (Driscoll, 1986). As water infiltrates into the ground, it passes through the topsoil. A small part is retained by the soil, usually used by plant. Raw water coming down infiltrates or seeps into the soil. Rain water can also infiltrate into the pores and cracks on the mountain surfaces. The cracks in the rock are originated by the difference of temperatures during summer and winter or also from day and night due to gravitational force, water continues to pass through to the unsaturated zone. Driscoll (1986) clarified that water descends further into an unsaturated zone which is dominated by the presence of air in pore spaces within the soil or rock. This part of the profile which contains vadose water is known as vadose zone.

Precipitation is a vital component of how water move through earth’s water cycle, connecting the ocean, land and atmosphere. Precipitation occurs when the weight of water vapour condensing in the atmosphere is too heavy to be supported by air pressure. This precipitation occurs as rainfall, fog, mist, snow, frost and may be associated with topography or generated by most air originating from evaporation over the oceans. The water cycle describes how water evaporates from the surface of the earth, rises into the atmosphere, cools and condenses into rain or snow in clouds and fall again to the sub-surface as precipitation. (Todd, 1980)

Todd (1980) added that the rate at which water passes through the groundwater phase of the cycle varies considerably from tens of meters a day to as little as a meter a year or even less. Apart from the fact that groundwater can be helpful to all living things as whole, underground water can also have a negative effect on the entire civil engineering structures. Water circle or hydrological circle is shown in Fig.1.

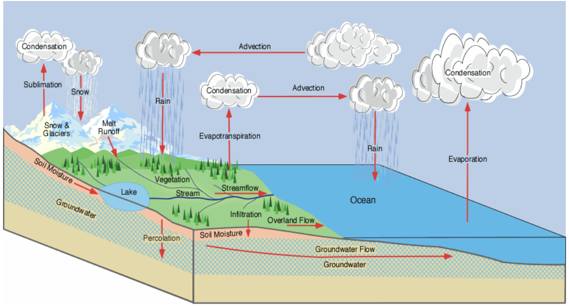

Fig. 1: Water cycle **(** www .google.com **)**

Fig. 2: Efflorescence on building at Gaa-Odota, Ilorin.

2. Research Methodology

Gaa-Odota, Ilorin was visited and aerial photographs were taken on the problems that occurred due to the effect of underground water on civil engineering structures. Water samples collected from two sampled wells were taken to Lower Niger River Basin Authority Ilorin for laboratory tests to determine the physical, chemical and bacteriological composition of underground water present in Gaa-Odota, Ilorin.

Defects on building Structures due to effect of underground water at Gaa-Odota, Ilorin

(i) Efflorescence: Is a whitish deposit on surface of masonry, wall and concrete. Efflorescence is a major problem found on many buildings in the study area. It consists of gypsum, salt or calcite. It is formed as mineral water rises to the surface through capillary and then evaporates.as shown in Fig. 2.

(ii) Mold growth: As underground water rises during rainy season, it penetrated into the block wall which led to mold growth on block wall and gradually weaken block walls as shown in Fig. 3.

Fig. 3: Mold growth on building at Gaa-Odota, Ilorin

Fig. 4: Partial collapse of building at Gaa-Odota,Ilorin.

(iii) Partial collapse of building: Penetration of water from underground to building structure at Gaa-Odota led to partial collapse of building as shown in Fig.4.

(iv) Paint peeling: Peeling of paint is caused by the presence of damp through underground water as shown in Fig. 5.

Fig. 5: Paint peeling on building at Gaa-Odota, Ilorin. Fig. 6: Disintegration of reinforced concrete slab at Gaa-Odota Ilorin.

(v) Disintegration of reinforced concrete slab: Disintegration of concrete at Gaa-Odota occurred as a result of freeze cycles on surface moisture which is caused by too much of water and the concrete pores then expand. The expansion of concrete forces off the concrete surface as shown in plate Fig. 6.

(vi) Cracks: Water movement from underground water to the foundation of building causes cracks in building at Gaa-Odota. This movement are cyclic in nature and are caused by increase or decrease in interpore pressure with moisture change when underground water rise through capillary action as shown in Fig. 7.

Fig. 7: Cracks on building at Gaa-Odota , Ilorin

Fig. 8: Potholes on road pavement at Gaa-Odota, Ilorin

Defects on roads structures due to effect of underground water at Gaa-Odota, Ilorin

(i) Potholes: This is a small, bowl shaped depression in pavement surface that penetrate all way through the asphalt layer down to the base course. They have sharps edge and vertical sides near the top of the hole. Potholes in this area was caused by moisture infiltration from underground water as shown in Fig. 8.

(ii) Edge cracks on road pavement: Edge cracks travel along the inside edge of the pavement surface within one or two feet. The cause of these cracks on road pavement at Gaa-Odota is poor drainage system as shown in Fig. 9.

Fig. 9: Edge crack on road pavement at Gaa-Odota,Ilorin

Fig. 10: Lined drainage collapse at Gaa-Odota, Ilorin.

Defects on hydraulic structures due to effect of underground water at Gaa-Odota, Ilorin.

(i) Lined Drainage Collapse: Lined drainage collapse at Gaa-Odota was as a result of excessive pressure of water in the ground beneath and beside drain lining as shown in Fig. 10.

(ii) Failure of road culvert: Culvert is a structure that allows water to flow under a road, railroad and trail. Failure of culverts in Gaa-Odota is due to upsurge of water through capillary action which led to corrosion of reinforcement and later breaks the concrete as shown in Fig.11.

Fig. 11: Failure of road culvert at Gaa-Odota, Ilorin.

Fig. 12: Water samples collected for tests at Lower Niger River Basin laboratory in Ilorin

3. Laboratory tests.

Water Sampling: Well water samples were collected from well A and well B, in Gaa-odota, Ilorin. Samples were collected in 2litres plastic bottle that were washed and double rinsed with distilled water before sampling. Tests to determine the physical, chemical and bacteriological parameters in the underground water was carried out as shown Fig.12.

4. Result and Discussions

Through site visitation it was discovered that all buildings closer to river at Gaa-odota, Ilorin experiences the impact of underground water than those far to the river. Defects on buildings are Efflorescence, mold growth, paint peeling, cracks, concrete spalling, and disintegration of reinforced concrete slab. Efflorescence is predominant in Gaa-Odota because the soil of the area is marshy. Defects on roads and hydraulic structures at Gaa-Odota are potholes, lined drainage collapse, failure of road culvert and edge crack on road pavement. Lined drainage collapse in Gaa-Odota is predominant because the area is water logged due to poor channelization of the Gaa Odota River as shown in Fig 9. The results of Physio-chemical Test obtained for water sample A and sample B are presented in Table1.

Table 4.1 Physio-chemical Test result of underground water from Gaa- Odota, Ilorin

S/N	PARAMETER	SAMPLE A	SAMPLE B
1	pH	7.6	6.54
2	Carbonates, mg/l	0.00	0.00
3	Bicarbonate, mg/l	0.75	0.65
4	Total hardness, mg/l	5.80	5.80
5	Calcium, mg/l	3.75	3.75
6	Magnesium, mg/l	2.05	2.05
7	Chlorides, mg/l	19.5	23.99
8	Sulphates, mg/l	480.01	515.88

pH value: W.H.O permissible limit of pH for drinking water range between 6.5 and 9 thus pH of Gaa-Odota, Ilorin is within permissible limit for drinking but for concrete the pH at Gaa-Odota is not within permissible limit which resulted into deterioration.

Total Hardness (Th): Total hardness is considered as the main characteristics property of potable drinking water. The term total hardness is used to describe the combination of calcium and magnesium hardness and when the calcium hardness is too low or too high, pitting of concrete pool surface, Cloudy water, etching of plaster, Rough surface, dissolving of grouts, clogged filters and reduce circulation through piping, pitting of concrete pool deck are common problem. Permissible limit of calcium and magnesium hardness for drinking water according to W.H.O is 1.0, Indian Standard Institution is 0.05. Due to high content of calcium and magnesium in Gaa-Odota, corrosion of reinforcement usually occurs.

Chloride: The samples are having chloride content above the permissible limit as B.S 8110. B.S 8110 part1 clause 6.2.5.2 limits the total chloride content expressed as a percentage of chloride ion by mass of cement to 0.4% for concrete containing embedded metal and the chloride content in the study area are 19.50 and 23.99 which is above permissible limit. High concentration of chloride ion cause corrosion of reinforcement and its durability is affected.

Sulphate: Sulphate is present in most cement and some aggregate. Sulphate may also be present in soil, groundwater and seawater, industrial waste and acid rain. The product of sulphate in concrete or civil engineering structures occupy a larger space and these causes the concrete structures to disintegrate and permit corrosion of steel. B.S 8110 part 1 clause 6.2.5.3 stated that the total water soluble sulphate content of the concrete mix express as SO_3 should not exceed 4% by mass of cement in the mix and the sulphate content in the study area exceed 4%. The sulfate content in Gaa-Odota are 480.0 and 515.88 these are beyond permissible limit as per BS 8110.

Carbonate (Phenolphtalein Alkalinity): The alkalinity (carbonate) in the study area is within permissible limit, the result is 0.00 which indicate that no alkalinity is present

Bicarbonate (Methyl Orange Acidity): Ordinary Portland cement is not acid resistance and acid attack may remove part of the set cement. Acids are formed by the dissolution in water of carbon-dioxide or sulphur-dioxide from the atmosphere. Acids can also come from industrial wastes. Acids is present in underground water of the study area and content of acidity in two samples at Gaa-Odota is 0.75 and 0.45 these cause deterioration of civil engineering structures.

5. Conclusions

The research work reveals that water retention on civil engineering structures is a great enemy and chemical attacks from rising underground water on structure can affect the durability of structure. The permissible limit of concrete for sulphate is 4% (BS 8110), chloride is 0.4%, calcium and magnesium hardness is 1.0 (W.H.O and ISI), pH is between 6.5 to 9 (W.H.O for dinking water) while that of concrete is 7. Also, the underground water in Gaa-Odota is very close to the earth surface and contained chemicals that are non-friendly to civil engineering structures resulting into defects on building such as efflorescence, cracks, paint peeling,concrete disintegration,concrete spalling, mold growth. Defects on roads and hydraulic structures; potholes on road pavement, edge cracks on road pavement, failure of road culvert, collapse of lined drainage are common in Gaa-Odota,Ilorin. The use of damp proof membrane, geotechnical tests, introduction of drain pipes, land filling with aggregates and addition of sulphate resisting Portland cement into concrete are recommended in order to prevent civil engineering structures in the study area against deterioration and damages done by underground water.

References

[1] Bish, S. and Bradd, J. M. Groundwater Reconnaissance Survey", Manilla - Tamworth " DWR Technical Report No. TS94.027. Quirindi Area, New South Wales. (1994) p. 27-32

[2] B. S 8110 Structural Use of Concrete, Part 1 clause 6.2.5.2 and clause 6.2.5.3. British Standard Institute, London (1997) p. 35-38

[3] Chudley, R. and Greeno, R.; Advance Construction Technology ,4th edtion, Harlow England Longrnan, (1999) p. 143-151

[4] Chudley, R. and Greeno, R. "Building Construction Handbook". Elsevier Butterworth-Heinemann, United Kingdom. (2004) p. 233-235

[5] Concretenetwork.com. (April 2016). What is Foundation Waterproofing versus Dampproofing? The concrete Network (Online) Available at http://www.concretenetwork.com/foundation-waterproofing-drainage/damproofing.html.

[6] Driscoll, F. "Groundwater and wells". 2nd edition United States of America, H.M Smyth Company Inc, (1986) p. 278-333

[7] Fetter, C. Applied Hydrology. 2nd edition, New York, London. MacMillan Publishing Company. (1988) p. 305-309

[8] George, D. J. Rising Groundwater., Agid Report Series, Dordrecht, Netherland. Springer International Publisher, *A Problem of Development in Some Urban Areas of the Middle East* (1992) p. 171-173

[9] Greenwood N. N. Earnshaw A. Chemistry of the elements, Pergarnon Press.Oxford, England. (1984) p.1055-1056

[10] Jack C McCormac, Russell H .Brown. Design of Reinfoced Concrete, 10th Edition, United States of America. John Wiley & Sons (2016) p.64-65

[11] James, A.N, Edworthy K.T. The Effect of Water Interactions on Engineering Strutures, Hydrological Science. *Taylor and Francis Group,* (1985) p. 395-406

[12] Jennifer A. G. Hemant S.L and Ashok, M. K (April, 2017).Testing pH of Concrete . (Online) Available: https: //www.researchgate.net

[13] Todd, D. Groundwater Hydrology. 2nd editon, Albany, New York. Wiley and Sons Inc. (1980). p. 535

[14] Wikipedia contributors. Groundwater. Wikipedia, the Free Encyclopedia. 19 Nov. 2015.

[15] Wilkinson, W. Rising Groundwater Levels and Geotechnical Consequences". Informal Discussion, Ground Engineering Group and Water Engineering Group. Proa. Inst. Part I, 76. (1984) p. 791 - 793

[16] W.H.O, Guidline for drinking water-quality. 4th Edition.ISBN:9789241548151, Switzerland, (2011) p. 454-570.