Journal of Environmental Issues and Agriculture in Developing Countries
Volume 14, Number 3, December 2022
ISSN(p): 2141-2731 ISSN(e): 2795-2967
Published By
International Centre for Integrated Development Research, Nigeria
In collaboration with
Copperstone University, Luanshya, Zambia

The Effect of Subsoil Water on Foundation Stability in Abuja Metropolis, Nigeria

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ABSTRACT

This study was to determine the moisture content and bearing capacities during the rainy and dry seasons so as to determine the difference in moisture content and the lowest bearing capacity with a view to find out whether it can safely carry the load exerted by the structures or whether the structures are at risk of collapse. This is because 75% of the recorded collapses in Abuja metropolis occurred during the rainy seasons. Excess water in foundations sub soil leads to reduced shear strength of the soil and where there are sustained increase loading, leads to failure/collapse. The methodology include the qualitative inductive method, where samples of soil were obtained through the excavation of trial pits at the depths of the existing foundations that is at 1.00m deep in five (5) different locations of Gwarimpa, Garki, Wuse, Utako and Jabi areas of Abuja metropolis where there are high rise buildings. Findings showed that the bearing capacities are higher during the dry season and become very low during the rains due to too much moisture in the soil which leaves the subsoil fully saturated, hence reduced bearing pressure. The study recommends the provision of drainages around high rise buildings so as to reduce excess water in foundations. The study also recommends that designs for high rise buildings should be done with the lowest bearing capacity, which in most cases can be obtained during the peak of the rains.

Keywords: *Excess water, foundation, poor bearing capacity*

INTRODUCTION

Bearing capacity is the most important soil property, which governs the design of foundations, while in measuring the integrity of foundation; the two important parameters are bearing capacity and settlement. These are the two most important parameters in the field of geotechnical engineering, (Pande, *et al.* 2014). Pande *et al.*

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added that when the water table rises up and reaches the foundation level and the sub soil becomes submerged, the soil foundation system exhibits reduced bearing capacity. Also the apparent angle of friction decreases rapidly with increasing pore pressure. Barry (2010) asserts that if foundations compress the soil below them so heavily that the whole building sank into the ground uniformly (settlement) and at the same time, that no harm will come to the building, but where some parts sink more than others, it will develop failure signs such as cracks. This is differential settlement.

Ndefo (2011) said the ability of soil to support the foundation of a structure is measured by its compressibility or consolidation potential as well as its bearing strength. That too many voids in granular soils is the major cause of movement. A good mixture of particles size normally will increase stability. Ndefo (2011) added that silt types of soils are weak when exposed to excessive amounts of water. They are held together by cementing materials, while expansive soils (clay) are prone to volume changes related to moisture content. They shrink in dry seasons, but swell in wet seasons or in the presence of water, and conclude that they lead to dramatic kinds of failures.

If the entire foundation of a structure settles uniformly, the structural framework and other super structural elements remain intact and there will be no stress redistribution and consequently no damage to the facility (Matawal, 2012). And that the allowable total (maximum) settlement depends on the type of soil, the type of foundation and the structural framing system. Matawal (2012) gave the maximum settlement range permitted for various structures as 20mm to 300mm and that Nigeria limits total settlement to 40mm for isolated foundations on sand and 65mm on clay.

Atume (2006) said that foundation is the most important part of the building, unfortunately a lot of people are not giving adequate attention to this and it is causing problems. Anyone planning to build a multi storey building, need to consult the appropriate professional for a guide, he said. He concluded that a lot of aging buildings stand on inadequate foundations. Amobi (2006) classified factors that contribute to sub structural components failures to include differential settlement of foundation, shear and plastic failures and design failures. Austin (2012) gave the following as the causes of foundation movement: Variation in climate, change in depth of water table, removal of trees, planting of trees, inadequate drainage, seepage along construction interfaces, irrigation, leaking utility lines, drying of soil below heated rooms, seepage of moisture along utility trenches, poor compaction of fill, improper fill material. Building collapse is caused by many factors put together and if blames were to be apportioned, every stakeholder will have a fair share of the blame. Austin further gave the following list as some of the causes of building failure.

Absence of soil test, Adoption of wrong foundation, Structural design by quacks, Absence of co-ordination between professionals, Non adherence to specifications, Poor and bad construction practices/ methodology, Use of substandard building materials, Lack of proper supervision by professionals, Inadequate enforcement of enabling existing laws, Illegal conversion of buildings which often lead to structural deficiencies, Flagrant disobedience of town planning regulations by developers, Compromising attitude of supervising and planning professionals (staff), Lack of sanctions against erring professional or quacks, defaulting developers and land lords and Climate change.

According to Matawal (2012), a very important factor to be considered in relation to the catastrophes in the building industry is the impropriety of designing and constructing structures with no geotechnical investigations, tests and reports; which are requested to provide for proper design of the foundations, as structural foundation is aimed to transfer the structural loads from the superstructure safely to the ground below. He further said, if foundation load exceeds maximum passive pressure of ground (that is bearing capacity), a down ward movement of the foundation could occur. He again added that the remedy to this kind of problem is to increase the plan size of the foundation to reduce the load per unit area or alternatively reduce the loadings being carried by the foundation. Matawal (2012) further stated that whereas the minimum thickness of a structural foundation (even for nominal situations below a wall) is 150mm prepared using concrete grade 25, anything less is unacceptable.

Braja (2010) explains that: for shallow foundations to perform satisfactorily, they must have the following characteristics. The foundation has to be safe against overall shear failure in the soil that supports it. The foundation should not undergo excessive displacement that is settlement.

Braja (2010) further said that the load per unit area of the foundation at which the shear failure in the soil occurs is called ultimate bearing capacity (general shear failure). NBRRI also visited a couple of sites in Abuja in 2011 and one of such sites was that of a four (4) storey building at Mpape, Abuja. Another was a two (2) storey building belonging to Zenith Bank, collapsed at Mararaba on the out skirts of the Abuja (NBRRI, 2011).

The study aims at determining the effect of subsoil water on foundation stability in Abuja metropolis. This study has academic relevance in terms of knowledge increase and the generation of discussions on ways out of the problem of excess water in foundations sub soil. Many authors have worked on the aspect of the causes of building collapse such as poor concreting, inferior/ sub-standard building materials and in-adequate foundations, but the question of "excess water as a cause of failure in foundations of buildings" seems unanswered. It is the attempt to answer this question that this study seeks to address.

Moisture and soil quality are very important parameters when it comes to the stability of foundations, (Foundation Repair Services, 2008). Drainage may not stop foundation from settling, but it does divert the water away from the foundation and so reduces the amount of water that comes in contact with the soil around the foundation thereby reducing the resultant magnitude of expansion and shrinkage that may occur, hence reduced pressure on the foundation. This helps maintain the structural integrity of the foundation. Augustine (2012) in his paper on the case histories of building collapse in Nigeria, recorded eight (8) collapsed cases in FCT Abuja from 1992 to 2012 and out of these number six (6) occurred in the months of July and August which is 75% of the total collapses recorded. This period is the peak of the rainy season in Abuja. This goes to show that the excess water in the sub soil of foundations played a key role in causing these collapses. As a follow up to the above, the researcher decided to engage in a pilot study so as to determine the effect of excess water in foundations and underlying soils. It was observed that most of the high rise buildings did not have provisions for collection and channeling of storm water away from the surroundings of the buildings. This water rather permeates freely back into the sub soil making it saturated and expanded thereby exerting pressure on the foundations of the buildings, hence eventual failure. It is the

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effect of this excess water in foundations and sub soil that this study desires to look into with a view to proffer lasting solution to the problem.

Plate 1: Collapse In Gwarimpa, Abuja In 2012
(***Source:*** Matawal, 2012)

Plate 2: Partial Collapse in Garki, Abuja
(***Source:*** Augustine C. Ike, 2012)

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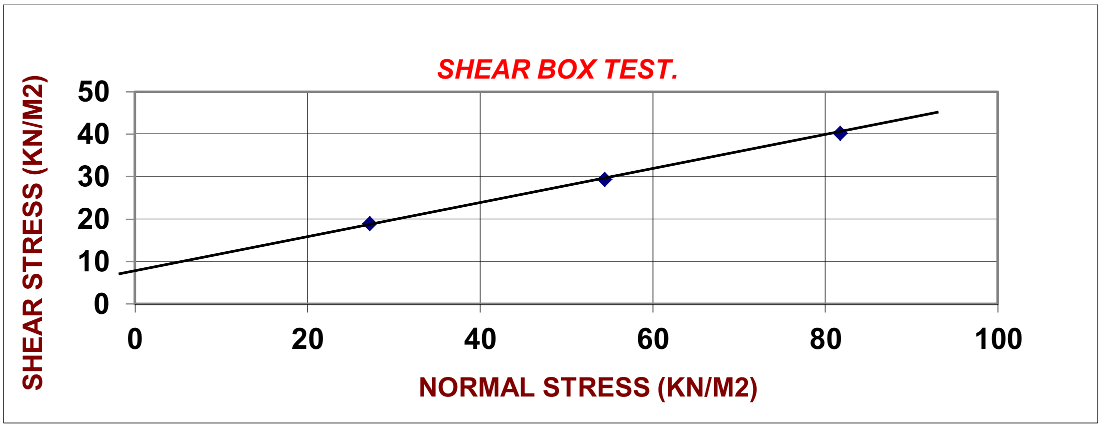
METHOD

Soil samples were obtained through the excavation of trial pits around the areas of the high rise buildings at the depth of the existing foundations (1.00m deep) to determine both the moisture content and the bearing capacities. Samples were obtained during the dry season, precisely in March, 2019 and investigated in the Civil Engineering soil and Geology Laboratory of Kaduna Polytechnic and another set of samples were obtained during the rainy season in August, 2019 and investigated separately in the same laboratory. The results are presented showing dry season separately and rainy season separately.

RESULTS

Table 1: Direct Shear Box Test For Tp 1 Wet
Sample No.: Tp 1 @ 1.00m Wet.

Test No.	Normal Load (KG)	Normal Stress (KN /M2)	Shear Stress (KN /M2)	Unit Weight (KN /M3)
1	10	27.25	18.75	
2	20	54.50	29.17	21.22
3	30	81.75	40.00	
	C = 8 KN/M2	Ø = 13°	□ =21.22KN/M3	



Pit one for wet (rainy season) at the same depth of 1.00 meter gave the following parameters during soil investigation.
C = 8 KN/M^2 Ø = 13° □ =21.22KN/M^3

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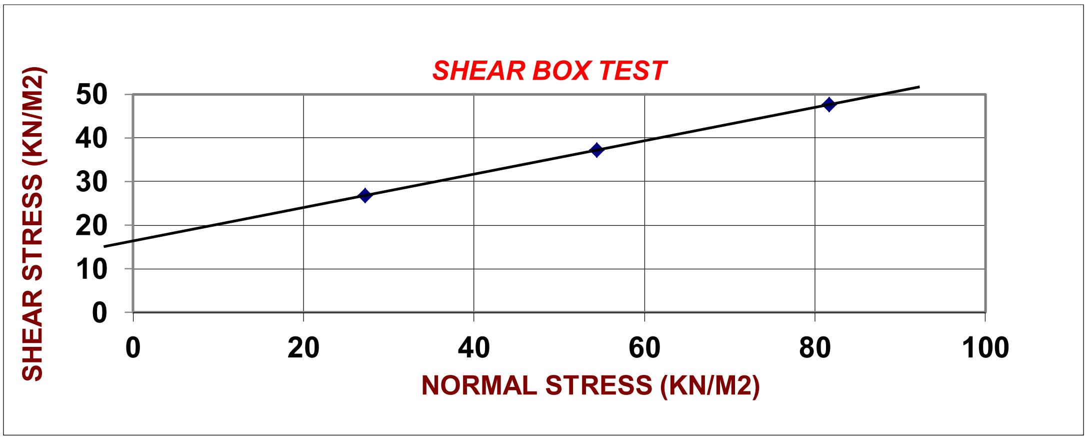
Table 2: Direct Shear Box Test For Tp 1 Dry
Sample No.: Tp 1 @ 1.00m Dry.

Test No.	Normal Load (KG)	Normal Stress (KN /M2)	Shear Stress (KN /M2)	Unit Weight (KN /M3)
1	10	27.25	26.67	
2	20	54.50	37.08	16.78
3	30	81.75	47.50	

C = 17 KN/M2 Ø = 13° γ =16.78KN/M3



The results of Pit one at 1.00 meter (dry season) soil investigation gave the following parameters which are used for calculating the bearing capacity of the soil.
C = 17 KN/M^2 Ø = 13° γ =16.78KN/M^3

Table 3: Direct Shear Box Test for Tp 2 Wet
Sample No.: Tp 2 @ 1.00m Wet.

Test No.	Normal Load (KG)	Normal Stress (KN /M2)	Shear Stress (KN /M2)	Unit Weight (KN /M3)
1	10	27.25	22.08	
2	20	54.50	35.00	20.74
3	30	81.75	48.33	

C = 9 KN/M2 Ø = 13° □ =20.74KN/M3

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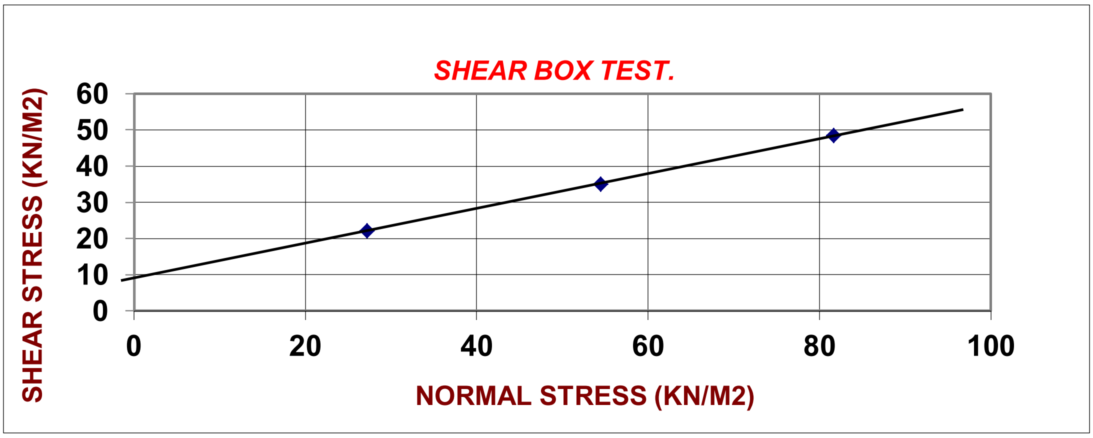
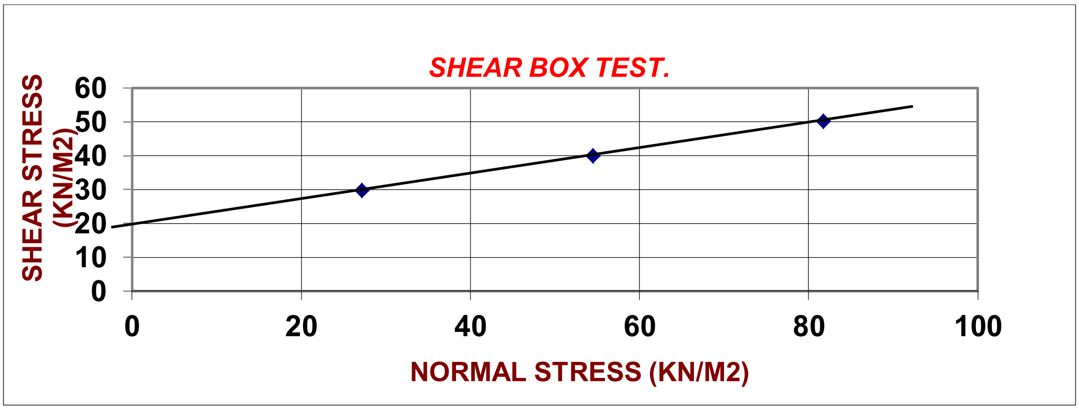


Pit 2 at 1.00 meter (wet season) presented the following parameters during the investigation:
C = 8 KN/M^2 Ø = 13° □ =20.74KN/M^3

Table 4: Direct Shear Box Test For Tp 2 Dry
Sample No.: Tp 2 @ 1.00m Dry.

Test No.	Normal Load (KG)	Normal Stress (KN /M2)	Shear Stress (KN /M2)	Unit Weight (KN /M3)
1	10	27.25	9.58	
2	20	54.50	39.79	16.88
3	30	81.75	50.00	

C = 19 KN/M2 Ø = 11° □ =16.88KN/M3

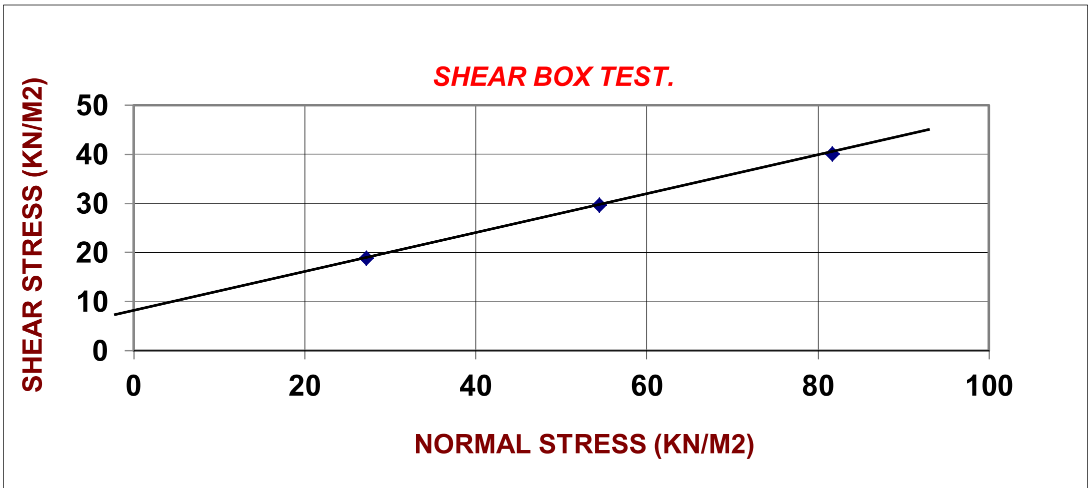


Results of the investigation of Pit 2 (dry season) gave the following parameters:
C = 19 KN/M^2 Ø = 11° □ = 16.88KN/M^3

Table 5: Direct Shear Box Test For Tp 3 Wet
Sample No.: Tp 3 @ 1.00m Wet.

Test No.	Normal Load (KG)	Normal Stress (KN /M2)	Shear Stress (KN /M2)	Unit Weight (KN /M3)
1	10	27.25	18.75	
2	20	54.50	29.58	21.06
3	30	81.75	40.00	

C = 8 KN/M2 Ø = 13° □ =21.06KN/M3



The investigation of Pit 3 (wet season) produced the following parameters:
C = 8 KN/M^2 Ø = 13° □ =21.06KN/M^3

Table 6: Direct Shear Box Test For Tp 3 Dry
Sample No.: Tp 3 @ 1.00m Dry.

Test No.	Normal Load (KG)	Normal Stress (KN /M2)	Shear Stress (KN /M2)	Unit Weight (KN /M3)
1	10	27.25	27.50	
2	20	54.50	39.17	16.02
3	30	81.75	50.00	

C = 17 KN/M2 Ø = 12° □ =16.02KN/M3

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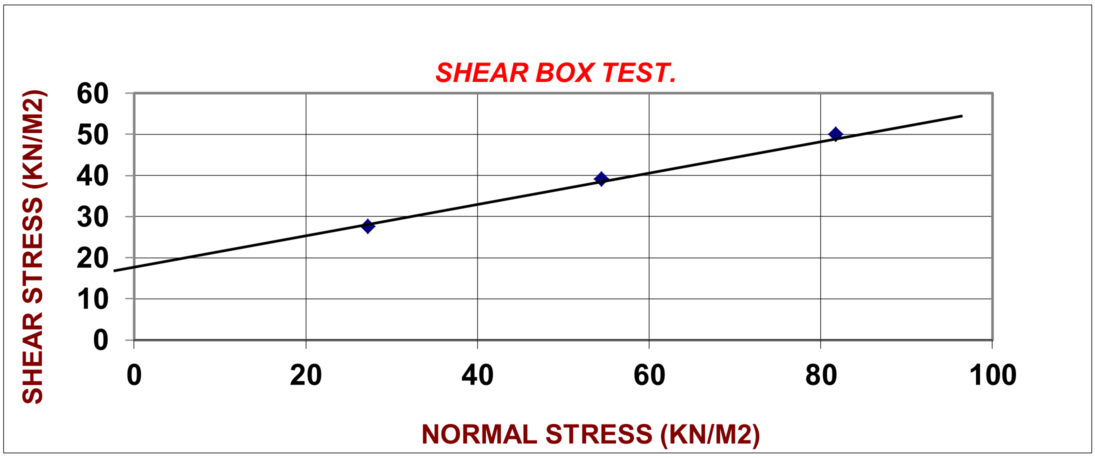


Source: researcher's laboratory work, 2020

The investigation for pit 3 gave the following parameters:

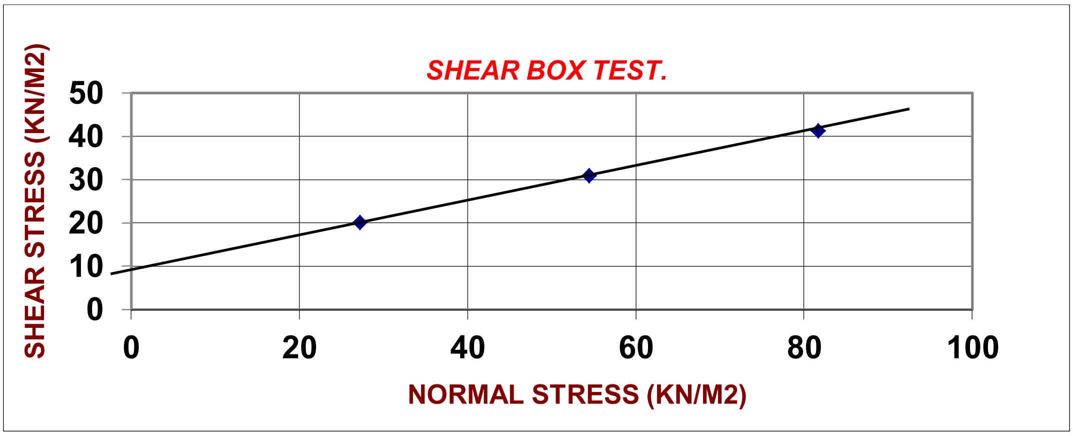
C = 17 KN/M^2 Ø = 12° □ =16.02KN/M^3

Table 7: Direct Shear Box Test For Tp 4 Wet

Sample No.: Tp 4 @ 1.00m Wet.

Test No.	Normal Load (KG)	Normal Stress (KN /M2)	Shear Stress (KN /M2)	Unit Weight (KN /M3)
1	10	27.25	20.00	
2	20	54.50	30.83	20.99
3	30	81.75	41.25	

C = 9 KN/M2 Ø = 12° □ =20.99KN/M3



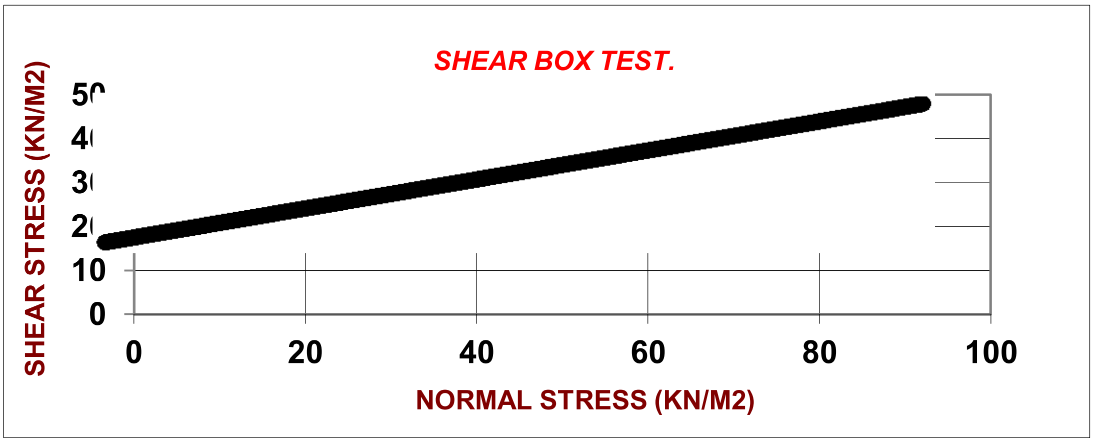
Source: Laboratory work, 2020

The investigation of Pit 4 (wet season) produced the following parameters:
C = 9 KN/M^2 Ø = 12° □ =20.99KN/M^3

Table 8: Direct Shear Box Test For Tp 4 Dry
Sample No.: Tp 4 @ 1.00m Dry.

Test No.	Normal Load (KG)	Normal Stress (KN /M2)	Shear Stress (KN /M2)	Unit Weight (KN /M3)
1	10	27.25	27.50	
2	20	54.50	36.67	16.94
3	30	81.75	45.83	

C = 18 KN/M2 Ø = 11° □ =16.94KN/M3



Source: Laboratory work, 2020

The investigation of Pit 4(dry season) produced the following parameters:
C = 18 KN/M^2 Ø = 11° □ =16.94KN/M^3

Table 9: Direct Shear Box Test For Tp 5 Wet
Sample No.: Tp 5 @ 1.00m Wet.

Test No.	Normal Load (KG)	Normal Stress (KN /M2)	Shear Stress (KN /M2)	Unit Weight (KN /M3)
1	**10**	**27.25**	**22.50**	
2	**20**	**54.50**	**32.50**	**21.08**
3	**30**	**81.75**	**44.17**	

C = 12 KN/M2 Ø = 13° □ =21.08KN/M3

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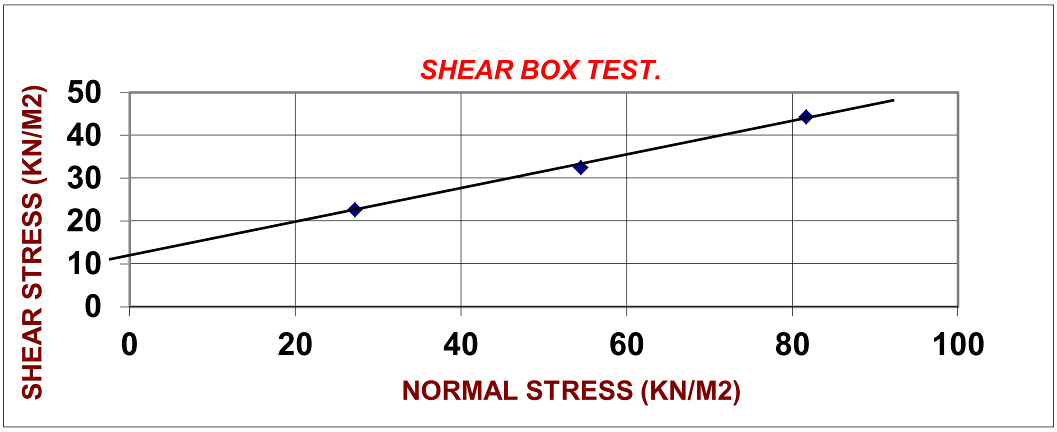


Source: Laboratory work, 2020

The investigation of Pit 5 (wet season) produced the following parameters:

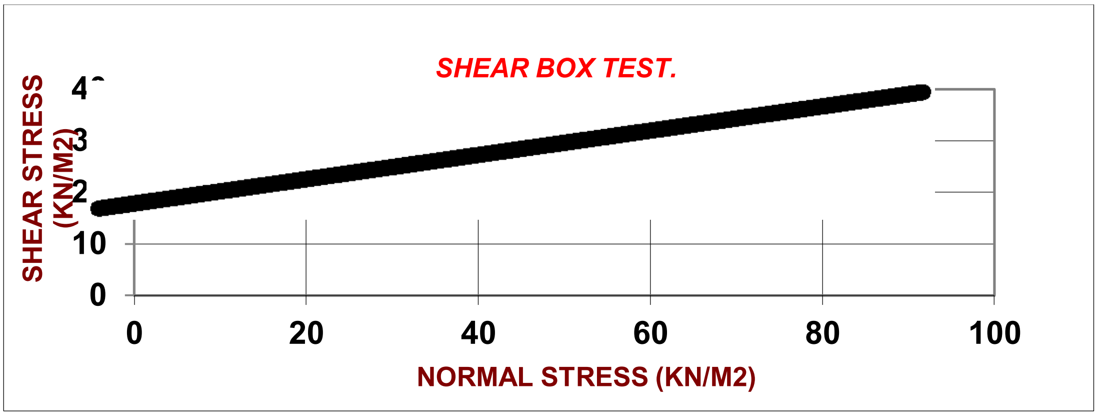
C = 12 KN/M^2 Ø = 13° □ = 21.08KN/M^3

Table 10: Direct Shear Box Test For Tp 5 Dry

Sample No.: Tp 5 @ 1.00m Dry.

Test No.	Normal Load (KG)	Normal Stress (KN /M2)	Shear Stress (KN /M2)	Unit Weight (KN /M3)
1	10	27.25	25.00	
2	20	54.50	31.67	15.77
3	30	81.75	37.92	

C = 18 KN/M2 Ø = 12 □ =15.77KN/M3



Source: Laboratory work, 2020

The investigation of Pit 5 (dry season) produced the following parameters:

C = 18 KN/M^2 Ø = 12 □ =15.77KN/M^3

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Table 11: Bearing Capacity Calculation for Pit 1 (Dry & Wet Season)

Sample No.: TP1 @ 1.00m depth (Dry)				Sample No.: TP1 @ 1.00m depth (Wet).			
DATA.				**DATA.**			
C	17.00			C	8.00		
γ	16.78			γ	21.22		
φ	13.00			φ	13.00		
D	1.00			D	1.00		
Nc	9.80			Nc	9.80		
Nq	3.30			Nq	3.30		
Nγ	0.80			Nγ	0.80		
B	1.00			B	1.00		
F.S.	2.50			F.S.	2.50		
Q(ULT)		211.91	KN/M2	Q(ULT)		135.69	KN/M2
Q(SAFE)		84.76	KN/M2	Q(SAFE)		54.28	KN/M2

The result of the bearing capacity calculations for pit one during the dry season and the wet season showed that the safe bearing capacity for dry season was found to be 84.76 KN/M2 while the corresponding safe bearing capacity during the rainy season was found to be 54.28KN/M2. This result indicates a drop in soil shear strength by 30.48KN/M2 which represents 36% drop in the soil's bearing capacity between the two seasons.

Table 12: Bearing Capacity Calculation for Pit 2 (Dry & Wet Season)

Sample No.: TP2 @ 1.00m depth (Dry)				Sample No.: TP2 @ 1.00m depth (Wet).			
DATA.				**DATA.**			
C	19.00			C	9.00		
γ	16.88			γ	20.74		
c	11.00			v	13.00		
D	1.00			D	1.00		
c	8.80			c	9.80		
Nq	2.70			Nq	3.30		
Nγ	0.50			Nγ	0.80		
B	1.00			B	1.00		
F.S.	2.50			F.S.	2.50		
Q(ULT)		200.12	KN/M2	Q(ULT)		144.20	KN/M2
Q(SAFE)		80.05	KN/M2	Q(SAFE)		57.68	KN/M2

The result of the bearing capacity calculations for pit one during the dry season and the wet season showed that the safe bearing capacity for dry season was found to be 80.05 KN/M2 while the corresponding safe bearing capacity during the rainy season was found to be 57.68KN/M2. This result indicates a drop in soil shear strength by 22.37KN/M2 which represents 28% drop in the soil's bearing capacity.

Table 13: Bearing Capacity Calculation for Pit 3 (Dry & Wet Season)

Sample No.: TP3 @ 1.00m depth (Dry)			Sample No.: TP3 @ 1.00m depth (Wet).		
DATA.			**DATA.**		
C	17.00		C	8.00	
γ	16.02		γ	21.06	
φ	12.00		φ	13.00	
D	1.00		D	1.00	
Nc	9.30		Nc	9.80	
Nq	3.00		Nq	3.30	
Nγ	0.60		Nγ	0.80	
B	1.00		B	1.00	
F.S.	2.50		F.S.	2.50	
Q(ULT)	194.95	KN/M2	Q(ULT)	135.26	KN/M2
Q(SAFE)	77.98	KN/M2	Q(SAFE)	54.10	KN/M2

The result of the bearing capacity calculations for pit one during the dry season and the wet season showed that the safe bearing capacity for dry season was found to be 77.98 KN/M2 while the corresponding safe bearing capacity during the rainy season was found to be 54.10KN/M2. This result indicates a drop in soil shear strength by 23.88KN/M2 which represents 30.6% drop in the soil's bearing capacity

TABLE 14: Bearing Capacity Calculation for Pit 4 (Dry & Wet Season)

Sample No.: TP4 @ 1.00m depth (Dry)			Sample No.: TP4 @ 1.00m depth (Wet).		
DATA.			**DATA.**		
C	18.00		C	9.00	
γ	15.77		γ	20.99	
φ	11.00		φ	12.00	
D	1.00		D	1.00	
Nc	8.80		Nc	9.30	
Nq	2.70		Nq	3.00	
Nγ	0.50		Nγ	0.60	
B	1.00		B	1.00	
F.S.	2.50		F.S.	2.50	
Q(ULT)	189.15	KN/M2	Q(ULT)	131.98	KN/M2
Q(SAFE)	75.66	KN/M2	Q(SAFE)	52.79	KN/M2

The result of the bearing capacity calculations for pit one during the dry season and the wet season showed that the safe bearing capacity for dry season was found to be

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75.66 KN/M2 while the corresponding safe bearing capacity during the rainy season was found to be 52.79KN/M2. This result indicates a drop in soil shear strength by 22.87KN/M2 which represents 30.2% drop in the soil's bearing capacity.

TABLE 15: Bearing Capacity Calculation for Pit 4 (Dry & Wet Season)

Sample No.: TP5 @ 1.00m depth.			**Sample No.: TP5 @ 1.00m depth.**		
DATA.			**DATA.**		
C	18.00		C	12.00	
γ	15.77		γ	21.08	
φ	12.00		φ	13.00	
D	1.00		D	1.00	
Nc	9.30		Nc	9.30	
Nq	3.00		Nq	3.00	
Nγ	0.60		Nγ	0.60	
B	1.00		B	1.00	
F.S.	2.50		F.S.	2.50	
Q(ULT)	203.67	KN/M2	Q(ULT)	113.67	KN/M2
Q(SAFE)	81.47	KN/M2	Q(SAFE)	51.46	KN/M2

The result of the bearing capacity calculations for pit one during the dry season and the wet season showed that the safe bearing capacity for dry season was found to be 81.47 KN/M2 while the corresponding safe bearing capacity during the rainy season was found to be 51.46KN/M2. This result indicates a drop in soil shear strength by 30.01KN/M2 which represents 36.84% drop in the soil's bearing capacity.

Table 16: Natural Moisture Content Determination Test

Sample No.	Depth (M)	CAN No.	WT. of CAN (g)	WT. of CAN + Wet Soil (g)	WT. of CAN + Dry Soil (g)	WT. of Moisture (g)	WT. of Dry Soil (g)	M.C. (%)	A.M.C. (%)
		A19	**8.10**	**31.10**	**29.70**	**1.40**	**21.60**	**6.48**	
TP1	1.00	G14	7.60	29.90	28.60	1.30	21.00	6.19	6.34
		G30	8.00	41.80	39.90	1.90	31.90	5.96	
TP2	1.00	A49	8.00	36.10	34.50	1.60	26.50	6.04	6.00
		H3	7.80	37.40	35.90	1.50	28.10	5.34	
TP3	1.00	A46	7.60	36.00	34.20	1.80	26.60	6.77	6.05
		A3	7.70	35.20	33.70	1.50	26.00	5.77	
TP4	1.00	A26	8.00	37.30	35.80	1.50	27.80	5.40	5.58
		A2	7.60	34.80	33.50	1.30	25.90	5.02	
TP5	1.00	A42	8.10	29.40	28.30	1.10	20.20	5.45	5.23

In table 16 above, the results of the moisture content test conducted on soil samples which were obtained during the dry season indicates that the soil was well drained, which explains the reasons for the low values obtained. Average weight from pit 1 is 6.34g, pit 2 is 6.00g, pit 3 is 6.05g, pit 4 is 5.58g and pit 5 is 5.23g.

Table 17: Natural Moisture Content Determination Test

Sample No.	Depth (M)	CAN No.	WT. of CAN (g)	WT. of CAN + Wet Soil (g)	WT. of CAN + Dry Soil (g)	WT. of Moisture (g)	WT. of Dry Soil (g)	M.C. (%)	A.M.C. (%)
		BT	6.90	45.60	37.90	7.70	31.00	24.84	
TP1	1.00	T3	8.00	37.80	32.10	5.70	24.10	23.65	24.25
		A6	7.40	39.70	34.00	5.70	26.60	21.43	
TP2	1.00	52	7.20	40.40	34.50	5.90	27.30	21.61	21.52
		EA	7.50	42.80	36.20	6.60	28.70	23.00	
TP3	1.00	D4	8.20	39.60	33.70	5.90	25.50	23.14	23.07
		A31	6.90	39.90	32.90	7.00	26.00	26.92	
TP4	1.00	D1	5.90	42.10	34.20	7.90	28.30	27.92	27.42
		P2	6.60	38.40	31.50	6.90	24.90	27.71	
TP5	1.00	WQ2	7.30	39.80	32.90	6.90	25.60	26.95	27.33

During the rainy season, the values for the average moisture contents are higher than what are obtained during the dry season. This is because the soil contains moisture and that makes the soil samples denser. Results in table 17 show that pit 1 posted 24.25g, while pit 2 gave 21.52g, pit 3 was 23.07g, pit 4 was 27.42g and pit 5 was 27.42g.

Discussion of Results

Results of Bearing capacity in Pit 1 during the dry season was found to be 84.76KN/M2 while the corresponding result during the rainy season was found to be 54.28KN/M2. This gives a difference of 30.48KN/M2 representing 36% drop in shear pressure of the soil. Pit 2 during the dry season posted a bearing capacity of 80.05KN/M2 while the corresponding rainy season result for pit 2 was 57.68KN/M2. This produced a difference of 22.37KN/M2 which represents 28% drop in the bearing capacity when the two seasons are compared. Pit 3 results showed that the dry season samples produced a result of 77.98KN/M2 and a corresponding rainy season bearing capacity of 54.10KN/M2. This showed a difference of 23.88KN/M2 which represents 30.6% drop between the two seasons. The result of pit 4 showed that the dry season soil samples produced 75.66KN/M2 bearing capacity, while the rainy season produced 52.79KN/M2, giving a difference of 22.87KN/M2 which represents 30.2% drop in shear strength. Pit 5 dry season samples produced a bearing capacity of 81.47KN/M2, while the rainy season samples produced 51.46KN/M2, giving a difference of 30.48KN/M2 which represents 36.84% drop in the soil's shear strength. Results of the moisture content investigation indicated that while the soil was saturated during the rainy season with values such as pit 1 = 24.25g, pit 2 = 21.52g, pit 3 = 23.07g, pit 4 = 27.42g and pit 5 = 27.33g, the corresponding samples during the dry season were well drained with values such as: pit 1 =6.34g, pit 2 = 6.00g, pit 3 = 6.05g, pit 4 = 5.58g and pit 6 = 5.23g.

It can be observed that the bearing capacity of soil samples investigated produced very sharp differences in the results obtained with values during the dry season showing an average of 32.16% above those of the rainy season. This sharp difference in the soil's shear strength pauses a great challenge to the stability of high rise buildings. In situations where such buildings have increased or sustained live loading during the rainy season, during which time the sub soil shear strength is drastically reduced due to the effect of excess water which leaves it saturated, the buildings will be at the risk of failure which might lead to eventual collapse.

CONCLUSION AND RECOMMENDATIONS

The negative effect of subsoil water on the stability of foundations cannot be over emphasized. Therefore, such excess water needs to be given proper considerations during the design stage of high rise buildings by taking the bearing capacity of the rainy season as the base line for structural designs. Also, the provision of drainage around such buildings will leave the foundations properly drained. This will help maintain the soil's bearing capacity. Lack of which allows the ingress of surface water into the foundation thereby making the underlying soil to be saturated, hence, failure will begin to occur. The recommendations are:

1. All existing high rise buildings that have two or more suspended floors above ground floor within Abuja metropolis should be provided with surface drainages which should be channeled away from the buildings.
2. Structural designers should always take the soil bearing capacity during the rainy season as the safe bearing capacity (base line) upon which the design of foundations for high rise buildings should be based. This is because designs based on dry season bearing capacity leaves the subsoil stressed during the rainy season due reduced shear strength as a result of excess water, which leads to failure.

REFERENCES

Amobi, C.O. (2006) Pro-active measures to avoid failures and collapse of buildings in Nigeria. *Journal of the Nigerian Institute of Building* 13 (2): 25-29

Atume F. (2012) Causative Factors of Building Collapse in Nigeria. National Workshop on Building Collapse in Nigeria. 15th-16th May, 2012

Augustine C. I. (2012) Case Histories Of Building Collapse in Nigeria, National Technical Workshop on Building Collapse in Nigeria. Sheraton Hotel, May 15th-16th, 2012

Austin, G. (2012). An online article on Foundation Movement Symptoms causes and repairs solutions, by Austin Foundation Repairs. Found on http//www.austin-foundation-repaires.

Barry (2010) Introduction To Construction of Buildings Fouth edition. Black well Science Limited . Oxford OX2 OFL. Pp 100-116.

Braja M.D. (2010) Principles of Foundation Engineering. Seventh edition. Brooks/Cole Publishing Company, 511 Forest Lodge Road, Pacific Groove, CA 93950, USA. Pp 152-240.

Foundation Repair Services Inc (2008) Exploring the Connection between the Soil and the Stability of a Home's Foundation. Found online on www//http//foundation.repair services.inc.

Matawal, D. S. (2012) Deformation of Soils, Consolidation, Settlement and Ground Improvement Techniques. Cephas and Clems Nigeria Limited, pp 31-57, 2012.

Matawal, D.S. (2012), Curbing the Incidences of Building Collapse in Nigeria. A communiqué of the National Technical Workshop on Building Collapse in Nigeria. Sheraton hotel, May 15th - 16th, 2012, Abuja

Ndefo, O. (2011) the Mechanics of Construction Soil. Second edition, Acena Publishers, Enugu Nigeria. Pp 9-18

Pande, P. B., Bajad, S. P. and Khandeshwar, S. R. (2014) The Effect of Degree of Saturation on the Bearing Capacity of Shallow Foundations. *International journal of Innovative Research in Science, Engineering and Technology,* 3, 7.