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Investigating the Problem of Foundation Failure in Buildings in Anambra State

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Abstract: The foundation of a building acts as an interface to transfer the load from the superstructure to the underlying soil in order to reduce pressure. The study aims at examining the failures of foundation in Anambra state with a view to providing mechanism to curb the incidence of foundation failure. The study determined factors responsible for foundation failure and evaluated the effects of the failure. This study adopted survey research design. The population of study consists of public and private contractors involving Architects (110), Builders (85), Civil Engineers (130), Estate Surveyors (35) and Quantity Surveyors (40) in Anambra State. According to the Corporate Affairs Commission data, total registered contractors in the state are 402. The research found out that faulty construction contributed up to 40% to structural failures in building with a mean of 4.6 which is the highest mean, poor quality of building material has a mean of 4.45, foundation failure due to settlement of soil fill has a mean of 3.9, Foundation failure due to soil movement has a mean of 4.15, unequal settlement of masonry has a mean of 4.05, Lateral pressure on the walls has a mean of 3.9, Sub-soil moisture movement has a mean of 4.15, Atmospheric action has a mean of 4.1 and unequal settlement of sub soil has the least mean of 2.9. The research therefore concludes that up to 70% of the cases of reported building collapse as a result of foundation failure and recommends that the town planning authority maintain competent professionals in the relevant areas for design approval and from a long term perspective.

Keywords: foundation failure, Building, Investigation, soil movement

I. Introduction

The foundation is the lowest part of a building or civil structure and acts as an interface to transfer the load from the superstructure to the underlying soil in order to reduce pressure. It can be shallow or deep. The foundation must bear the dead and live load of the superstructure. The dead load is the weight of the structure itself while the live load is the load of the content and the people (Aruna & Arulselvan, 2017). A built house holds together like a box because foundations are built out of solid base like concrete, they resist shaking better than a house superstructure.

So many factors contribute to foundation failure. According to Rzezniczak, Mlynarek, Gololik, Michalak, (2019), failure is a complex process influenced by several factors. They further stated that failure can be as a result of soil features, foundation works and design. It is rare for a failure to be caused by all the three factors simultaneously, but each share qualitatively in the process. There is foundation failure any time the foundation is unable to support the full weight of the building due to movement of the soil and excessive settlement.

Foundation failure is classified as general shear failure, punching shear failure and local shear failure (Singh, 2020). Singh further stated causes of failure as unequal settlement of soil, unequal settlement of masonry, subsoil moisture movement, lateral pressure on the superstructure, horizontal movement of the earth, transpiration of trees and shrubs and atmospheric action. The foundation bears the load of the building, it anchors it against natural forces and isolates it from ground moisture. Foundation failure in a building can be attributed to several factors. Most common foundation failures are caused by the movement or expansive of highly plastic soils beneath different sections of the foundation footings.

This movement of soil can be in the form of shrinkage which causes settlement, or expansion, which causes heave. When dry conditions prevail soil consistently loses moisture and shrinks when moisture levels are high, soil swell. Regardless of the nature of the movement, it will most likely manifest itself in the form of visible cracks in the foundation walls, exterior brick walls, or interior sheetrock or plaster walls. Officially, any structure movement is known as differential settlement.

In addition to expansive soils, subsurface peat, which has a low bearing capacity and deteriorates over time, can also cause differential settlement. Other soil types such as sand and silt also have lower than required bearing capacities. The main function of a building is to protect the occupants and contents from the weather, mainly rain, wind and extremes of temperature. It is most important to provide the basic needs which will achieve all of these functions. Features such as windows, pipe, air conditioning system and finishes are only additional.

Obviously a building must be structurally safe in order to survive, and the floors must be capable of resisting any normal imposed loads (Michael, 2008). The study aims at examining the failures of foundation in Anambra state with a view to providing mechanism to curb the incidence of foundation failure. The study determined factors responsible for foundation failure and evaluated the effects of the failure.

II. Literature Review

A. Factors to Consider when Evaluating Foundation Failure

There can be no failure of a building without a prior failure of a building components (Olusola and Akintayo, 2009). Buildings are subjected to settlement right from the time of construction (Tomasz, Witold, & Lukasz, 2019). The cause of foundational failure can as well be traced to lack of geotechnical investigation, while geotechnical failure results from leakage of water main and sewage systems, lowering of groundwater table, water-induced shrinkage and swelling of expansive soils.

B. Causes of Building Failure

1. Settlement cracks are due to differential settlement of the wall footings, poor original construction, water and nearby blasting operations.

2. Leaning or tipping foundation wall cracks and angles, the wall is said to be rotating or leaning inwards or outwards from an axis point that is usually the wall footing.

3. Interior cracks in buildings may be traced to foundation movement or damage.

It is expedient to examine a building where failure has occurred before ascertaining the causes of failure so as to obtain necessary information needed `for remedy (Nagarajan & Premalatha, 2014)

Building failures can be attributed to; movement of soil, poor soil condition, poor drainage, plumbing leaks, poor building site preparation, weather condition, transpiration. Failure of foundation apparently leads to failure of the entire structure (Aruna & Arulselvan, 2017)

C. Effects of Building Failure

Physical damage and psychological trauma are the aftermath effects of building collapse, the degree of which is often beyond easy prediction. Depending on the nature and extent of damage of building collapse as a result of foundation failure incidents, the effects are felt almost in all human endeavors. These effects sometimes include loss of human life, loss of materials and capital investments, as well as psychological pains.

1 **Loss of Human Life**: Loss of human life has become a common report of most of the collapse building incidents in Anambra State. It is an irreparable loss to both the victims' relatives and the nation at large and thus called for the need to find a lasting solution to forestall its incessant occurrence.

2 **Loss of Materials and Capital Investments**: When building collapsed, most of its structural components and materials will be damaged often beyond re-use, while capital investments in most cases are not recoverable. This kind of situation, more than often leads to bankruptcy on the part of the investor and high economic implications on the nation's economy.

3 **Psychological effects**: The consequences of building collapse as a result of foundation failure cannot be underestimated. A bungalow that collapse on the occupant cannot be regarded as a small loss neither will a multi-storey building that collapse with no human casualty be regarded as no loss. In fact, Akinjare, (2012) submitted that owners and stakeholders in failed structure often die of high blood pressure. Consequence of building collapse as a result of foundation failure include loss of physical properties, destruction of movable properties, injury and loss of life. Beyond this, building collapse as a result of foundation failure always has far reaching economic, financial. Psychological and sociological implications.

4 **Waste of Resources:** Resources like capital, time, materials and labor inputs are wasted when building collapses. Investments ideas are frustrated and those who have a stake in it become temporarily or permanently destabilized or frustrated (Ede, 2010). Furthermore, the collapse may lead to bankruptcy where there is no alternative plan to recover the capital. Also the loss of job with its far-reaching effect on the people and financial pressure it caused on occupants that got injured or lost their belongings to the collapse. Decapitation, injuries and death are fatalities recorded in building collapse as a result of foundation failure which cannot be estimated, replaced or restored. The shock, trauma and anxiety experienced by escapes, witness and rescue agents in the aftermath of a building collapse as a result of foundation failure are better imagined. Ede (2010) summarizing the impact stated that each case of building collapse as a result of foundation failure carries along with it tremendous effects that cannot be easily forgotten by the victims.

D. Remedies to Foundation Failure

1. Soil test, Environmental Impact Assessment (EIA) and structural analysis needs to be made mandatory to be submitted along with the building plans to planning authorities by all the developers or building approval seekers/applicants, especially for all institutional, commercial and industrial buildings.

2. All plans for approval must be made to pass through all the professionals associated with building industry working in every State/Local Government Development Control Boards before its final approval.

3. All plans for approval must be ensured to be in compliance with the Nigeria's new building code and all the affected local government's byelaws.
4. Inspection team must be made to regularly be on the move to inspect all construction works in their locality with the aim of enforcing the building code and the local byelaws.

5. Use of pile foundation where the soil is shrinkable, taking the foundation level down to avoid foundation on shrinkable soil and the presence of any mining areas needs to be inspected and professional help shall be taken while construction new buildings in such area.

III. Research Methodology

This study adopted survey research design. The population of study consists of public and private contractors involving Architects (110), Builders (85), Civil Engineers (130), Estate Surveyors (35) and Quantity Surveyors (40) in Anambra State. According to the Corporate Affairs Commission data, total registered contractors in the state is 402. Therefore, population of this study is 402. Using Taro Yamane formular, the total population was reduced to 200. The data was generated using questionnaire. The questionnaire was measured using 5-scale likert scale. In order to analyze the data collected effectively and efficiently for easy management and accuracy, bar chart, simple percentage method and graphic representation were used for analysis as well as frequency. A sample size of two hundred (200) was represented by 100% for easy analysis of the responses.

IV. Data Presentation, Analysis and Interpretation

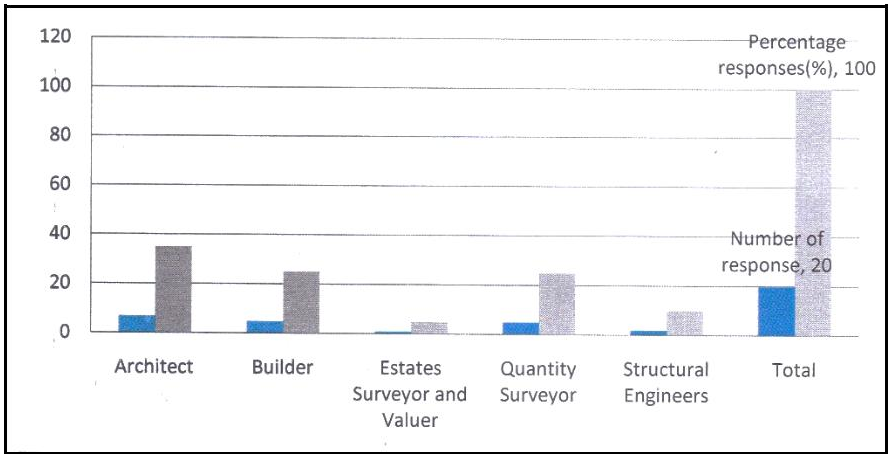


Fig 1.0: Category of the respondent in building profession.

Fig 1.0 indicates that 35% of the respondent are professional Architect, 25% are Builder, 5% of them are Estate Surveyor and Valuer, 25% of them are Quantity Surveyors, 10% of them are Structural Engineers.

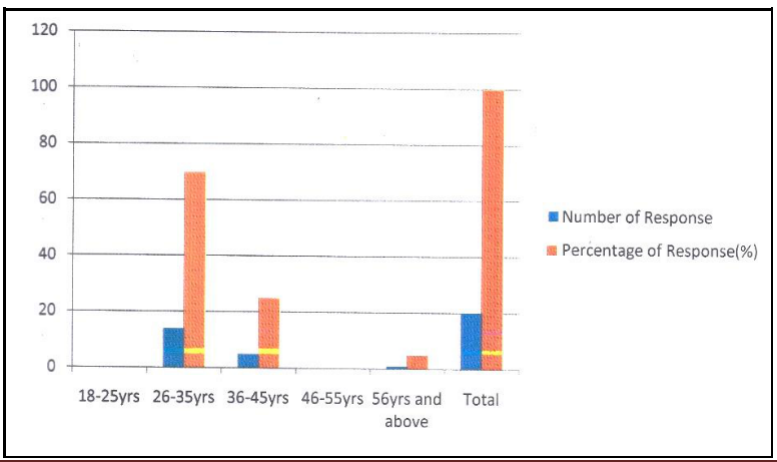


Fig 1.1 Respondent Age bracket.

Fig. 1.1 indicates 70% of the respondent are between the age 26-35 years, 25% are between the age of 36-45 years, 5% of them are between the age of 56 and above and 0% Of them are between the age of 46-55years and 18-25 years

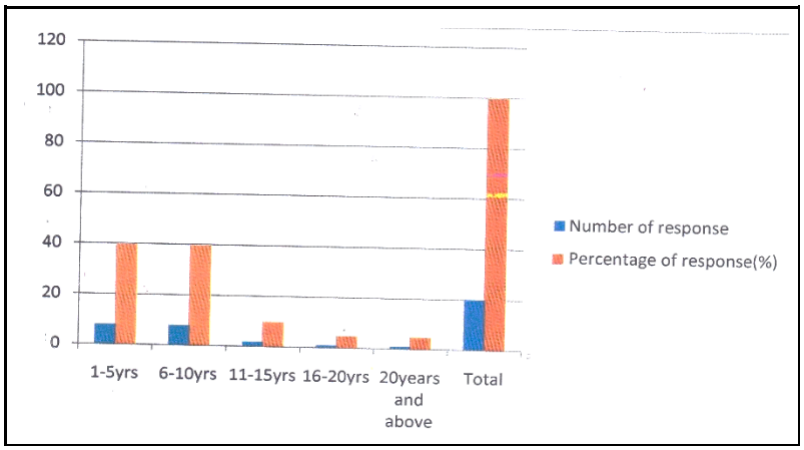


Fig: 1.2 Respondent's duration in building industry/ministry/regulatory agency.

Fig 1.2 indicates that 40% of the respondents have worked in the industry between 1-5 year, another 40% of the respondent have worked in the industry between 6-10 years, 5% of the them have worked in the industry between 11-15 years, another 5% of them have worked for 20years and above.

Section B

This section was designed to obtain from the respondents, the key research based information such as the causes of building collapse as a result of foundation failure in Anambra State, the effects of building collapse in Anambra State and the mechanisms put in place to curb incidence of building collapse as a result of foundation in Anambra State. The analysis in this section is obtained using percentage, mean scores, standard deviations and Ranking. Respondents were required to tick [√] as to the degree of agreement, where 5= Strongly Agree, 4=Agree, 3=Undecided, 2 =Disagree 1= Strongly Disagree, and also make comments where needed.

The collected data were analyzed as follows:

Table 1. Causes of Building collapse as a result of foundation failure in Anambra State

S/N	Causes	5	4	3	2	1	Mean score	STD	Ranking
		SA	A	U	SD	D			
1	Bad architectural and structural design	10	7	1	1	1	4.2	0.883	3rd
2.	Faulty construction	13	7	0	0	0	4.6	0.632	1st
3	Poor quality of building materials	11	8	0	1	0	4.45	0.85	2nd

4	Foundation failure due to settlement of soil fill soil	6	9 9	2	3 3	0	3.9 3.9	0.969	7th 7th
5	Foundation failure due to soil movement	7	10	2	1	0	4.15	0.894	4th
6	Unequal settlement of masonry	8	6	5	1	0	4.05	0.915	6th
7	Lateral pressure on the walls	6	9	3	1	1	3.9	0.969	7th
8	Sub-soil moisture movement	5	14	0	1	0	4.15	0.894	4th
9	Atmospheric action	6	10	4	0	0	4.1 4.1	0.895	5th 5th
10	Unequal settlement of sub-soil	3	4	3	8	2	2.9	1.003	8th

Table 1. indicates that Bad architectural and structural design has a mean of 4.2, Faulty construction contributed up to 40% to structural failures in building has a mean of 4.6 which is the highest mean among them and also has the least Standard

Deviation of 0.632 ranking 1st among them, Poor quality of building material has a mean of 4.45. foundation failure due to settlement of soil fill has a mean of 3.9, Foundation failure due to soil movement has a mean of 4.15, unequal settlement of masonry has a mean of 4.05, Lateral pressure on the walls has a mean of 3.9, Sub-soil moisture movement has a mean of 4.15, Atmospheric action has a mean of 4.1 and unequal settlement of sub soil has the least mean of 2.9 with the highest Standard Deviation of 1.003 ranking 8 among them. So based on this, the findings shows that the common causes of Building collapse as a result of foundation failure in Anambra State are Faulty construction, Poor quality of building materials and Bad architectural and structural design.

Table 2: Effects of building collapse as a result of foundation failure in Anambra State.

S/N	Effects	SA	A	U	D	SD	Mean Score	STD	Ranking
11	Loss of human lives	11	7	2	0	0	4.45	0.894	1st
12	Loss of materials and capital investments	6	13	1	0	0	4.25	0.958	^rd
13	Wasting of resources like capital, time, materials and labor inputs.	11	6	3	0	0	4.4	0.926	2nd
14	Socio-economical and psychological Effects	7	9	3	1	0	4.1	0.969	4th

Table 2. Loss of human lives has a mean of 4.45 with a standard deviation of 0.894 ranking 1st among them, loss of materials and capital investments has a mean of 4.25, Wasting of resources like capital, time, materials and labor inputs has a mean of 4.4, Socio-economical and psychological effects has a mean of 4.1 and a Standard deviation of 0.969 ranking 4th among them. Based on this, the findings shows that the common effects

of Building collapse as a result of foundation failure in Anambra State are Loss of Human Lives, Wasting of resources like capitals, time, material and labor inputs.

Table 3. Mechanisms put in place to curb the incidence of building collapse as a result of foundation failure in Anambra State.

S/N	Mechanisms	SA	A	U	D	SD	Mean Score	STD	Ranking
15	Compliance of All building designs and plans with the Nigeria's new building code	15	5	0	0	0	4.75	1.035	3rd
16	Soil test, Environmental Impact Assessment (EIA) and structural analysis	17	3	0	0	0	4.75	1.024	1st
17	Inspection team	14	6	0	0	0	4.7	1.025	4th
18	Engaging professionals in building construction works by the clients	17	3	0	0	0	4.85	1.024	1st

Table 3. indicates that Compliance of all building designs and plans with the Nigeria's new building code has a mean of 4.75, Soil test, Environmental Impact Assessment (EIA) and structural analysis has a mean of 4.85 with a Standard Deviation of 1.024 ranking 1st among them, Inspection team has a mean of 4.7, Engaging professionals in building construction works by the Clients has a mean of 4.85 with Standard Deviation of 1.024 and also ranked 1st among them showing that Engaging professionals in building construction works by the Clients and Soil test, Environmental Impact Assessment (EIA) and structural analysis are the first mechanisms that will effectively curb the incidence of Building collapse as a result of foundation failure as a result of foundation failure in Anambra State.

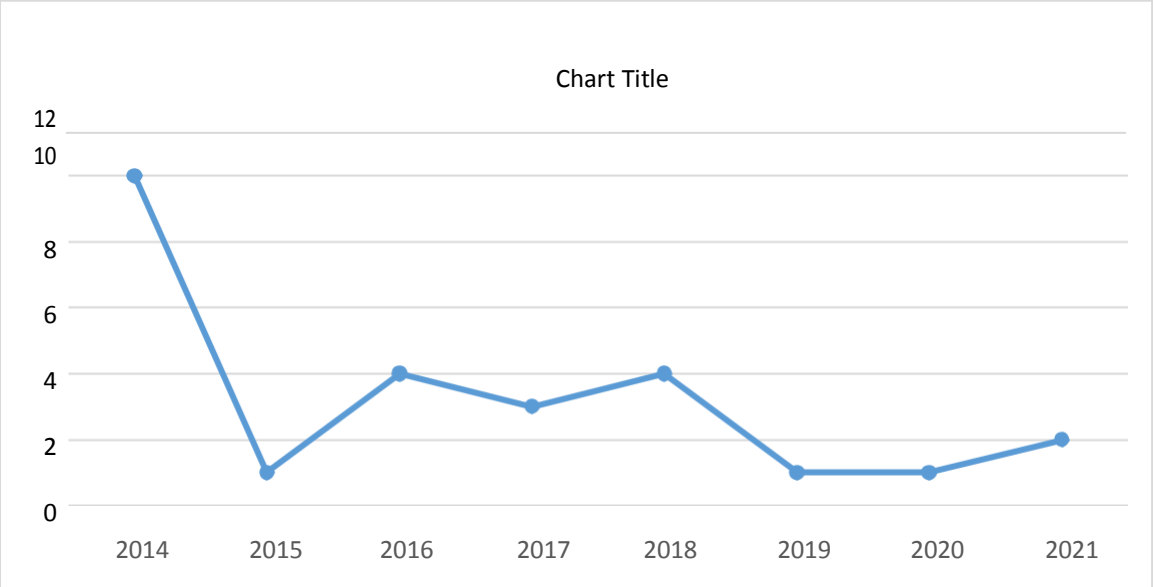
Table 4: Trend of building collapse as a result of foundation failure in Anambra State for the past 6 years.

No.	Description of the property	Location	Date of collapse	Casualties
1	A 5-storey building under construction	No. 10 Udi Street Fegge, Onitsha	13th June,2014	No life was lost
2	A 4-storey building under construction	St. Christopher's Anglican Church, Odokpu, Onitsha.	2nd June, 2014	4 people died
3	A 3 storey building	At Ndiagu, Ikenga-Ogidi	19th June 2014	No life was lost
4	A 2 storey building	Uruagu Nnewi	29th June 2014	No life was lost
5	A 5 storey building	Amafor Land, Mgbuka, Nkpor	9th July 2014	No life was lost
6	A 4-storey school building	Ezinifite Village, Okpuno, Awka	10th July 2014	No life was lost
7	A 2-storey residential building (partial collapse)	Okachi-Okpuno, Awka	9th July, 2014	No life was lost
8	A 2-storey office and church hall building	Otakpo Land 3-3 Onitsha	12th August, 2014	Killing one person
9	An existing students Hostel (partial collapse)	Nodu-Okpuno, Awka	26th August, 2014	Killing one student and others injured
10	A 5-storey block of flats under construction	Udume, Obosi	17th September, 2014	No life was lost
11	A 3-storey building	Awka Town	17th September, 2015	5 people died
12	A storey building	Awka, behind Dora Akunyili Women Development center	3rd November, 2016	No life was lost
13	A 2-storey building under construction	Ndiagu, Idemili-North L.G.A	14th July 2016	3 people died
14	A 4 storey building under construction	Near Federal Polytechnic Oko	22nd May,2016	No life was lost
15	A 2-storey building under construction	Ula Village, Ekwulobia	31st May, 2016	2 persons died

16	A 3-storey building	Amansea close to Awka	29th November, 2017	No life was lost
17	A 4-storey building	Oko in Orumba North L.G.A	15th June 2017	3 people died
18	A 3-storey Hotel building	Nkwo Ezinudo Market, Ogidi, close to Onitsha	25th march, 2017	No life was lost
19	A two storey building	Ekwulobia	31st May, 2018	3 people died
20	A 3-storey building under construction	Nwagu Village near federal Polytechnic Oko.	22nd May, 2018	7 people died
21	A 4-storey building under construction	Owelle-Aja Layout, Obosi, Idemili North L.G.A	17th July, 2018	No life was lost
22	A 2-storey building	Aguleri, Anambra East, L.G.A.	10th January, 2018	Six people died
23	A 3-storey building	#9 Ezenwa street, Onitsha	27th May, 2019	2 deaths recorded
24	A storey building	Obosi, Idemili North L.G.A, Anambra state.	20th September, 2020	A pregnant woman was trapped
25	A 2-storey building	Amikwo Village, Awka	7th July, 2021	No death
26	A 2-storey building	Oko, Orumba North L.G.A, Anambra state.	7th July, 2021	4 Injured

Source: (ANSPPB and SEMA Anambra State, 2021)

Figure 1.3. Trend of building collapse as a result of foundation failure in Anambra State for the past 8years in a graph



Source: (ANSPPB and SEMA Anambra State, 2021)

Fig 1.3. Indicates the trend of collapses in Anambra State from 2014 to 2021 which shows that the total cases of building collapse is 26. Ten (10) buildings collapsed in 2014 which represent 38.5% of the total building collapses. In 2015, one (l) building collapsed in Anambra State representing 3.8% of the total building collapse. In 2016, four (4) buildings representing 15.4% of the total building collapse. In 2017, three (3) buildings collapsed representing 11.5% of the total building collapses. In 2018, four (4) buildings collapsed representing 15.4% of the total building collapse. In 2019, one (l) building collapsed in Anambra State representing 3.8% of the total building collapse. In 2020, one (l) building collapsed in Anambra State representing 3.8% of the total building collapse. In 2021, two (2) buildings collapsed in Anambra State representing 7.7% of the total building collapse. Based on this, the findings on table 4, shows that The issues of building collapse as a result of foundation failure was highest (10) in 2014 but decreases to

(1) after that year and increases to (4) in 2016, In 2017 decreases a little to three (3), then in 2018 there are 4 cases of building collapse which also experienced a significant decrease in 2019 and 2020 to one case of building collapse and later increased to two (2) buildings in 2021.

V. Discussion

Faulty construction, bad design, poor quality of materials and construction methods, sub-soil moisture movement are seen as the causes of foundation failure in this research. The issues of building collapse as a result of foundation failure was highest (10) in 2014 as seen in table 4, but decreases to (1) after that year and increases to (4) in 2016, In 2017 decreases a little to three (3), then in 2018 there were 4 cases of building collapse but decreases to (1) after that year for 2019 and 2020 and then increases to two (2) in 2021. Building collapse as a result of foundation failure has so a tremendous effect on the economic development of Anambra state as shown from the analysis like; loss of human lives, materials and capital investments, resources like time and labor inputs and also has socio-economical and psychological effects like high blood pressure, heart failure, disputes among the citizens in Anambra State

If clients and building professional should adhere to those mechanisms like Engaging professionals in building construction works and Soil test, Environmental Impact Assessment (EIA) and structural analysis it will help to curb the incidence of building collapse as a result of foundation failure in Anambra State.

VI. Conclusion and Recommendation

From the analysis and discussions presented, it can be inferred that up to 70% of the cases of reported building collapse as a result of foundation failure from 2014 to date occurred in the private setting. Also, the level of compliance with the approval of building plans before construction commencement is very low. This could be hinged on the ineffective monitoring mechanism put in place by the relevant government agencies and the low level of awareness of the existing Building/Planning Regulations by clients/contractors. It must be stressed that apart from the economic waste exhibited by building collapse, the occasional loss of lives is having devastating effects on the dwellers and the progress of Anambra State and the nation as a whole. This definitely calls for a proactive action in **This Perspective.**

VII. Recommendation

Public enlightenment is expedient in order to create the awareness on the need for compliance with appropriate building regulations among the professionals, the stakeholders and the public on the dangers associated with none compliance.

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