Causative Indices of Building Collapses in Awka South Local Government Area of Anambra State, Nigeria: The Missing Links

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Abstract: - The incidences of building collapse in Awka, Anambra State Nigeria recently is growing at an alarming rate and seemingly beyond control. Therefore, this study investigates the missing links in proffering solutions to the issue of building collapse in the study area. The study conducted cone penetrometer test (CPT) and borehole-drilling to determine the soil bearing capacity/adequacy of the subsoil, compressive strength and tensile stress test for concrete and steel reinforcement bars test respectively. The study revealed that Lack of sub-soil and geotechnical investigations led to improper and wrong foundation types and works, concrete mix quality was extremely low and less than the expected standard, use of substandard building materials, loading pattern tampered with or changed such that the structural elements were loaded beyond their ultimate capacities, both the yield stress, elongation and the ductility requirements of the reinforcement bars fell short with the construction standard stipulated respectively contributed to the collapses; all the findings are the missing links that contributed to building collapse in the study area. The study strongly advocates the indulgence of government in monitoring all imported building materials to ensure that only materials of good standards are brought into the country, compulsory checks and testing of the materials to be used for buildings should be made compulsory by quality control firms, subsoil/geotechnical investigations on proposed building sites should be enforced especially for multi-storey buildings, registered Builders should be enhanced to enforce the enacted building codes and regulations.

Key Words: — *Building collapse, Subsoil investigation, Compressive strength, Tensile test.*

I. INTRODUCTION

The contribution of buildings to Nigeria's development has not yielded the desired potentials because of building failure/collapse and more recently their poor functional performance [1]. Buildings are structures which serve as shelters for man, his properties and activities; and when properly planned, designed and erected it gives desired satisfaction to the client or user's [2]. Some of the factors to be considered in measuring the standard of a building include durability, adequate stability to prevent its failure or discomfort to the users, resistance to weather, fire outbreak and other forms of accidents [3].

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The styles of building construction are constantly changing with introduction of new materials and techniques of construction. Factors observed during building construction include; the functional performance requirements of durability, adequate stability to prevent structural failure, discomfort to the users, resistance to climatic conditions and use of good quality materials [4]. The styles of building construction are constantly changing with the introduction of new materials and techniques of construction. Consequently, the work involved in the design and construction stages are largely those of selecting materials, component and structures that will meet the expected building standards and aesthetics on an economic basis [5].

Building collapse incidence are still regularly occurring despite increasing diffusion of engineering knowledge over the years and this calls for some re-examination of development in building production and control process [6]. The incessant buildings collapse in Nigeria has become a great concern to all the stakeholders and the professionals in the building industry, government, private developers, clients and users, as well as the residents. Irrespective of the availability of building codes and increase in numbers of registered construction professionals in the Nigerian construction industry, the reported cases of building collapse had become very alarming and worrisome[6]. The incidence of building collapses has become major concern toward socio-economic development of the nation as the frequencies of their occurrence and the magnitude of the losses in terms of lives and properties are now becoming very alarming [7]. The other effects include but not limited to loss of human lives, economic waste in terms of loss of properties, jobs, incomes, loss of trust, psychological, dignity and exasperation of crises among stakeholders and environmental disasters[8].

According to [9] building collapse occurs in all forms of buildings but more frequent in residential buildings of two to four floors. Based on this, [10] asserted that structural failure has become recurring decimal, a worrisome menace nightmare and an enduring embarrassment. This, best describe the current condition of building collapse in Awka which is becoming more rampant and alarming, and seem to be increasing in both numbers and frequencies.

II. Literature Review On Causes Of Building Collapses

Failure can be considered as occurring in a component when that component can no longer perform its designed functions [11]. Building collapse is an extreme case of building failure, which leads to the total or partial cascading of the superstructure [12, 13]. The total failure of the building elements and components can be referred to as building collapse [3]. Collapse of a building may be either a partial, progressive and total or sudden collapse [14]. As posited by [15], each and every member of a structural system should be able to resist, without failure or collapse, the applied loads under service conditions. In other words, it must possess adequate strength

Researchers have attributed building failures and collapses to several causes. [16] suggests that 50% of building failures are caused by design faults, 40% by construction site faults and 10% by product failures. [17] offers causes of structural failures as; environmental changes; natural and man-made hazards; improper presentation and, interpretation of the design.[18] opines that deterioration of concrete could occur as a result of corrosion of reinforcement caused by carbonation and chloride ingress, cracking caused by overloading, subsidence or basic design faults, and construction defects. [19] considers faulty design, faulty execution of work and use of sub-standard materials as a major cause of building failures. Furthermore, [20] in their study identified low quality of materials as the most important cause of poor concrete work in building construction projects. In addition to the foregoing,[6] sums up the causes of building collapse as either that caused by Man or that due to natural causes. [21] further noted that geotechnical regulation and violations have influenced the frequency of the occurrence of building collapse and the magnitude of the losses both in terms of lives and properties in the country.

Further research was carried out by [22] and [23] on the causes of building collapse in Nigeria and identified the following five (5) major causes which include; natural phenomenon, design error, procedural error, sub-standard material, poor workmanship, the lack of maintenance, the abuse of use of building etc. Research showed that the substandard material and poor workmanship contribute 45% to the overall causes of building collapse in Lagos State. [24] added that substandard materials amount to 18.4% of the total cause of building collapse while poor workmanship amount to 19%. Building collapse can be as a result of some defect in building which are not quickly put in place by the property owner such as; fungus stain and harmful growth, erosion of mortar joints, peeling paint, defective plastered renderings, cracking of walls and tearing walls, defective rainwater goods, decayed floor boards, insect or termite attack, roof defect, dampness penetration through walls, unstable/faulty foundation, poor installation of air-condition units etc. All these defects in building if not properly controlled and maintained, with time can lead to unexpected building collapse [25]. In Nigeria, the common causes of building collapse have been traced to bad design, faulty construction, use of low-quality materials, hasty construction, foundation failure, lack of proper supervision, ineffective enforcement of building codes by the relevant Town Planning Authorities, lack of proper maintenance etc. [26] and [27]; [24]. [28] Posits the phase of building project delivery as were quackery prevails and constitutes one of the missing links for collapse free building projects.

III. Study Area

Awka south is one of the local government areas in Anambra State, Nigeria. The local government is made up of nine towns namely: Amawbia, Awka, Ezinato, Isiagu, Mbaukwu, Nibo, Nise, Okpuno and Umuawulu. The table 1 below shows details of the building collapses in Awka South

L.G.A of Anambra State in the past five (5) years (2015-2019), while table 2 represents the case study.

Table.1. Lists of Collapsed Buildings in Awka South L.G.A from 2015– 2019

S/N	Date of collapse	Site Location	Local Government	No. of Floors
1	27/07/2015	No. 1 Chief Charles street, off Abakiliki street, Awka	Awka South	4 floors on-going
2	August, 2015	Standard Plaza Unizik Temporary Site, Awka	Awka South	4 floors on-going
3	30/07/2016	Agbani village behind second market, IfiteAwka	Awka South	3 floors on-going
4	22/06/2017	Road 15 Udoka Housing Estate, Awka	Awka South	4 floors on-going
5	Nov. 2017	Close to Odogwu Hostel Amansea – Awka	Awka South	4 floors on-going
6	April 2018	Beside Master B hotel, Ngene-Amawbia	Awka South	4 floors on-going
7	30/07/18	Ifite Amansea Road, Unizik Prem Site, Awka	Awka south	floors 4 on-going
8	4/10/18	Near yahoo junction, Ifite Awka	Awka south	4 floors on-going
9	15/07/19	No 7 Ngene Street, Okpuno Awka South	Awka South	4 floors on-going
10	16/09/19	Along Amansea/Ifite Road, Awka	Awka South	4 floors on-going

Source: Researchers Fieldwork.

Table.2. Case Studies of Collapsed Buildings

Site Designation	Site Address	Number of Floors	Stage of Work	Date of Collapse
A	Along Amansea/Ifite Road, Awka.	4	Finishing stage	16/09/19
B	Ifite Amansea Road, Unizik Prem Site.	4	On-going	30/07/18

IV. Materials And Methods

The materials used for the tests were obtained in-situ at the site of the collapsed buildings. They include soil samples, concrete mass samples, masonry blocks, reinforcement bars. The method adopted to determine the cause(s) of collapse include visual inspection of the collapsed building, subsoil investigation, determination of the compressive strength of concrete samples, yield stress of steel reinforcement and framed structure analyses. They are as follow;

4.1 Visual Inspection of the Collapsed Buildings

It involves observing the workplace relationships among workers/people and work processes/procedures and recording, describing, analyzing and interpreting the research subjects behavior. Visual inspection is probably the first stage and most important aspect of investigation. Because at this stage, necessary details regarding the initial causes of the problem is obtained. The collapsed building site A was at the finishing stage before the collapse incident while its similar twin structure was still standing and was a 4-floor on-going structure until the collapsed incidence. The collapsed building site B was also a 4-floor on-going structure. In the case of building collapsed the following issues are address during visual inspection:

- Surface observation and close examination of the remnants of the buildings.
- Inspection of the rubbles to determine if the structural elements used were appropriately sized.
- Retrieval from the debris useful materials for laboratory tests.

4.2 Subsoil Investigation

Waltham (2002) asserted that the objective of subsoil investigation is to determine the subsoil conditions and its suitability for the proposed project. The subsoil investigation was conducted to determine the capability of the soil in sustaining the imposed bearing pressure of the collapsed building. The investigation was also aimed at determining the engineering properties and suitability of the subsoil strata across the sites up to the tested depth of 10.0m, as well as determines the appropriate foundation type adopted for the collapsed buildings and its adequacy/suitability.

The collapsed building site subsoil was investigated by means of two numbers (2 nos) boreholes to a depth of 10.0m below existing ground level and execution of Dutch Cone Penetrometer Tests (CPT) using 2.5-ton capacity machine to depth of refusal ranging between 2m- 4.75m.These involved borehole drillings and Cone Penetrometer tests to respectively determine the soil layers and their bearing capacity.

The subsoil investigation works for the collapsed building has been carried out in accordance with accepted geotechnical engineering practice as stipulated in standard code of practice which includes the following.

- B.S. 1377 (1990) – Method of Testing Soils for Civil Eng. Purposes.
- B.S. 5930 (1999) – Code of Practice for Site Investigations.
- B.S. 8004 (1981) – Code of Practice for Foundations.

4.3 Borehole Drilling

Geotechnical boreholes were drilled on the sites of the collapsed buildings using a percussion type drilling rig. It was used to cut down borehole through the soil strata. Relatively undisturbed samples were obtained. The borehole was lined with either 150mm or 250mm diameter steel casings, utilizing the 250mm diameter casings to a depth of 4.5m before reducing to 150mm diameter casings until the termination of the hole.

The drilling tools consisted of an open-tube with a non-return flap valve at one end called a shell**,** for non-cohesive (sandy) strata, and mixed soils. A clay cutter is normally employed to drill through stiff cohesive soils. This is attached to the drilling weight called sinker-bar and subsequently attached to the drilling string.

The casings were turned down using chain grips, but in occasional cases, may be driven down using a special hammer. Undisturbed samples were taken using the conventional open tube sampler by driving a 100mm diameter sampler through a total of 450mm length. These samples are usually taken at depths relevant to the objectives of the investigations. Standard Penetration Tests were carried out in-situ usually in the non – cohesive strata encountered. The standard penetration tests consist of driving a thick – walled 50mm diameter steel tube into the sand at the bottom of the borehole by means of a 63.5kg hammer dropping 75cm. The number of blows required to drive 30cm after an initial penetration of 15cm is recorded as the SPT Number.The subsoil strata encountered during drilling operations are presented in the borehole logs; however, the summary of the subsoil condition is presented in the tables 3and 4 respectively.

Table.3. Subsoil Strata Encountered during Borehole Drilling on site A

BH NO.	Top Stratum (m)	Base Stratum (m)	Description of Stratum	Thickness of Stratum (m)
BH 1	0.0	0.2	Top soil	0.2
	0.2	9.5	Reddish brown lateritic clayey sand	9.5
	9.5	10.5	Reddish brown lateritic clayey sand	10.5
BH 2	0.0	0.2	Top soil	0.2
	0.2	9.5	Reddish brown lateritic sand with traces of clay	9.5
	9.5	10.5	Reddish brown lateritic clayey sand	10.5

Source: Researchers Fieldwork.

Table.4. Subsoil Strata Encountered During Borehole Drilling on Site B

BH NO.	Top Stratum (m)	Base Stratum (m)	Description of Stratum	Thickness of Stratum (m)
BHI	0.0	3.0	Reddish brown lateritic sandy clay with gravel	3.0
	-3.5	15.0	Mottled colour clay with gravel	7.5
BH 2	0.0	3.0	Reddish brown lateritic sandy clay with gravel	3.0
	-3.0	10.5	Mottled colour clay with gravel	7.5

Source: Researchers Fieldwork.

4.4 Cone Penetration Test (CPT):

The cone penetration tests (CPT) were executed using 2.5 tons capacity Dutch Cone Penetrometer Machine. This machine is a precise instrument which measures the resistance to penetration into soil layers. The sequence of layers is interpreted from the variations of the cone end resistance with depth. The cone is pushed into the ground for 20 or 25cm by means of attached winch system at a uniform rate of about 20mm per seconds.

The resistance to penetration of the cone registered on the pressure gauge connected to the pressure capsule is recorded. The tube is then pushed down to the cone and the process described above is repeated.

Based on the CPT readings and the bearing capacity formula (Meyerhof) qa = 5Cu/2.5 (Cu = Undrained Cohesion, qa = Allowable bearing pressure)

The table 5 below is an indicative of the allowable bearing pressure by layers or respective depths for the shallow foundations at the collapsed sites A and B.

Table.5. CPT Readings and the Bearing Capacity of Site A & B

Depth (m)	Allowable bearing pressure (KN/m^2)A	Allowable bearing pressure (KN/m^2) B
0.5	28	114
1.0	28	114
1.5	57	114
2.0	57	114
2.5	85	142
3.0	85	171
3.5	85	171
4.0	114	171

Qa =5cu/2.5 (Qa=allowable bearing pressure, Cu = Undrained Cohesion)

Source: Researchers Fieldwork.

4.5 Determination of the Compressive Strengths of Concrete Samples

Compressive strength tests were conducted on randomly handpicked samples of concrete mass from the heaps of debris generated from the collapsed building. Coring was done on the concrete mass samples using a core drilling machine with 100 mm diamond bit. The cored concrete samples were later cured for 24 hours before being subjected to compression test. Compressive strength tests were carried out on the cored samples using a 3000 KN capacity compression machine to determine the compressive strength of the concrete mix. The assumed Design strength is 25N/mm2. Below is the summary of the compressive strength of concrete samples for site A and B presented in the tables 6 and 7 respectively.

Table.6. Concrete Compressive Strength Test for Site A:

S/N	PARAMETER	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5	SAMPLE 6
1	DIAMETER(mm)	98	98	98	98	98	98
2	HEIGHT (mm)	100	100	100	100	100	100
3	Cross Sectional Area (mm^2)	7544	7544	7544	7544	7544	7544
4	Volume (m^3)	0.000754	0.000754	0.000754	0.000754	0.000754	0.000754
5	Mass (kg)	1.60	1.55	1.80	1.75	1.60	1.75
6	Density (kg/m^3)	2122.02	21055.70	2387.27	2320.95	2122.02	2320.95
7	Load (KN)	53.2	43.8	44.1	51.5	48.2	46.2
8	Compressive Strength (N/mm^2)	7.0	5.8	5.8	6.8	6.3	6.1

The Designed Compressive Strength is 25N/mm^2

Source: Researchers Fieldwork.

Table.7. Concrete Compressive Strength Test for Site B.

S/N	PARAMETER	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5	SAMPE 6
1	DIAMETER (mm)	98	98	98	98	98	98
2	HEIGHT (mm)	100	100	100	100	100	100
3	Cross Sectional Area (mm^2)	7544	7544	7544	7544	7544	7544
4	Volume (m^3)	0.000754	0.000754	0.000754	0.000754	0.000754	0.000754
5	Mass (kg)	1.80	1.85	1.90	2.00	1.85	1.85
6	Density (kg/m^3)	2387.27	2453.58	2519.89	2652.52	2453.58	2453.58
7	Load (KN)	40.3	39.4	41.0	32.3	42.6	35.8
8	Compressive Strength (N/mm^2)	5.3	5.2	5.4	4.2	5.6	4.7

The assumed Designed Compressive Strength is 25N/mm^2

Source: Researchers Fieldwork.

4.6 Yield Stress Test on Steel Reinforcement

Samples of concrete reinforcement bars were picked from the heap of debris generated from the collapsed building.

Tensile test was carried out on the concrete reinforcement bar samples to provide information on ductility, ultimate and yield stress for the reinforcement bars under uniaxial tensile stress. Below is the summary of the yield stress of steel reinforcement samples for site A and B presented in the tables 8 and 9 respectively.

STANDARD: NIS 117:2004, YIELD ≥ 410N/mm2 ELONGATION ≥ 12%

STANDARD: BS 4449:1998 YIELD ≥ 460N/mm2

Table 8: Tensile Test Result on Steel Reinforcement for Site A.

BAR SIZE	Yield		Ultimate		
	Load(KN)	Stress N/mm²	Load(KN)	Stress N/mm²	Elongation%
10mm A	35.52	449.60	50.74	642.28	10.25
B	35.51	449.51	50.73	642.16	10.34
C	35.50	449.41	50.72	642.01	10.22
Average	35.51	449.51	50.73	642.15	10.27
12mm (IGS) A	38.67	341.89	55.24	488.42	9.09
B	38.58	341.10	55.11	487.28	11.40
C	38.64	341.68	55.21	488.12	10.43
Average	38.63	341.56	55.19	487.94	10.31
16mm A	90.38	449.41	129.11	642.02	11.95
B	85.61	425.70	122.30	608.14	11.62
C	87.57	435.47	125.10	622.10	11.34
Average	87.85	436.86	125.50	624.09	11.64

Source: Researchers Fieldwork

Table.9. Tensile Test Result on Steel Reinforcement for Site B.

BAR SIZE	Yield		Ultimate		
	Load(KN)	Stress N/mm²	Load(KN)	Stress N/mm²	Elongation %
12mm (EUROTHERM) A	48.42	428.11	69.17	611.58	10.94
B	49.30	435.90	70.43	622.72	12.06
C	48.61	429.81	69.45	614.02	11.08
Average	48.78	431.27	69.68	616.11	11.36
16mm (RINL) A	85.99	427.62	122.85	610.89	11.25
B	85.68	426.05	122.40	608.64	11.07
C	85.14	423.37	121.63	604.82	11.69
Average	85.60	425.68	122.29	608.82	11.34

Source: Researchers Fieldwork.

4.7 Framed Structure Integrity Assessment

The framed structure is made up of columns, beams, slabs and load bearing walls, all connected to one another to resist lateral and gravity load (deformation) and overcome the large moments due to the applied loading. The columns are anchored in a foundation for overall stability of the structure.

The ability of the frame to continue to support vertical loads depends on both the capacity of the framing system to transfer these loads to adjacent components and the capacity of the components to support the additional loads. Progressive collapse of a structure takes place when the structure has its loading pattern or boundary conditions tampered with or changed such that the structural elements are loaded beyond their ultimate capacities. It is a dynamic process, usually accompanied by large deformations.

V. RESULTS AND DISCUSSION

5.1 Results and Discussion for Site A

5.1.1. Subsoil Investigation

According to the foundation analysis the building is assumed to have asserted load of about 15KN/m2 per floor and 60KN/m2 for four floors. Based on the condition of subsoil strata encountered as shown in table 3, the presence of ground water at a depth of 2.0m, the most appropriate type of foundation that ought to have been used is Reinforced Raft Foundation and to be adopted at a minimum depth of 4.0m below existing ground level. Lack of subsoil investigation which resulted to inadequate foundation type, size and depth used for the construction of the collapsed building contributed largely to failure and the subsequent collapse of building.

The Laboratory analysis shows the subsoil as susceptible to expansion and contraction, magnitude depending on the level of rainfall saturation. The CPT readings for the collapsed building site as shown in table 5 were relatively low up to a depth of about 3.5m. This would have greatly affected the bearing capacity of the foundation soil leading to ultimate cascading collapse. The low bearing resistance values recorded may have further diminished in soil shear strength due to rainfall saturation. The building foundations were also rested on expansive clay soil.

However, considering before collapse that precipitation was consistent for days, soil saturation must have taken place which led to rapid rise in ground water level. A sudden drop in the ground water table with cessation of rainfall and seasonal variation would create volumetric change on the underlying foundation soil. A vertical displacement of soil underneath correspondingly would induce a vertical displacement of building foundations.

5.1.2 Compressive Strengths of Concrete

The compressive strength results of the tested cored concrete samples as presented in table 6 shows that the compressive strength ranges from 5.8 N/mm2 to 7.0 N/mm2and were remarked extremely not satisfactory. This emphatically shows that the concrete compressive strength values are far less than the required standard value of 25 N/mm2 for the structural elements of four floors (BS 1881:1983 PT 3). It could be inferred that the concrete mix quality was extremely low and less than the expected standard and this could be one of the errors in construction procedure that may have compromised the integrity of the building. Failure of any structural element either due to poor concrete strength, substandard building materials or any other defect may have led to progressive collapse. Progressive collapse of a structure takes place when the structure has its loading pattern or boundary conditions tampered with or changed such that the structural elements are loaded beyond their ultimate capacities. It is a dynamic process, usually accompanied by large deformation.

5.1.3 Yield Stress Test On Steel Reinforcement:

The tensile stress test conducted on the high yield concrete reinforcement bar samples (10mm, 12mm & 16mm in table 8 shows that the yield stress values of 341.56 N/mm^2, 436.86 N/mm^2, 449.51 N/mm^2 respectively are not satisfactory (Standard BS 4449:1998 YIELD ≥ 460N/mm^2) The ductility of the reinforced samples (10mm, 12mm & 16mm) elongation of 10.27%, 10.31% and 11.64% as shown in table 8 in not satisfactory (ELONGATION ≥ 12%).

Thus, it could be inferred that most of the yield stress of the tested reinforcement bars were not of expected standard and this could not be one of the errors in construction procedure that may have compromised the integrity of the building. Both the yield stress, elongation and the ductility requirements of the reinforcement bars fell short with the construction standard stipulated, and are likely to have contributed to the probable cause of collapse.

5.1.4 Framed Structure Analysis

Progressive collapse of the structure toke place because the structure had its loading pattern or boundary conditions tampered with or changed such that the structural elements are loaded beyond their ultimate capacities. This is a dynamic process, usually accompanied by large deformations. It is therefore very likely that the structural elements were subjected to loads beyond their ultimate capacities resulting to failure and subsequent building collapse

5.2 Results and Discussion for Site B

5.2.1 Subsoil Investigation

The result of the test conducted on the subsoil (see table 4) shows that the subsoil strata encountered while carrying out the boring and cone penetration test comprise of reddish brown lateritic sandy clay with gravel, which indicates a very stable bearing capacity for the soil. From the soil profile analysis, it was inferred that the bearing capacity (see table 5) of the investigated soil was adequate for the imposed load and so could not have been the cause of Collapse. However, lack of geotechnical investigation may have led to improper and wrong foundation works.

5.2.2 Compressive Strength

The compressive strength results of the tested cored concrete samples as shown in table 7 ranges from 4.2 N/mm2 to 5.6 N/mm2and is extremely not satisfactory. This emphatically shows that the concrete compressive strength values are far less than the required standard value of 25 N/mm2 for the structural elements of this number of floors.

Thus, it could be inferred that the concrete mix quality was less than the expected standard and this could be one of the major errors in construction procedure that may have compromised the integrity of the building.

5.2.3 Yield Stress Test on Steel Reinforcement

The tensile stress test conducted on the high yield concrete reinforcement bars samples (sizes of 12 mm & 16 mm) according to table 9 shows that all the reinforcement bars with the values 425.68 N/mm^2 – 431.27 N/mm^2 are below the accepted standard and thus were remarked as not satisfactory (Standard BS 4449:1998 YIELD ≥ 460N/mm^2). The ductility of the reinforced samples (12mm & 16mm) as shown in table 9 has an elongation of 11.34% and 11.36% and not satisfactory (ELONGATION ≥ 12%).

Thus, it could be inferred that the yield stress and ductility of the tested concrete reinforcement bar samples were not of expected standard and this was one of the errors in construction procedure that compromised the integrity of the building.

VI. CONCLUSION

The primary cause of the building collapse is the loss of vertical load carrying capacity in critical building components leading to cascading vertical collapse. This study attributes inadequate foundations (type and depth) resulting from lack of sub-soil and geotechnical investigation for appropriate foundation design, thereby leading to wrong construction method as another major critical factor that leads to building collapse. The use of poor quality concrete mix, substandard construction materials as seen in the reinforcement bars, are other critical factors that contributed to building collapse as shown in this study.

The study therefore attributes the missing link in building collapse to poor quality concrete mix, substandard construction material, poor construction method, inadequate foundations (type and depth) and poor workmanship.

RECOMMENDATION

- Compulsory checks on the materials to be used for buildings should be made on building sites by quality control firms. This is to ensure their compliance with the stipulated Standards. This includes proper scrutinizing and testing of the building materials in laboratories to ensure adequate quality.
- Subsoil/geotechnical investigations on proposed building sites should be enforced especially for multi-storey buildings. This will help to ascertain the nature, capacity of the sub-soils and the suitable foundation type to be used.
- Government should monitor all building materials to ensure that only materials of good standards are used in the country. This includes proper scrutinizing of building materials by Standard Organization of Nigeria.
- Relevant authorities should enact and enforce laws guiding construction services. Registered Builders should be employed to enforce the enacted National building code.
- Periodic building maintenance culture should be imbibed to increase the service life of buildings.

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