World Academy of Science, Engineering and Technology
International Journal of Civil and Environmental Engineering
Vol:16, No:2, 2022

Analysis of Incidences of Collapsed Buildings in the City of Douala, Cameroon from 2011-2020

T. G. L. J. Bikoko, J. C. Tchamba, S. Amziane

***Abstract*—**This study focuses on the problem of collapsed buildings within the city of Douala over the past ten years, and more precisely within the period from 2011 to 2020. It was carried out in a bid to ascertain the real causes of this phenomenon, which has become recurrent in the leading economic city of Cameroon. To achieve this, it was first necessary to review some works dealing with construction materials and technology as well as some case histories of structural collapse within the city. Thereafter, a statistical study was carried out on the results obtained. It was found that the causes of building collapses in the city of Douala are: Neglect of administrative procedures, use of poor quality materials, poor composition and confectioning of concrete, lack of Geotechnical study, lack of structural analysis and design, corrosion of the reinforcement bars, poor maintenance in buildings, and other causes. Out of the 46 cases of failure and collapse of buildings within the city of Douala, 7 of these were identified to have had no geotechnical study carried out, giving a percentage of 15.22%. It was also observed that out of the 46 cases of structural failure, 6 were as a result of lack of proper structural analysis and design giving a percentage of 13.04%. Subsequently, recommendations and suggestions are made in a bid to place particular emphasis on the choice of materials, the manufacture and casting of concrete as well as the placement of the required reinforcements. All this guarantees the stability of a building.

***Keywords*—**Collapse buildings, Douala, structural collapse, Cameroon.

I. Introduction

THE collapse of buildings is a worldwide problem; the causes of collapse must be investigated starting from the preliminary works to the construction phases. Reference [1] studied some aspects of construction technology that lead to the collapse of buildings in Yaoundé and Douala over the period from 2010 to 2014. They concluded that the absence of a study of the foundation soil, inadequate preliminary works, use of poor quality concrete and environmental factors is at the origin of this phenomenon. Reference [2] stated that causes of failures and collapses fall into five general areas, namely design deficiencies, construction deficiencies, material deficiencies, administrative deficiencies and maintenance deficiencies. Reference [3] examined structural failure in buildings under construction in Akure, Nigeria in order to make proposals to reduce and possibly stop the incessant cases of building collapse. Studies carried out by [4], Reference [5] and Reference [3] show that the use of inferior materials can lead to the ruin or even the collapse of buildings. Reference [6] estimated that the degradation of buildings made of reinforced concrete materials during the construction phase could occur due to: corrosion of the reinforcement caused by carbonation and chloride attack, and also cracking due to overloading. Reference [7] conducted a study on building collapses in Cameroonian cities and found that the causes of collapses of buildings are ranging from neglect of control of site construction by the local authorities to environmental factors such as rain, erosion, cavitation, etc. Reference [8] analyzed and classified the different causes that lead to the collapse as being poor design, failure of the foundations, unnecessary overloads from a combination of other factors and finally the engineers responsibility resulting from a negligence of proper structural calculations and implementation.

Reference [9] discussed the factors that determine the degree of loss of human life during collapse of structures. To estimate the number of human lives lost during an earthquake for type ''b'' buildings they proposed the model:

$$K_{sb} = D5_b[M1_b * M2_b * M3_b 2 * (M4_b + M5_b)]$$

where: D5 is the number of collapse buildings, M1 the number of people per building, M2 is the occupancy of the building at the time of the earthquake, M3 is the number of occupants trapped during the earthquake, M4 is the number of deaths during the collapse, M5 is the number of deaths after the collapse.

This study focuses on the collapse of reinforced concrete frame buildings within the city of Douala. In this context, the investigation of the causes will begin with the administrative procedure then to the design and construction. The quality of the materials used and the workmanship can also cause enormous problems for the supporting structure of a building. This is accentuated when the monitoring and control of the execution of the work is not always well done, which nevertheless play the role of support to avoid the accumulation of production errors that could lead to the worst. A building, once completed, is affected by the problems of degradation, aging, corrosion, various attacks, etc., in short, upkeep or maintenance. The influence of the environment in which a building is located can also be detrimental to it, such as floods, earthquakes, landslides, etc. [10]. So the probable causes of collapses are numerous and of various kinds. Therefore, we present some aspects during the construction phase that lead to

T. G. L. J. Bikoko is with the University of Johannesburg, South Africa (corresponding author e-mail: lejeunegautier@rocketmail.com). He is also with Institut Supérieure des Sciences des Techniques Industrielles et Commerciales (ISTIC)/Ecole d'Ingénierie Industrielle, Cameroun.

J. C. Tchamba is with the University of Douala, ENSET, Cameroon.(e-mail: jctchamba@yahoo.fr).

S. Amziane is with the University Clermont Auvergne, Polytech Clermont-Ferrand, France (e-mail: sofiane.amziane@uca.fr).

the stability of a building during the investigation time, as well as some cases of collapse identified in Cameroon and in particular in Douala.

II. Description of the City of Douala

Douala is a city located on the estuary of the Wouri river and located 30 km from the Atlantic Ocean with coordinates of 4°253 N latitude and 9°4215 E of longitude within the Gulf of Guinea in the Cameroon coastal (Littoral) region. The city extends over an area of 410 km^2 divided into 6 districts such as Douala 1, Douala 2, Douala 3, Douala 4, Douala 5 and Douala 6. Its demography in 2019 was 3.6 million inhabitants giving a population density of 8.874 inhabitants/Km^2. Douala has an altitude of 17 m with a monsoon type climate characterized by a temperature on average of 26.2°C and very abundant rainfall particularly during the rainy season spanning from June to October and a relative humidity of 99%. The dry season spans from the month of October to May and has a relative humidity of 80%. A summary of the climate data is given in Table I.

TABLE I
AVERAGE TEMPERATURES AND PRECIPITATION OF THE CITY OF DOUALA [11].

Month	Jan.	Feb.	Mar	Apr	May	Jun	July	Aug	Sept	Oct.	Nov.	Dec.
Average minimal temperature (°C)	22.44	25	24.44	2.44	23.89	23.89	23.33	23.33	23.33	23.33	23.89	23.89
Average maximal temperature (°C)	30	30.56	30.56	30	29.44	27.78	26.67	26.67	27.22	27.78	28.89	30
Precipitation (mm)	50.8	81.3	195.6	226.1	307.3	477.5	622.3	627.	581.7	419.1	154.9	55.9

III. Historicity of Causes and Consequences of Some Cases of Collapsed Building Structures in Douala

Douala has witnessed some number of building collapse, amongst others are: On May 09, 2014, a four-storey building collapsed due to subsidence in Bonamouang in Akwa-Nord. On August 03, 2015 in Ndogbong suburb, the collapse of a five storey building occurred, damaging part of an opposite building. Just three weeks thereafter, on September 24, 2015 in the Nkongmondo suburb, the collapse of another five storey building occurred. A year later, on June 19, 2016, it was the turn of the Ndogbat suburb where a building collapse had caused the deaths of 05 people and many injuries (Fig. 1). An accusing finger was pointed at the non-compliance with construction standards and the quality of building materials. As if that were not enough, on March 20, 2017, there was the collapse of a retaining wall resulting in 03 deaths and 03 injuries in Bonadouma-Home. This once again reveals the thorny issue of the granting of building permits and the poor quality of building construction standards as well as the lack of quality expertise in the city of Douala at every stage of the whole construction cycle in Douala. In February 2018, a building collapsed in the Koumassi neighbourhood, leaving a family homeless. Five months later, precisely in June 2018, there was yet another building collapse killing 05 people. On July 18, 2019, a 4 storey building located in the Ngangue suburb collapsed, killing the site manager. Local residents testified that the owner initially intended a two storey building, after which, two more floors were added. On August 21, 2019 in the Bonabéri-Sodico suburb, a two- storey building housing two church facilities and a primary school witnessed one of its sections collapse.

On January 13, 2020, in Ndogbong suburb, there was a partial collapse of one storey building, causing extensive material damage (see Fig. 2). In fact, it was the first floor of the building that had collapsed and had fallen onto a nearby student hostel destroying about five rooms including their contents. Again, the cause of this was attributed to poor quality construction. The latest in these series of collapses took place in Beedi suburb, in front of the Douala General Hospital, on May 30, 2020, where a four-storey building collapsed, partially destroying a house nearby as well as a parked vehicle.

Fig. 1 Collapse of four- storeys building in the Ndogbat suburb

Fig. 2 Collapse of one storey building in the Ndogbong suburb

IV. Methodology

To achieve the goal assigned to this study, the methodology was conducted as follow:

- Firstly, we have consulted previously published works related to building failures and collapses.
- Secondly, we designed questionnaires and administered them to the various stakeholders within the construction industry such as real estate developers, architects, engineers and contractors in order to obtain an informed opinion on this collapse phenomenon which has become recurrent.
- Thirdly, we visited some building collapses site. We also interrogated the Douala city council, the Cameroonian National Civil Engineering Laboratory (LABOGENIE), Sol Solution Civil Engineering Laboratory, the Army Rescue, where consultations were carried out with various stakeholders. The discussions hovered around issues of structural collapse that have taken place over the past ten years in the city of Douala have been made.

- Fourthly, an inventory of the various cases of building collapses that have occurred in the city of Douala since 2011 was established, taking note of their exact dates, locations, suspected causes and casualties involved.
- Finally, the collected data were processed and analysed and some recommendations are suggested to reduce or minimize or limit building accidents in Cameroon.

V. Analysis of Data and Discussion of Results

Table II presents some of the reported cases of building collapse within the city of Douala from 2011-2020 showing the dates of collapse, the building locations, the suspected causes as well as the casualties involved which reveal that 12 people died and 7 others were injured. It can also be seen from this table that the primary causes of this phenomenon, which has become recurrent in the leading economic city of Cameroon are: Wrong implementation of construction methods, adoption of wrong foundation, use of poor materials, poor concrete works followed by the secondary causes which are: faulty construction, lack of structural design, lack of soil study and finally the less common causes of: faulty design, lack of building permit etc.

TABLE II
Some Reported Cases of Collapsed Buildings (Structures) in Douala (2011-2020) ([1]; Authors Field Works)

S/N	Building location	Type of building structure	Date of collapse	Suspected causes of building collapse	Number of lives lost/Injuries
1	Lapeyrere-Akwa	Four-Storey Residential Building Under Construction	July 17,2013	-Faulty Design -Faulty Construction -Use of poor materials	2 Died
2	Ndogbong	Five-Storey Residential Building under Construction	May 13,2013	-Foundation settlement	1 Died
3	Bépanda	Multi-Sport Complex Steel Truss Roof under Construction	January 7,2013	-Faulty Construction	Nil
4	Akwa-Nord	Four-Storey Residential Building under use though under Construction	May 18,2014	-Excessive loading - Faulty Design -Degradation due to environment	Nil
5	Kotto Village	Four-Storey Residential Building Under Construction	June 15,2012	-Erosion	Nil
6	Akwa-Sud	Residential Building Under Construction	April 11,2011	-Faulty Construction -Use of poor materials	Nil
7	Ndogbati	Collapse of a 3 storey building during construction	19 June 2016	- Wrong implementation of construction methods - Lack of structural design - Adoption of wrong foundation - Use of poor materials - Poor concrete works	05 Deaths
8	Bépanda	Building collapse during construction	07August 2016	- Adoption of wrong foundation - Lack of soil study	Nil
9	Bonadouma Home	Collapse of retaining wall at the end of construction	20 March 2017	- Lack of building permit - Lack of soil study - Lack of structural design - Wrong implementation of construction methods - Adoption of wrong foundation	03 Deaths & 03 Injured
10	PAD Sté ALACAM	Collapse of a warehouse at the end of construction	27 June 2017	- Wrong implementation of construction methods - Adoption of wrong foundation	01 Death & 01 Injured
11	Bonapriso	Collapse of a 3 storey building during construction	19 January 2018	- Wrong implementation of construction methods - Poor concrete works	Nil
12	Koumassi	Building collapse during construction	February 2018	- Lack of building permit - Lack of soil study - Lack of structural design - Adoption of wrong foundation - Wrong implementation of construction methods - Poor concrete works	Nil
13	Beedi	Collapse of a 3 storey building when occupied	30 May 2020	- Wrong implementation of construction methods - Use of poor materials - Poor concrete works	03 Injured

VI. Causes of Building Collapses in Douala

As stated above, the collapse of a building is indicative of a problem which must be investigated starting from the preliminary studies to the construction phases through the design (architectural design, structural design etc.), the administrative procedure (obtaining building permit etc.) and inspection by the municipality or city council. The following factors listed below among others have been identified as the causes of building collapses in the city of Douala:

A. Neglect of Administrative Procedures

It is rare, and even impossible, to see a large-scale construction project in Cameroon, like those mentioned above, where the promoters have requested administrative procedures beforehand, or even after its completion. They can be committed either to obtain a building permit at the start of the project, or to obtain a certificate of conformity at the end, or for any authorization regarding land use. Construction works done without acquired a building permit would normally be deemed illegal [1], [12].

B. Choice and Quality of Materials

The degradation or deterioration of buildings depends on the quality of the materials used. This means that the poorer the quality of the materials, the more likely the building to degrade or deteriorate rapidly, in the worst case, collapse. Thus, to guarantee a good lifespan to our buildings, the inspection and monitoring services of the construction contracts will have to ensure the choice and the quality of the materials to be used.

C. Poor Composition and Confectioning of Concrete

Some of the construction sites in Cameroon used poor quality sand with high levels of organic matter and high salinity. Sand from the Wouri River was fraudulently delivered to construction sites intended for at least 3 story buildings. In some of these sites, it was observed that the cements used were from poorly preserved cement with the packaging often torn and the cement is being utilized ignorantly. Also, some of the reinforcements used were smaller than the prescribed nominal dimensions. It was also observed that the proportions of constituents in the concrete mix were not respected as well as non-respect of conditions of manufacture. At several construction sites we observed that a given quantity of ready mixed concrete was casted, and then 1h30 and 2 hours later a remaining portion of this concrete was remixed with added water then poured in concrete moulds. This practice reduce the compressive strength of concrete and greatly affect the concrete quality and Reference [13] stated that the compressive strength of re-mixing concrete with 1h30 and 2 hours' time delay is lower than concrete prepared with a time delay of 30 minutes. The reduction in 28 days compressive strength was up to 28.28% when compared with the concrete prepared with 30 minutes delay in time [13].

D. Lack of Geotechnical Study

Lack of geotechnical study includes lack of soil testing and foundation. It was reported that 15.22% of failure and collapse of buildings within the city of Douala at that time was due to lack of geotechnical study. For any building construction, it is important to predict the likely behaviour of the supporting soil. This is in order to avoid any disaster during or after the construction phase.

E. Lack of Structural Analysis and Design

It was observed that out of the 46 cases of structural failure, 6 were as a result of lack of proper structural analysis and design giving a percentage of 13.04%. In this regards we can affirm that this does not greatly influence the total number of structural failure that have occurred within the past ten years in the city of Douala.

F. Corrosion of the Reinforcement Bars

Corrosion of steel reinforcement in concrete is one of the most important factors reducing the durability and the service life of reinforced concrete structures. It is characterized by a progressive loss of mass of metal and the formation of rust in presence of an environment containing chloride ions or carbon dioxide.

Corrosion of steel in reinforced concrete is the consequence of many interactions between structures and their environment (presence of chloride, carbon dioxide, humidity etc.), leading to the so called oxido-reduction reactions between reinforcement and oxygen content in the surrounding weather [14], [15]. The main consequences of this phenomenon are: concrete cracking and spalling, brownish staining, the decrease of the bond between concrete and the reinforcement, the reduction of the section of the reinforcement. The possible cause of cracking and spalling is: Poor workmanship during the construction phase.

G. Poor Maintenance in Buildings

Maintenance work includes preventive maintenance and corrective maintenance. Preventive maintenance aims to reduce the probability of failure or damage of a building and corrective maintenance is all the activities conducted after the failure of a building or the degradation of its function. It was observed that very few buildings undergo maintenance works in Cameroon after their service.

Other factors identified include:

- Lack of equipment in the construction industry
- Absence of professional supervision of site works
- Faulty construction methodology
- Illegal conversion of buildings
- Change of use of buildings
- Financial pressures
- The use of non-professionals in building construction
- Fire disaster

VII. Recommendations

The following measures would aid to reduce or limit building accidents in Cameroon:

- Getting the building permit before commencing construction on site

- Inspection of construction site should be enforced at the local government authorities and relevant government departments to ensure compliance with approved building plans.
- A preliminary geotechnical investigation should be carried out before design.
- Prohibiting the use of non-professionals in building construction.
- Construction materials quality control check should be made before using them into construction works.

VIII. Conclusions

This paper reports the analysis of incidences of collapsed buildings in the city of Douala, Cameroon from 2011-2020. The study concluded that, the causes of buildings collapse in the city of Douala from 2011 to 2020 are:

- Neglect of administrative procedures
- Use of poor quality materials
- Poor composition and confectioning of concrete
- Lack of Geotechnical study
- Lack of structural analysis and design
- Corrosion of the reinforcement bars
- Poor maintenance in buildings
- And other causes.

References

[1] Tchamba J. C., and Bikoko, T. G. L. J., "Failure and collapse of building structures in the cities of Yaoundé and Douala, Cameroun," from 2010 to 2014. Modern Applied Science, 10(1), pp 23-33, 2016.
[2] T. G. L. J. Bikoko, Jean Claude Tchamba, Felix Ndubisi Okonta, "A Comprehensive Review of Failure and Collapse of Buildings/Structures," International Journal of Civil Engineering and Technology 10(3), pp. 187–198, 2019.
[3] A. A. Taiwo, J. A. Afolami "Incessant building collapse: A case of a hotel in Akure, Nigeria," Journal of Building Appraisal 6, 241-248 (2011).
[4] Ogunseemi (ed) Proceedings on building Collapse: Causes, Prevention and Remedies Ondo State, Nigeria: The Nigerian Institute of Building, pp. 110-121.
[5] Folagbade, S. O. "Case studies of building collapse in Nigeria," In D.R.
[6] Richard, R. L. (2002) Leading the Way in Concrete Repair and Protection Technology, Vol.1, Costa Rica: Concrete repair Association, pp.1.
[7] T. G. L. J. Bikoko and J. C. Tchamba, "Causes of Failure and Collapse of Building Structures in Cameroonian Cities," Academic Journal of Civil Engineering 10(3), pp. 187–198, 2019.
[8] Mohammed Almarwae (2017) "Structural Failure of Buildings: Issues and Challenges ," World Scientific News WSN 66 (2017) pp. 97-108
[9] A. W. Cobrun, R. J. S. Spence and A. Pomonis "Factors determining human casualty levels in earthquakes: Mortality prediction in building collapse," Earthquake Engineering, tenth World Conference Balkema, Rotterdam. Pp. 5989-5994, 1992.
[10] KhobiziSena, "Réhabilitation des structures en béton armé" mémoire présenté et soutenu en vue d'obtention du Master en génie civil, option structures, 2017.
[11] Bikoko, T. G. L. J. (2021). "A Cameroonian Study on Mixing Concrete with Wood Ashes: Effects of 0-30% Wood Ashes as a Substitute of Cement on the Strength of Concretes," Revue des Composites et des Matériaux Avancés, In Press.
[12] Alinaitwe, H. M., and Ekolu, S .O. (2014). " Failure of Structures in East Africa with focus on the causes of failures in the construction phase.," In S. O. Ekolu et al. (Eds.), Proceedings of the First International Conference on Construction Materials and Structures, 24-26 November, 2014, Johannesburg, South Africa, 76-85.
[13] D. Pradeep Kumar and Abraham Biable, "Experimental Investigation on the Effect of Compressive Strength of Concrete Due to Delay in Pouring Concrete, " International Journal of Advanced Research in Engineering and Technology, 11(9), 2020, pp. 448-456.
[14] Liu Y., and R. E. Weyers,' "Modeling of the Time to Corrosion Cracking in Chloride Contaminated Reinforced Concrete Structures," ACI Materials Journal, Vol 95, pp.675-681, 1998.
[15] T. A. El Maaddawi and K. A. Soudhi, "Effectiveness of Impressed Current Technique to simulate Corrosion of Steel Reinforcement in Concrete," Journal of Materials in Civil Engineering, January/February, 2003.