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Modelling, Analysis and Design of a Multi-Storey Helipad-Car Park: a Proposal for Canaan Land

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Abstract*—The rapid growth of urbanization and the ever increasing population of urban centers in modern age of today, has brought about increase in the use of cars, roads and other transportation facilities. This singular factor has created constrains on traffic management system and parking of cars in most of these areas. That is why new innovations and technology need to be put in place to help address this issue and reduce some of the constrains on traffic management system of urban centers and also help improve their parking system. One of these innovations is the introduction of multi-storey car park. The multi-storey car park is one major innovation put in place to help with traffic management system of urban centers in most developed countries and introducing this kind of innovation into the developing countries such as Nigeria would help the traffic management system of major urban centers, bring less environmental hazards with the attendant social and economic gains for the society. That is why this research aims at the modelling, analysis and design of a multi-storey car park which would improve the traffic management of a functional modern society like that of Canaan land. Autodesk Revit and Robot soft wares are adopted and the results obtained are promising and replicable.

Index Terms*— Helipad Design, Modelling, Multi-Storey Car Park, Structural Analysis, Structural Design, Traffic Challenges, Urbanization.

I. INTRODUCTION

Transportation has been an important aspect of human activity, especially in the socio-economical interaction of the human society. It has helped with the effective interaction between different locations, bringing about robust movement of people and good and therefore forming the wheel on which economic activities rely to grow. The growth of every country's economy is measured by the growth of its transport infrastructure [1]. With the fast growing population of the world today, towns and cities are experiencing difficulties in managing the traffic flow in the society. The increasing population and expanding urban centres has been accompanied by increasing rate of car ownership and increasing demand for movement for various purposes which has led to heavy traffic congestion on roads today [2].

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The high rate of urbanization has also caused an increase in the cost of land in the city, making it difficult to create effective parking space for the high number of vehicles that ply the roads. Urban overpopulation and the desire to optimize the use of scarce land resources in urban city centers have led to the trend in modern cities all over the world of developing high-rise buildings [3]. Since adequate parking space cannot be adequately provided, car owners abandon their cars recklessly along the road sides or street corners thereby obstructing the movement of traffic, causing accidents, leading to traffic congestion/jam on major roads within the cities and thereby making life unbearable as the society as whole incurs a lot of social and economic damages due to lateness to work, to business, aborted appointments, pollution and health hazards. Effective vehicular traffic management and availability of parking space has become a critical issue in major city centres when the level of huge investments that have been made to the road sector by the Governments is being considered. One of the realistic approaches to solving this problem is the provision of multi-storey car park. As there are various developments in technology, factories, offices, companies, cars and house ownership, the importance of provision of adequate parking facilities to meet up with the increase in traffic movement in public areas cannot be over emphasized. Multi-storeys car park is one of the main facilities that helps increase the ease and efficiency of parking. Multi-storeys car parks provide optimum utilization of space by increasing the number of cars that can be parked in an available space through the use of multiple floors. Multi-storeys car park also helps to eliminate side street parking in congested areas thereby reducing traffic problems and challenges.

A Multi-Storey car park is an elevated or underground structure designed and built essentially for parking cars [4]. The earliest known multi-storey car park was built in 1918 for the Hotel La Salle at 215 West Washington Street in the west loop area of downtown Chicago, Illinois [5]. Molti-storey parking house is a very effective facility that has helped traffic control and manage traffic congestion in most developed countries such as the United Kingdom and United State of America. This have been a very good option in providing adequate parking space with little availability of land for massive parking space and with improved security for parked cars. That is why in developing countries like Nigeria, there is a need to incorporate such facilities in our cities so as to help reduce traffic congestion and save the citizens from the hazards connected to traffic problems. In modern society today, parking has become a major challenge for most urban

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centres and places of mass congregation which has led to build-up of traffic on the roads and also the insecurity of the cars been parked on road sides and street corners. The challenges of indiscriminate parking cars such as insecurity, theft and vandalism of vehicles and molestation of car owners are common in most developing countries such as Nigeria.

Researches have shown that traffic congestion are caused by inadequate parking space, poor traffic signs/signals, indiscipline of car drivers, poor design standard for parking, poor traffic management, unavailability of land for parking facilities, just to mention a few. This why a multi-storey car park should be put in place as a way of mitigating the problems of insufficient parking space. Due to the massive traffic that swarm to Canaan land on Sundays and periods of special events like Shiloh, Covenant University Matriculations and Convocations etc., there is a need for better traffic management and this case study is designed to facilitate car parking for Canaan land visitors.

This research aims to model, analysis and design a multi-storey car park with helipad that will help mitigate the traffic congestion in public areas like Canaan land with the attendant benefits that comes with it. The research will develop an architectural model of a multi-storey parking lot using AutoCAD and Revit. Then, the structure will be modelled, analysed and designed with Autodesk Robot.

Canaan land is an ultra-modern, large and fast growing community that accommodates large number of people that resides within its premises and large influx of people (such as visitors, church member, workers) that come in for various activities. This implies that a large number of automobiles (cars, vans, buses and trucks) do go in and out of Canaan land on days of mass influx. Sunday services depict the peak of traffic in Canaan land and also during the Shiloh program at the end of every year. Canaan land experience an average of 25,000 cars per Sunday which gives a good understanding of the amount of cars that comes in and out of Canaan land. Thus, this indicates the need for better traffic management, extra parking spaces and safety of cars. The need for helipad can be justified with the increasing number of rich Nigerians that can afford Jets and Helicopters and to give options to those that can afford it to beat the traffic jams and hassle on Lagos-Ota roads.

II. LITERATURE REVIEW ON MULTI-STOREY CAR PARK AND HELIPAD DESIGN

Few works exist in this sector when compared to other kind of designs such as buildings and bridges. Pike and few others [6], [7], [8], [9], [10] considered the problematics of multi-storey car parks and the special features. The difficulties range from some distinct characteristics that have led to some failed multi-story car parks, to the uniqueness of some basic features to be considered, to the limited number of functional examples on which to follow and create more innovative models etc. Due to the uniqueness of this structure, the static and dynamic loads coming on the slabs must be effectively transmitted to the beams, columns and to the foundation. Therefore, elements of the frame must be capable of resisting the worst load cases applicable. The slab on the last floor must be particularly reinforced to be able to resist the complicated load case deriving from the landing of helicopters. The modelling, analysis and design must be accurately executed in line with the material properties, structural details and different load combinations [11], [12], [13], [14], [15].

III. METHODOLOGY

Here, the general overview of the methods of approach that were applied for the development of the structural model, analysis and design of selected members of the structure are considered. The architectural model was developed with AutoCAD and Revit, but the structural model was developed on Robot Structural Analysis. The analysis and design of the structure in reinforced concrete will be in accordance with BS codes [16], [17], [18], [19]. The approach of this research will be similar to works in [20]. The estimated dead load and imposed loads values used are in accordance with the British Standards. The design load, N, on the suspended slabs is computed as:

$$N = 1.4G_K + 1.6Q_K \quad (1)$$

where G_K is the characteristic dead load and Q_K is the characteristic imposed load.

The proposed car park is on four floors above ground, have 1,200 parking spaces, occupies 7660m^2, have a mechanical service centre and a car wash, have two external ramps (one for entry and one for exit), two entrances and exits each, lifts and stairs at appropriate places and emergency exits.

The architectural model was developed on Revit which is very good also for creating the necessary detail of the structure that would be needed for the structural modelling on Robot. The structure would have external helical ramps which permits the transition of cars from one floor to another. After the Revit model has been completed, the model can be transferred to robot for analysis. Otherwise, a new structural model can be created from the scratch on Robot or starting from an AutoCAD architectural plan. The 3D computer model of the structure is developed on Autodesk Robot Structural Analysis software. The analysis will derive the response of the structural element to loading. The Robot Structural Analysis software adopts the finite element method which furnishes the maximum shear stresses in beams and columns, the maximum bending moments in slabs, beams and columns, the maximum deformations of the structure under different load cases and the stresses in the shear walls. Figure 1 shows a 3D view of the multi-story helipad-car park while figure 2 is the general arrangement of the structural elements which shows the location and position of the structural members such slabs, beams and columns.

Figure 1: view showing the external ramp for exit

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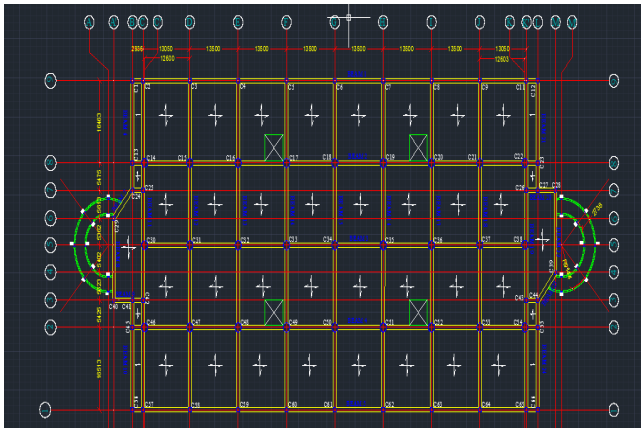

Figure 2: General Arrangement drawing

IV. RESULTS AND DISCUSSIONS

Here the result of this research on multi-storey parking structure is presented. The process of the research work consisted of architectural design with AutoCAD and Revit, modelling, structural analysis and design with Autodesk Robot. The architectural design was a very important aspect of this project. The design provided basic information about the structure, information like the total length-width of the structure, the location and diameter of the helical ramp, the dimensions of the packing bay, of the aisle and basic geometrical information of the parking facility. It also provides pictorial information of the way cars are being parked within the car park. It also gives an insight of the structural elements and where they are to be placed. The sectional properties are shown in table 1.

Table 1: Section of different structural member with their position

Sections (mm)	Position
BEAM	
300 X 600	Beam 25 to Beam 28
600 X 900	Beam 1 to Beam 24
COLUMNS	
300 X 900	C67, C68, C69, C70, C71, C72, C73, C74, C75, C76, C77, C78, C79, C80, C81, C82, C83, C84, C85
600 X 900	C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C13, C23, C24, C25, C26, C27, C28, C29, C39, C40, C41, C42, C43, C44, C45, C55, C56, C57, C58, C59, C60, C61, C62, C63, C64, C65, C66
1200 (Diameter)	C14, C15, C16, C17, C18, C19, C20, C21, C22, C30, C31, C32, C33, C34, C35, C36, C37, C38, C46,C47, C48, C49, C50, C51, C52, C53, C54

V. MODELLING

The model went through different stages of development before attaining the final stage that was used for analysis. The first phase of the modelling process started with importing the general arrangement layout from AutoCAD to Robot where the initial modelling started. The layout was careful developed so as to prevent any form of error when modelling in Robot. The various phase of the modelling process are being illustrated in figures 3 and 4.

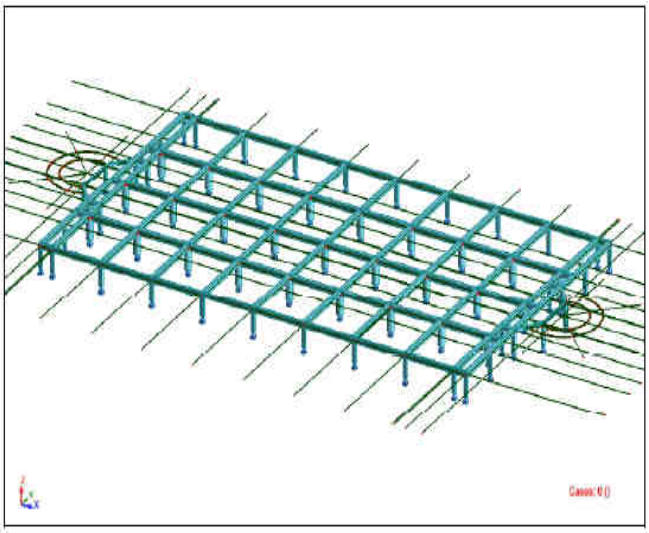

Figure 31: Placement of columns and beams on the first floor

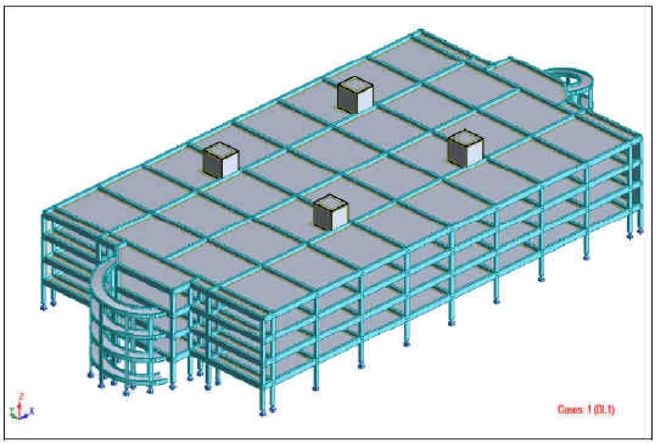

Figure 42: Wire frame of the 3D model

VI. ANALYSIS AND DESIGN

The structural analysis was carried out on robot after the model has been developed on it. Several load cases were taken into consideration before the analysis were carried out. The load cases considered for the analyses of the structure were dead load, live load (which comprises of static load + dynamic load), helipad load and wind load. The single load cases were then combined in the various manner according to the code prescription. The combined load cases determined the worst scenarios of all the load cases that could affect the structure and lead to collapse. Table 2 shows the various load case and their value. Figure 5, 6 and 7 show the helipad load case, the displacement diagram for the wind load case and the bending moment due to combination of all the load cases respectively.

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Table 2: Various load cases

Case	Label	Case name	Nature	Analysis type	Load values
1	DL1	Dead Load	dead	Static - Linear	PZ Negative Factor =1.00
2	LL1	Live Load (static + dynamic)	live	Static - Linear	PZ= -5.00(kN/m^2)
3	LL2	HLP (Helipad load)	live	Static - Linear	PZ= -3.00(kN/m^2)
4	WD	WIND	wind	Static - Linear	PY= -5.00(kN/m^2)
4'	WD'	WIND	wind	Static - Linear	PX= -5.00(kN/m^2)

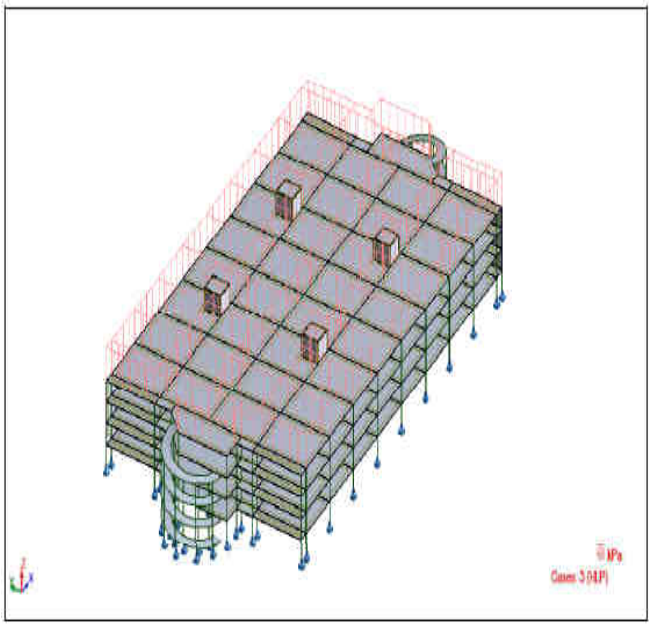

Figure 53: Helipad load case

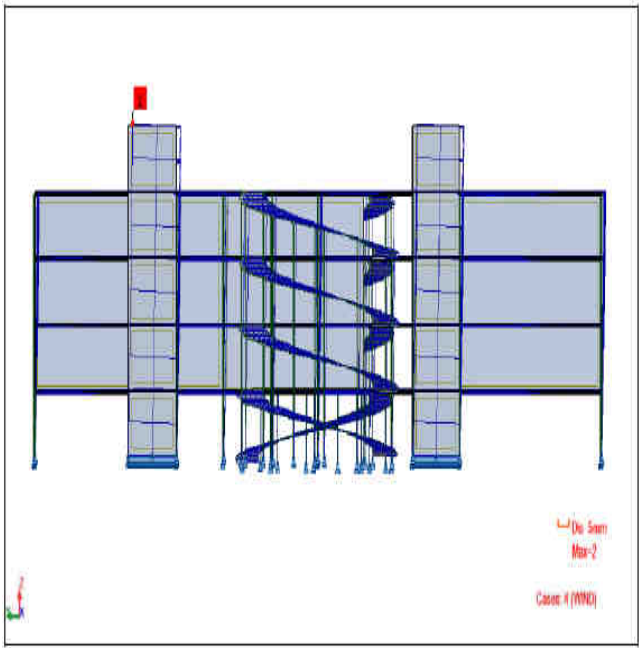

Figure 64: Displacement diagram for load case 4

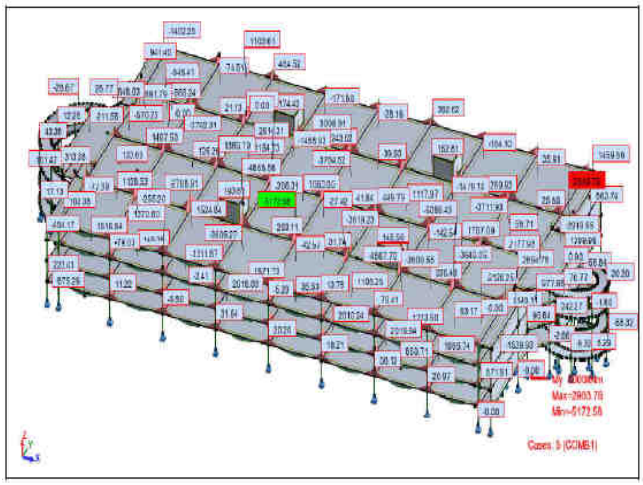

FIGURE 75: BENDING MOMENT DUE TO COMBINATION OF ALL THE LOAD CASES CHALLENGES

The principle challenge encountered was the modelling of the ramp since it is an irregular shaped element of the structure. Different methods and options of the ramp and sloping were tried. After several trials and failures, the final model passed. Figure 8 shows one of the failed cases. Another challenge was limited example of a multi-storey car park for case study. There were only two multi-storey car park the researchers could visit which indicated that the usefulness of a multi-storey car park has not been fully understood in the in Nigeria and this made it difficult to obtain more useful data for this research.

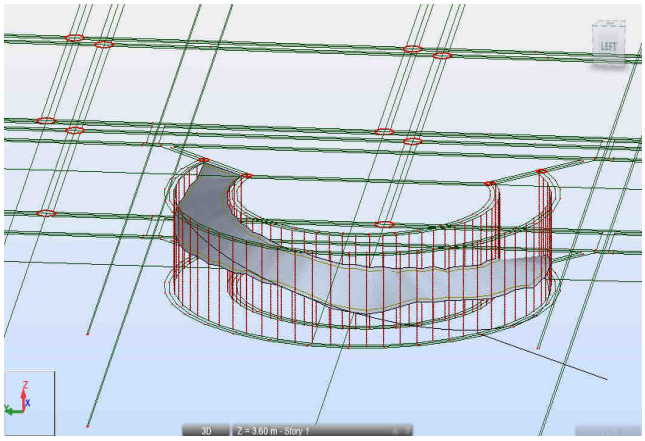

Figure 8: Typical example of a failed irregular ramp

VII. CONCLUSION

The architectural model was successfully developed on Autodesk Revit and the structural model was effectively analyzed and designed on Autodesk Robot Structural Analysis software. From the design result obtained, the sections selected and used on each floor of the structure under the loading conditions considered are valid and the lateral drift for each floor is within the limit of acceptability. Multi-storey car park is an important structure when it comes to car parking and traffic management which reduces road side parking and its negative effect and optimizes land use. The aim and objectives of the research was achieved. This model can be replicated anywhere there is much influx of cars. This idea of a multi-storey car park design project could be forwarded to the Living Faith Commission for implementation as it offers an effective and safe parking

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solution for cars and helicopters during events of mass attendance.

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