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Challenges of Car Pack Design in Nigeria

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Abstract*—Problems of parking space in urban towns and in all places of large congregation is becoming a common issue around the world. Over the years engineers and architects have come up with a lot of solutions finding a way to create more parking spaces within minimum size of land by the design and construction of multi-storey car parks. This is line with the trend in modern cities all over the world of developing high-rise buildings as to overcome the challenges of urban over population, for optimal use of scarce land resources, as status symbol, etc. Standing on the advances made so far and the frequent problematics verified on existing multi-storey car parks, this research presents the design of a multi-storey car park for the mitigation of traffic challenges in public areas using Canaan land, Ota Nigeria as a case study. Canaan land, the seat of Faith Tabernacle in Ota, Ogun State of Nigeria is used as a case study because of the amount of vehicles that compete for parking space on Sundays or on other days of events. The research consist of the creation of the architectural drawings of the multi-storey car park with AutoCAD drafting and the modelling, structural analysis and design using the software Orion R16. The structural analysis and design were challenging but good results were obtained, approach for more innovative multi-storey car park identified.

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

I. INTRODUCTION

The population of the world is continuously on the increase and towns and cities have grown up around their public transport system. The increasing population and expanding urban centers has been accomplished by increasing car ownership and increasing demand for movement for various purposes. Regardless of income or social status, the condition under which people travel have become more and more difficult and for some absolutely intolerable. Demand for transport and travel intensity tends to increase sharply with the growing size of a city and town especially when the city center or major centers of activity continues to grow in terms of both size and employment [1]. Parking in public areas can be very tasking with little or no form of security because it is fraught with all sorts of hazards created by either humans or lack of parking structures. In order to reduce the stress of parking and any form of danger or insecurity to cars and owners, adequate parking facilities must be provided to meet up for the demand of parking.

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Findings in the research work done by Department of Transport Management Technology, Federal university of Technology, Minna, Nigeria [1] revealed that parking problems and traffic management issues in Nigeria which leads to time delays and traffic congestion are as a result of inadequate parking space, traffic signs/signals, indiscipline, encroachment of illegal activities at car parks etc. Recommendations were made for parking management, parking design standard, parking control, traffic management for both vehicular and pedestrian, land use and land development, enforcement of edict and bye-laws by statutory agencies. Today, automobile is the dominant mode of transportation in most nations of the earth including Nigeria, where an average family has at least a car, which has led to many transport and traffic problems within cities and inter-cities and the challenges of parking in large gatherings such as churches, shopping malls is beginning to be a great issue. Over the years engineers and architects have found a way to create more parking spaces within minimum size of land by the design and construction of multi-storey car parks. This is line with the trend in modern cities all over the world of developing high-rise buildings as to overcome the challenges of urban over population, for optimal use of scarce land resources, as status symbol, etc. [2]. Multi-storey car park also known as a parking garage or a parking structure is a building designed for car parking with a number of floors or levels on which parking takes place. It is essentially a stacked parking lot that has multiple access and exit system to avoid traffic congestion in and out. Car parking systems have been around almost since the time cars were invented. There are car parking systems in most areas where there is significant amount of traffic. Car parking systems and the accompanying technologies have increased and diversified over the years. Car parking systems were developed in the early 20th century in response to the need for storage space for vehicles. Multi-storey car park is used virtually in every advanced nation. It is called parking structure is used in the United States especially when it is necessary to distinguish the structure from the garage in a house. Architects and civil engineers usually call it a parking structure due to the nature of their work. The earliest known multi-storey car park was built in 1918 for Hotel La Salle at West Washington Street in the West Loop area of downtown Chicago, Illinois. It was designed by Holabird and Roche. Another early imaged multi-storey was in the 1920s when an English cartoonist imagined a hotel for cars; he drew a multi-storey car park [3]. Today, a lot of innovation has been done on parking system, ranging from providing services of man power to help in parking automobiles to the use of machines and robots.

The design of a car park involves various process and specifications. A lot of car park design guidance document have been made and are still in the making up till now but the

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very first one was prepared in 1970's and updated in 1980's. In the intervening years, the perception and design features of multi-storey car parks have changed significantly. The growth of car usage and increased familiarity with different multi-storey car park facilities has led to increased public expectations on issues such as security and ease of access. There has also been interest in upgrading provisions for car parking as a marketable facility. Increasingly, car parks are recognized as an integral and vital part of a development, often forming the first impression a visitor has of a town or specific development. Multi-level parking has come with a number of reliefs since they come with a number of advantages such as optimal utilization of spaces, for comfort for drivers since the stress of struggling for parking space is taken off, more security and environmental harmony. For the design of multi-story car park, the planners must weigh the relative merits of convenience versus cost. Some of the factors that need to be considered are desire to have a convenient parking space with direct access to those that need it, the need to ensure safety of all users, the desire to protect open space and the environment and availability of resources to build and operate parking facilities.

Some structural failures were reported in the mid-1990s concerning the 1970's car parks, which mainly involved the older stock of car park structures. Among these incidents was failure of car park barriers caused by accidental impact that resulted in cars falling onto the lower floors. There were other well publicized failures, one caused by concrete degradation with reinforcement corrosion in a slab with the structural consequences of a punching shear failure leading to a partial progressive collapse. The nature and mechanisms of this collapse was fragile, with little prior warning of structural distress. Brittle failures are more likely in reinforced concrete structures due to deteriorations of structural members or wrong choice of materials and bad combination of same [4]. Failure to detect this kind of mechanisms leads to concrete degradation and corrosion to progress until structural collapse occurs. In recognition of the problems affecting development of car park technology and to allow the lessons learnt from such failures to be incorporated into design guidance, review of institutional guidance began in July 1999 [5]. The review noted that failures in older car parks were not unconnected to inadequate design details and insufficient understanding of the adverse loading conditions to which the structures could be subjected and the poor performance of drainage and waterproofing systems, which are vital for the durability of the structure. The situation was worsened by the absence of proper monitoring and adequate maintenance. Structural health monitoring, inspection and maintenance of car parks by qualified professionals experienced in corrosion, fatigue and structural deterioration are essential for durable structures including car parking facilities. As with any other structure, design details that enhance durability, facilitate proper inspection and the maintenance of drainage and waterproofing will significantly extend the life and safety of a car park structure. Historically, car parks were designed according to building codes. The review suggested that durability requirements for closed car parks should be similar to those for bridges or marine structures due to vehicular wheel load effects not applicable to building structures.

This research presents the design of a multi-storey car park for the mitigation of traffic challenges in public areas using Canaan land as a case study. Canaan land, the seat of Faith Tabernacle in Ota, Ogun State of Nigeria is used as a case study because of the amount of vehicles that compete for parking space on Sundays or on other days of events. It has been observed that a lot of people arrive early for Church service but end up entering the Church late due to the problem of finding a space for their vehicles. Canaan land accommodates a lot of occupants, visitors, church members and workers. This implies that a lot of automobiles troop in and out every day with the peak on Sundays and during Shiloh and thus the ease of movement, parking and safety of these individual's cars against theft, vandalism and weather must be provided. This can be done with minimum consumption of space and land, orderliness and adding to the beauty of the environment by providing an aesthetic multi-storey car park facility. The research will consist of the creation of the architectural drawings of the multi-storey car park using AutoCAD then performing the structural analysis and design using the software Orion R16.

II. LITERATURE REVIEW

Multi-storey car parks have a number of unique features that distinguish them from other buildings or structures. A lack of understanding and recognition of these distinct characteristics by designers and those responsible for inspection and maintenance is believed to be the major cause of many of the common problems identified in these structures [5]. Parking structures are generally classified as either "static" or "automated." The automated parking are more common in Europe while static is the most prevalent type of parking structure in the United States [6]. The two types of ramps that can be used are straight ramp and curve ramp. Five types of layout that can be used in traditional parking structure includes parallel packing, perpendicular/ angle 90^{o}, angle 60^{o}, angle $45^{o}$and angle 30^{o} [7], [8]. The floor level system can be flat on the same floor, can be split level or staggered floor systems or sloping floor systems.

For the design aspect, there are numerous configurations of multi-storey car parks featuring different arrangements of deck and ramp. The final selection of the configuration will be determined by the overall size of the car park, the shape of the site and the use for which the car park is intended. Starting from the planning dimensions, you consider the bay width, aisle width, ramp dimensions, planning grid, alignment paths to exit barriers, means of escape distances, travel distances from the car to the destination, security, visibility, space allowances, lift provision and payment system among other things. In structural design, a buildings that is at least three-storey in height must be framed. The loads from the occupants are transmitted through the slab, beam and column and to the foundation and therefore each element of the frame must be designed to effectively handle its own dead load and the load being transferred to it [9], [10]. For the idealization of the actual structure, the structural model should relate the actual behavior to material properties, structural details, and loading and boundary conditions as accurately as it is practicable [11]. The structure should be so designed that adequate means exist to transmit the design ultimate load, wind and imposed loads safely from the highest supported level to the

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foundations as specified in [12]. As the height of a buildings becomes much, horizontal deflections must be computed with greater accuracy. The deflected shapes of individual structural members should be taken into account in the final analysis of tall slender structures [13], [14].

III. MATERIAL AND METHOD

The architectural drawing was realized with Autocad software as seen in figures 1, 2 and 3 for the plan and elevations respectively. Orion R16 is used for the structural analysis and design of the parking structure. Codes for design and analysis for the multi-storey car park were [15], [16], [12]. Procedures followed in this research conforms to the work of [17]. Dead load, imposed load, wind load, dynamic load and load combinations were all provided according to BS codes.

The features of the proposed car park include four floors above ground, 1,200 parking spaces, occupying 7660 square meters, mechanical service center, car wash, 2 external ramps, 2 entrances and exits each, Lifts and stairs at appropriate places and emergency exits. The analysis of the model was carried out using Orion 16 and considering the bending moment in slabs, shear stress and bending in beams, columns and walls. The slabs were analyzed using finite element method and the loads transferred to the supporting beams. The design of the beams, columns under uniaxial and biaxial bending was done with the Orion in accordance to BS. The wall analysis was done based on gravity and lateral loads.

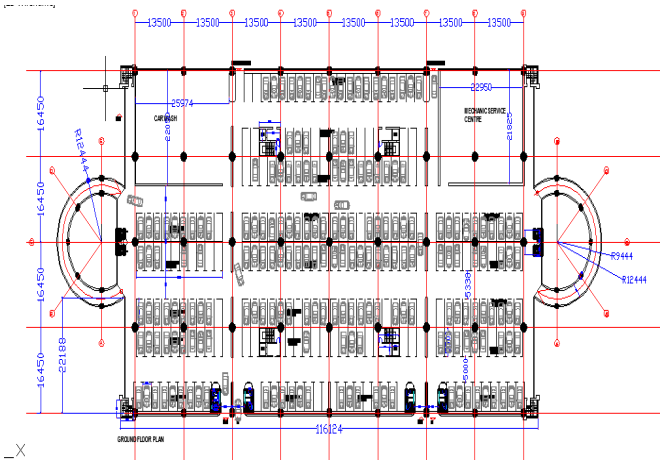

Figure 1 Architectural ground floor plan

Figure 2 Approach view of proposed multistory car park

Figure 3 Right side view showing the external ramp

IV. RESULTS AND DISCUSSIONS

Here the result of the work carried out in this research is presented. The result includes the outcomes of the modeling, structural analysis and design.

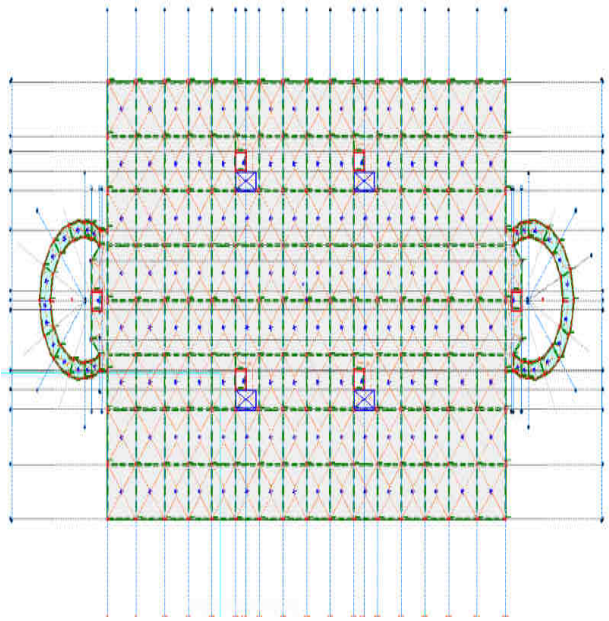

Figure 4 Floor slab modelling

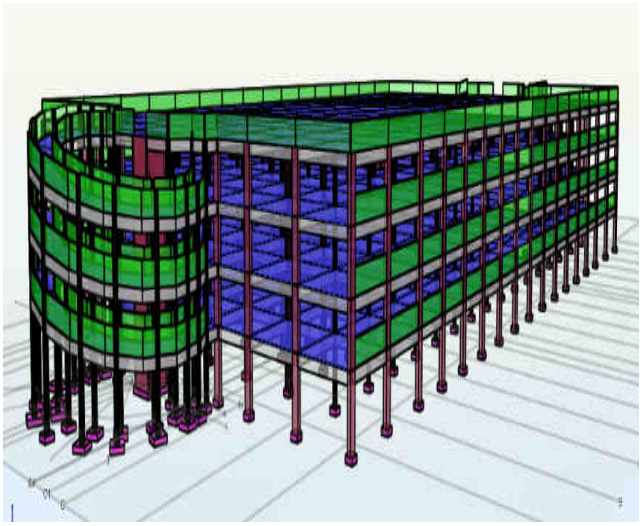

Figure 5 Angle view of structural frame

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Modelling and Analysis

The architectural model was carried out on AutoCD. The sloping of the ramps was carried out using planes. Figure 4 shows the slab modelling while figure 5 is the 3D view of the multi-storey car park with the two side ramps showing beams, slabs, shear walls, columns and slab openings of the structural modeling on Orion R16. Analysis Of different load cases were applied on the model before the analysis was performed. The analysis of the structure was performed deriving the beam loads from the slabs by the finite element floor analysis performed for each floor starting from the fourth floor to the first floor slab. After the analysis of the structure has been carried out, the software shows the structural members that pass with the applied forces in the structure frame as green and the members that fail as red. Result from the analysis of the first model gave most of the columns failing and the beams not analyzed at all due the beams sizes not being adequate to support the applied load especially from the point loads of the secondary beams at point of intersection and the columns failed because of excessive wide span between them. A second model was created, where columns of diameter 600mm were placed at the intersections of the secondary beams to reduce the effect of the point loads. After the analysis was run, all the beams in the structure passed except for the beams on the ramp and it was realized that this was due to the effective span depth ratio was exceeded. Another model was created with reduced length of beams along the ramp but the beams still failed. And finally the last model was created and the ramp modelled as if it is flat on each of the floors and then the loads transferred to the end beams to the next floor. After this approach, all the members including the ramp passed when this was done as shown in Figures 6 and 7.

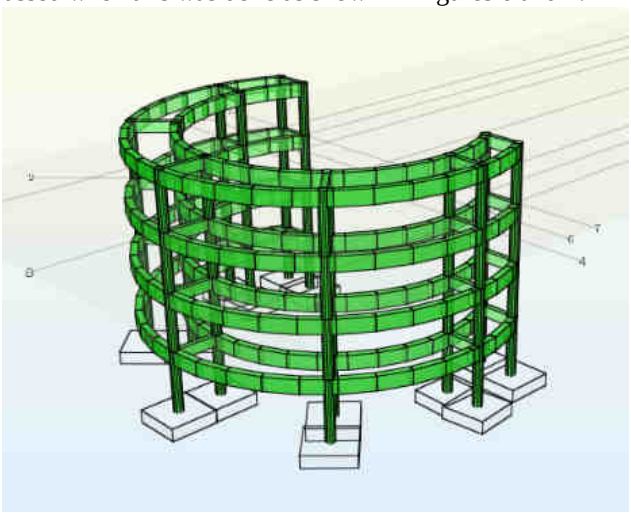

Figure 6: shows the 3D view of the analyzed ramp with all the members passing

Observations and Challenges Encountered

It was observed from the analysis result of the ground floor columns and shear walls that the regular combination of just dead and imposed loads gave the highest axial load but lower moment while the combination of the wind load with the dead and imposed loads gave a slightly reduced axial design loads but higher moment and shear force. Limited examples of multi-storey car parks were available as there are very few multi-storey car parks in Nigeria causing limitation as to examples for literature review and models to pattern the structure after. The modeling of the ramp was challenging due to the sloping of the structural members from one floor to another. Planes had to be created on each curved ramp by pick axis method, allocating the desired heights along the z-axis at three different points; the members along the plane definition were then moved to the plane height. For the analysis of the ramp, the loads applied on the ramp were difficult to identify and so was its placement on the sloped structure. The different beams along the curved ramp axis were broken into 12 straight line elements causing discontinuity between the beams at the joints thereby making the analysis moment very complex. This challenge was solved by placing columns at such joint and then linking the beams together.

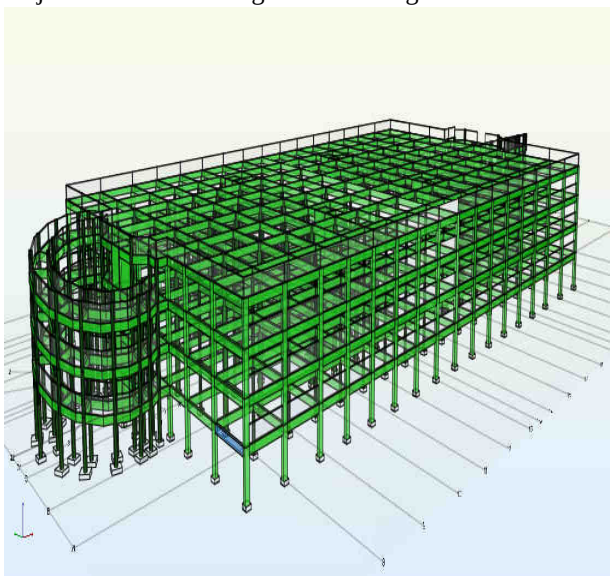

Figure 4: shows a 3D model with all members passed.

V. CONCLUSION

The objectives of this research were achieved as a multi-storey car park was proposed, effectively analyzed and designed. The construction of this multi-storey car park will help mitigate traffic challenge of parking spaces in public areas and also add aesthetic value to the environment in which it would be placed. The structural model was successfully developed and the analysis simulated in Orion R16 software. Detailed considerations were given to the effect of lateral loads since this is a medium-rise and expanse structure subject to dynamic loading due to vibrations from machineries and vehicles. From the design result of the first floor columns, walls and beams, it can be said that all the sections at the ground floor structure under the loading conditions adopted, is valid and the lateral drifts for each floor is acceptable. This research work is exiting, challenging and really educative as it brought out opportunities for problem solving, further learning and exposure to deep aspects of complex structural analysis much different from conventional building structures designed in civil engineering discipline. It was observed that most multi-storey car parks built in recent times in developed countries are automated, operated by machines and robots. For this kind of structure to be designed, there is need for synergy between the civil engineer, mechanical engineer and the electrical engineer before a truly functional structure to emerge. In order words, inter–disciplinary research will create a platform for different professionals to come together for a research such as this, where automated multi-storey car park project is carried out together for a better output in terms

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of innovative technology.

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