Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 2458-9403
Vol. 3 Issue 4, April - 2016

The Modeling, Analysis and Design of a Multi-Storey (Car park) Structure Using MIDAS/Gen Application Software

S.A. Raji*
Civil Engineering Department, Faculty of Engineering and Technology,
University of Ilorin, (Unilorin),
Ilorin, Nigeria
drsaraji@yahoo.com

D.A. Adu
Civil Engineering Department, Faculty of Engineering and Technology,
University of Ilorin, (Unilorin),
Ilorin, Nigeria
adudavid2012@gmail.com

T.O Adeagbo
Civil Engineering Department, Faculty of Engineering and Technology,
University of Ilorin, (Unilorin),
Ilorin, Nigeria
adeagboto@gmail.com

M.O. Bolaji
Civil Engineering Department, Faculty of Engineering and Technology,
University of Ilorin, (Unilorin),
Ilorin, Nigeria
mahmoodolayinka@yahoo.com

***Abstract*—This project intends to demonstrate the suitability and capability of MIDAS GEN software in comprehensive analysis and design of a multi-storey car park structure by comparing the output with that of manual analysis and design approach. An examination of the 3D modeling, structural analysis and design of the multi-storey carpark structure using Midas Gen was carried out to make comparison with the conventional manual approach to demonstrate its accuracy. The structure was subjected to self weight, deadload, liveload and windload. The structural element such as slab, beam and column were designed with the software package. Manual computation based on the BS code (BS 6399, Part 2, 1997) was also included. The parking levels are split levels. The storey height of 3m and ramp slope of 1:6 is kept. From the software design results, the maximum bending moment was found to be 228.10KNm at the support for selected beam number 231. The difference between the maximum and minimum shear forces is 26.42KN while the difference between the maximum and minimum reaction forces is 3483.97KN. A difference of 61.4KNm was obtained between the manual and software tool for the maximum support bending moment for the selected beam.**

Keywords— analysis, design, multi-storey structure, carpark, midas/gen software, shear forces, bending moment and structural elements.

I. INTRODUCTION

The rapid growth of urbanization and the ever increasing population of urban centers in modern age of today have brought about increase in the use of cars, roads and other transportation facilities. Today, automobile is the dominant mode of transportation in most nations of the earth including Nigeria, where an average family has atleast 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 (Ede, et.al, 2015). This singular factor has created constraint on traffic management system and parking of cars in most of these areas.

A previous work by some team of researchers 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 (Osuba, 2012). This is why new innovations and technology need to be put in place to help address this issue and reduce some of the constraints on traffic management system of urban centers and also help improve their parking system. One of these innovations is the introduction of the multi storey carpark structure.

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 which involves developing high-rise buildings as to overcome the challenges of urban over population, for optimal use of scarce land resources, as status symbol (Ede, 2014).

The multi-storey carpark structure 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 innovations into developing countries like Nigeria would help the traffic management system of major urban centers by bringing less environmental hazards with attendant social and economic gains for the society.

A structure refers to a system of two or more connected parts use to support a load. It is an assemblage of two or more basic components connected to each other so that they serve the user and carry the loads developing due to the self and super-imposed loads safely without causing any serviceability failure (Holme, 2011).

Multi-storey carpark 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.

II. LITERATURE REVIEW

A new car park may be procured, used and operated by a single owner but often, particularly in town center and shopping schemes, it may be provided by the developer and then passed to a second party for operation and maintenance (Howard, 2007). 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 (Pike et.al, 2011).

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 (Carl and Timothy, 2006). 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} (Khairunnur and Nuur, 2013). The floor level system can be flat on the same floor, split level, staggered floor systems or sloping floor systems (Ede, et.al, 2015).

In structural design, a building that is at least three storey in height must be framed. The loads from the occupants are transmitted through the slab, beam and column down 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 (Arya, 2009). 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, payment system and parking area layout among other things.

Parking-area layouts may be classed as flat deck, split level and ramped floor. In flat-deck layout, each deck is flat. The decks are linked by ramps, Straight ramps may be used. In most cases, they are usually internal. Flat-deck car parks are normally built in multiples of a bin width, but the layout is adaptable. Split-level layout operates with drivers entering by the up ramp system and leaving by the down ramp system. In ramped floor layouts, cars are parked off an aisle, which also acts as a ramp. The ramp may be two-way.

The ramp arrangement depends on the type of car park. In this respect, a distinction is made between the duration of occupation (continuous, short or long stay parking) and the period of occupation (intermittent or continuous). The ramps are located inside or outside the building and can be curved or straight. Helical ramps allow faster traffic than straight ramps. The parking access lanes must run along the parking spaces. Distances in the exit direction should be as short as possible. The ramp slope must be less than 15%, ideally below 12% (Arcelormittal, 1996). The slopes of external ramps must be lower. A small slope results in longer ramps and greater required surface area. On the other hand, wider ramps with gentle slopes add to the comfort of use, an important factor to be considered during design.

Car parks with low overall height and with low storey heights make it possible to shorten the ramps. Another way of reducing ramp lengths while maintaining reasonable slopes is to use the Humy system in which adjacent parking aisles are offset in height by half a storey. When designing the ramps, it is important to ensure that they provide sufficient ground clearance and free height at their top and bottom. Generally, the ramp width corresponds to the width of two parking spaces in case of one-way traffic or three spaces with two way traffic (Arcelormittal, 1996). When the lanes are one-way, it is best to organize traffic for left-hand bends which allow improved visibility for the driver.

The steel bearing structure consists of vertical columns and horizontal beams, usually connected by bolting. The horizontal forces due to wind and breaking of cars are transferred horizontally through the floor slabs to the vertical wind bracings or shear walls (e.g. stiff staircases). In multi-storey car parks, the outer columns are spaced at intervals corresponding to the width of one or more parking spaces (units of 2.30 m to 2.50 m). Where the spacing between two columns exceeds 5m, secondary beams are foreseen between the columns.

The choice of the floor beams depends on their span, the type of concrete deck and the available construction height. The various deck types consist either of cast-in-place concrete, composite or prefabricated concrete slabs. Cast-in-place concrete slabs can be made using temporary formwork or permanent formwork made of prefabricated concrete planks or metal deck. When using the temporary formwork, the spacing between the steel beams may be freely selected according to the thickness of the concrete slab. However, for economic reasons, this spacing should not exceed 5m and in any case, it is a good idea to take advantage of the effect of connecting the rolled steel sections with the reinforced concrete floor.

III. MATERIALS USED IN THE PREPARATION

The MIDAs GEN Software was the principal tool used for the modeling (analysis and design) of the carpark structure. This was done based on the British and Euro code embedded in the software tool. The manual computation was intended basically for comparism with the outcome of the software application which was done using the limit state design (ultimate and serviceability) method in accordance with BS 8110.

IV. EXPERIMENTAL PROCEDURE

The structural loads acting on each member elements were determined in accordance with BS6399 and the factor of safety was included in the computation.

The steps and procedure adopted are listed below:

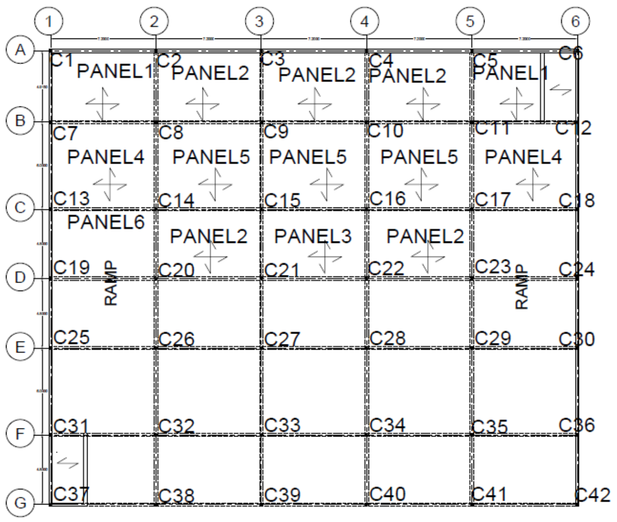
1.) Drafting of architectural drawing of the multi-storeyed car park using Auto Card.
2.) Structural planning (to produce general arrangement).
3.) Model generation (Using MIDAS GEN).
4.) Computation of loads.
5.) Manual analysis.
6.) Analysis and design using MIDAS GEN.
7.) Generation of the multi-storeyed car park model.
8.) Definition of model supports (fixed).
9.) Definition of material ($f_{cu} = 30N/mm^2$) and section properties.
10.) Definition of static and lateral load cases.
11.) Generation of load combinations.
12.) Analysis and design
13.) Generation of post analysis and design results and report.

The design data used are as follows:

Slab Loading:

Own weight	0.2×24	$= 4.8kN/m^2$
Partition allowance		$= 1.0kN/m^2$
Finishes		$= 2.0kN/m^2$
Wall and finishes		$= 3.47kN/m^2$
		$G_k = 11.27kN/m^2$
		$Q_k = 2.5kN/m^2(BS6399)$

$$F = 1.4 \times 11.27 + 1.6 \times 2.5 = 18.5kN/m \; per \; m \; run$$



GENERAL ARRANGEMENT

Figure: 1 General Arrangement

Software Application: MIDAS/GEN is a program for structural analysis and optimal design in the civil engineering and architecture domains. It is part of MIDAS family of software packages that is used for analyzing and designing of different structures.

The following are the steps involved in modeling and analyzing the structure (carpark).

1. Creating the Structural Diagram
2. Defining the Structural Properties
3. Defining the Support Conditions
4. Defining and Assigning of Loads
5. Set Analysis Option and Run Analysis
6. Display of Desired Result.

The procedures involved in the analysis and design of the multi-storey structure in MIDAS GEN is divided into three main categories; model generation, building analysis&design and report generation.

Model Generation:
At the launch of the MIDAS GEN software package, the first thing is to open a new project. Then using the model ribbon, a structure wizard was lunched to generate the grid in accordance with the dimensions from the general arrangement. The material and section properties were defined and the geometry was extruded to generate other stories. The storey information and element section properties were inputted as indicated below:

Storey height = 3.0m
Rise between parking level=1.5m
Typical Parking Bin=3x2.4m (7.3x5.1m and 7.3x6.23m).
Slab Depth= 200mm
Beam Section= 600x230mm
Shear Walls =230mm

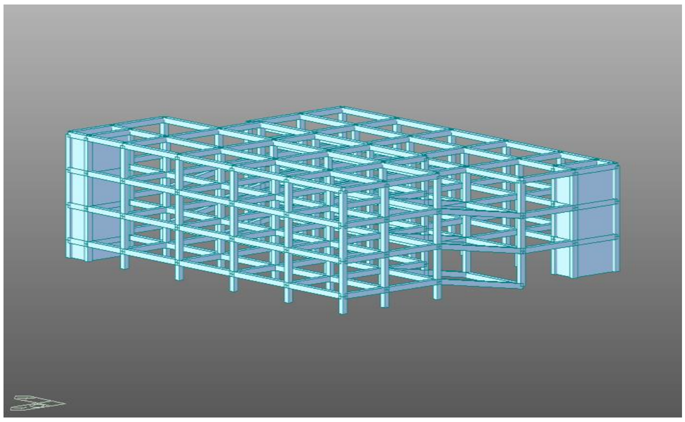


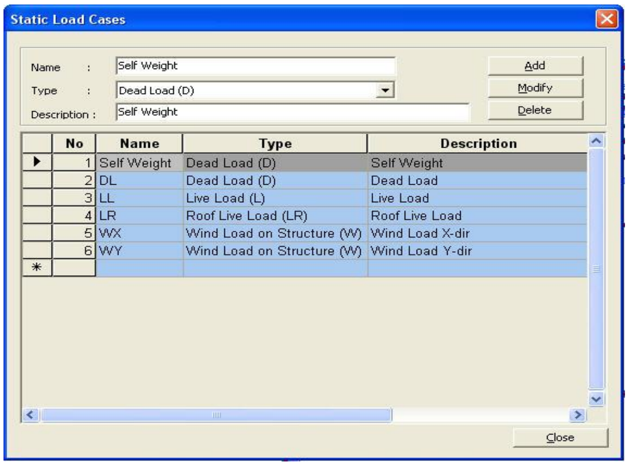
Plate 1: Model Generation Using MIDAS GEN

Structural Analysis:
Analysis in MIDAS GEN involves the following:

- Definition of Load Cases

Static load cases were defined as:
Dead Load (Typical Floors and Roof Slab) = $11.27kN/m^2$
Live Loads: 1.5KN/m^2 and 2.5KN/m for roof and typical floor respectively.

The structure was analyzed as a rigid framed structure by assigning floor load.



No	Name	Type	Description
1	Self Weight	Dead Load (D)	Self Weight
2	DL	Dead Load (D)	Dead Load
3	LL	Live Load (L)	Live Load
4	LR	Roof Live Load (LR)	Roof Live Load
5	WX	Wind Load on Structure (W)	Wind Load X-dir
6	WY	Wind Load on Structure (W)	Wind Load Y-dir

Plate 2: Static Load Case definition

DESIGN:

The design involves generation of load cases as shown in plate 3:

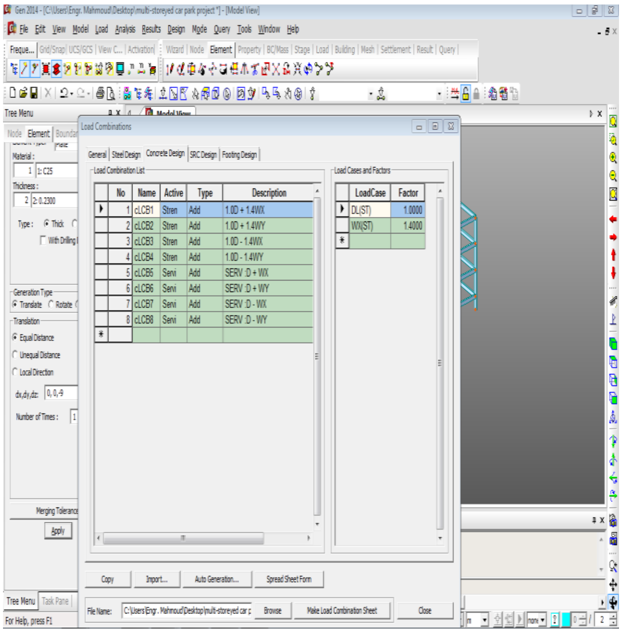


Plate 3: Generation of Load Combinations

Manual Computation: The manual analysis and design approach of the structural elements were carried out using the limit state design (ultimate and serviceability) method in accordance with BS 8110. The structural members analyzed and designed in this project include; slabs, beams and columns.

Reinforced Concrete Slab Design Procedure:

ULS (ultimate limit state) for a 1m width of slab

Slab thickness	= 200mm
Concrete own weight	= 0.2x24.0= 4.80kN/m^2
Partition allowance	= 1.00kN/m^2
Floor finishes	= 2.00kN/m^2
Wall and Finishes	= 3.47kN/m^2
TOTAL DEADLOAD (Gk)	= 11.2 kN/m^2
Imposed load (Q$_k$)	= 2.50kN/m^2

(BS 6399, PART 1996, TABLE 1)

Calculate Design Ultimate Load, η_b = 1.4 G_k **+ 1.6**Q_k

The design load used for the slab design

η_b **= 1.4**(11.27) **+ 1.6**(2.50 = 18.2 kN/m^2

ULS (ultimate limit state)

Calculate Design Ultimate Moment, M =$\eta_b L^2/8$(kNm) (for a 1-way slab, assumed to be simply supported

For 2-way slab as in Slab 1,2,3,7 and 8, the design moment was computed as follow:

$M_{sx} = \beta_{sx}\eta l_x 2$ For the shortspan midspan moment

$M_x = \beta_x \eta l_x 2$ For the shortspan continuous edge moment.

$M_{sy} = \beta_{sy}\eta l_x 2$ For the longspan midspan moment

$M_y = \beta_y \eta l_x 2$ For the longspan continuous edge moment.

The moment coefficient β_{sx}, β_x, β_{sy}, β_y were checked from the BS8110-1(19977) TABLE 3.14

Calculate: K = M/bd^{2}f$_{cu}$ *(use N & mm) b =1000mm*

Show that: K < 0.167 (K')

State No compression steel required

Calculate: Lever Arm Factor z/d = 0.5 + √ (0.25 – 0.882K)

Show that: 0.82 ≤ z/d ≤ 0.95

State z/d *OK*

Calculate: Lever Arm, z = z/d × d (mm)

MAIN REINFORCEMENT

Calculate: Required Area of steel reinforcement, $A_s = \frac{M}{0.95 f_y Z}$ (mm^2/m)

Determine: Bar *f* & Spacing, such that Provided A_s > Required A_s

Show that: A_s is between Max & Min Limits: 0.0013bd ≤ 0.00016 $f_{cu}^{2/3}$bd ≤ A_s ≤ 0.04bh (mm^2) *State* A_s *OK*

SECONDARY REINFORCEMENT (at 90^o to the main steel).

Calculate: Required Area of Secondary Reinforcement = 0.2A_s

Determine: Bar *f* & Spacing, such that Provided Area > 0.2A_s *State OK*

SLS (serviceability limit state)

Calculate: Main bar clear spacing**.**

Show that: Main bar clear spacing is greater than minimum limits.

Show that: Max Spacing of Main bars should be 2h but not greater than 250 mm.

Max Spacing of Secondary bars should be 3h but not greater than 400m. *State* Cracking *OK.*

SLS (serviceability limit state).

This was taken along the shortspan and midspan

Calculate: Actual span-to-effective-depth ratio, L/d

Calculate: Service stress $\mathcal{F}_s = \frac{5}{8} f_y \frac{A_{sreq}}{A_{sprov}}$ (N/mm^2)

$A_{s\ req}$ is the area of tension reinforcement required at the section considered for the ultimate limit state.

$A_{s\ prov}$ is the area of reinforcement actually provided.

Calculate: Modification Factor

$$M.F = 0.55 + \frac{477 - f_s}{120(0.9 + \frac{M_{sx}}{bd^2})}$$

Determine Basic span-to-effective-depth ratio, N. From Table 3.9 BS8110-1 (1997)

Calculate*:* Allowable L/d= N x M.F

Show that: Actual L/d ≤ Allowable L/d

State Deflection OK

Reinforced Concrete Beam Design Procedure:

The beam dimension used in the design is 230mmX450mm.

BEAM DIMENSIONS

Beam size = 230mm*450mm (except for the concealed beam as stated earlier).

Effective depth d = h-cover – links diameter- $\frac{1}{2}$ main reinforcement diameter = 450 -10 -25- $\frac{16}{2}$= 407mm

Using links diameter = 10mm

Main reinforcement diameter = 16mm

Cover to reinforcement = 25mm

For flanged beams, effective width of flange $b_f = b_w + \frac{0.7L}{5}$ (T-section)

$b_f = b_w + \frac{0.7L}{10}$ (L-section)

ULS (ultimate limit state)

Calculate: Design Ultimate Moment, M =ɳL^2/8 kNm (simply supported beam)

Where b_w is the beam width.

M = ɳL^2/12 kNm (fixed end beam support moment).

M = ɳL^2/12 kNm (fixed beam mid-span moment).

For the continuous beam, the moment distribution method is used in the analysis and establishing the corresponding moments at the support and the mid-span. The edge support and the interior supports are designed as a rectangular section.

Show that: Ultimate moment $M_u = 0.156 f_{cu} b d^2$ (rectangular section).

$M_u = \beta_f f_{cu} b_f d^2$ (Flanged beam section)

Where $\beta_f = 0.45 \frac{h_f}{d}\left(1 - \frac{b_w}{b_f}\right)\left(1 - \frac{h_f}{2d}\right) + 0.15 \frac{b_w}{b_f}$

If $M_u > M$ no compression reinforcement

$M_u < M$ Provide compression reinforcement

Calculate: K = M/bd^{2}f$_{cu}$ *(use N & mm)*b =1000mm

Show that: K < 0.167 (K')

State No compression steel required

Calculate Lever: Arm Factor z/d = 0.5 + √(0.25 – 0.882K)

Show that: 0.82 ≤ z/d ≤ 0.95

State z/d *OK*

Calculate: Lever Arm, z = z/d × d (mm)

Main Reinforcement:

Calculate: Required Area of tensile steel reinforcement

$A_s = \frac{M}{0.95 f_y Z}$ **(mm^2/m)**

If $M_u < M$ then both tensile and compressive reinforcement required is thus calculated as shown below;

Area of steel for compression reinforcement

$A_{s^1} = \frac{M - M_u}{0.95 f_y (d - d^1)}$ **OR** $A_{s^1} = \frac{(K - K^1) f_{cu} b d^2}{0.95 f_y (d - d^1)}$

Area of steel for tension reinforcement

$$A_s = \frac{M}{0.95 f_y Z} + A_{s^1}$$

In which d^1 is the distance from the top section to the centre of the compression reinforcement.

$$K^1 = \frac{M_u}{f_{cu} b d^2}$$

$$z^1 = d\left(0.5 + \sqrt{0.25 - \frac{k^1}{0.9}}\right)$$

Determine: Bar size, such that provided A_s> Required A_s.

For the continuous beam, the area of tensile steel reinforcement is determined for the mid-span, interior support and the edge support as the case may be.

Check For Shear:

Determine: maximum shear force

Calculate: design shear stress; $v = \frac{v}{bd} N/mm^2$

$$v < 0.8\sqrt{f_{cu}} = 5N/mm^2$$

Therefore, beam size is satisfactory.

Calculate: shear distance d from the support face; $\frac{100A_s}{bd}$

$$v_c = \frac{0.79\left(\frac{100A_s}{bd}\right)^{\frac{1}{3}}\left(\frac{400}{d}\right)^{\frac{1}{4}}}{\gamma_m}$$

υ <0.5υ$_c$

No links required

0.5υ$_c$ < υ < (υ$_c$ +0.4)

$$A_{sv} \geq \frac{0.4 b s_v}{0.95 f_{yv}}$$

(υc +0.4) < υ < $0.8\sqrt{f_{cu}}$ or 5 N/mm^2

$$A_{sv} \geq \frac{b s_v (v - v_c)}{0.95 f_{yv}}$$

Determine: Links bar size, spacing and A_{sv}/s_v

SLS (serviceability limit state)

Calculate: Actual span-to-effective-depth ratio, L/d

Calculate: Service stress $\mathcal{F}_s = \frac{5}{8} f_y \frac{A_{sreq}}{A_{sprov}}$ (N/mm^2).

$A_{s\ req}$ is the area of tension reinforcement required at the section considered for the ultimate limit state.

$A_{s\ prov}$ is the area of reinforcement actually provided.

Calculate: The Modification factor which is $M.F = 0.55 + \frac{477 - f_s}{120\left(0.9 + \frac{M_{sx}}{bd^2}\right)}$

Determine*:* The Required Basic span-to-effective-depth ratio, N.

From Table 3.9 BS8110-1 (1997)

Calculate*:* Allowable L/d= N x M.F

Show that: Actual L/d ≤ Allowable L/d
State Deflection OK

Reinforced Concrete Column Design Procedure:
The columns were designed for axial forces and biaxial moments per BS 8110 code. In this project, just one critical column was designed and the footing. The procedures involved in the column analysis and design are as follow;

- Frame analysis of selected frame in the multi-storey and further sub-dividing the frame into sub-frame to compute the moments and shear forces acting on the member
- For the bi-axial column, the final moment is computed by combining the two moments using either equation 40 or equation 41 in BS8110.

Equation 40 from BS8110

$$M_x / h^1 \geq M_y / b^1, M_{x^1} = M_x + \beta \frac{h^1}{b^1} M_y$$

Equation 41 from BS8110

$$M_x / h^1 \geq M_y / b^1, M_{x^1} = M_x + \beta \frac{h^1}{b^1} M_y$$

- Define the section properties (section breadth, overall depth, grade of concrete, grade of steel).
- Compute N/bh, $M_x{}^1/bh^2$ and d/h (all notations definition are well defined on the notation page).
- Check BS8110: Part 3, Chart 28 with the value from d/h .
- Equate the value from the chat to $100A_{sc}/bh$ and make A_{sc} subject to compute the area of steel required and make the necessary provision.

V. RESULTS AND DISCUSSION

Result of Midas/gen
The results listed below were obtained from the MIDAS GEN computer program:

ELEMENT LOAD	AXIAL (KN/m^2)	SHEAR(-y)(KN/m^2)	BEND(+y) (KN/m^2)
72	-	9.35E+00	-
DL	7.41E+02		1.85E+02
72	-	9.35E+00	3.03E+02
DL	6.71E+02		
74	-	8.39E+00	1.45E+02
DL	1.22E+03		
74	-	8.39E+00	2.92E+02
DL	1.55E+03		
75	-	1.60E+00	3.10E+02
DL	1.19E+03		
75	-	1.60E+00	1.14E+02
DL	1.11E+03		
76	-	1.28E+00	4.07E+01
DL	1.20E+03		
76	-	1.28E+00	1.08E+02
DL	1.13E+03		
77	-	-	-
DL	1.04E+03	1.04E+03	1.19E+02

Table 1: Beams Bending Moment Results

The output of the shear force and bending moment diagram shows a linear and parabolic curve which signifies a gradual change in result obtained for every change in span.

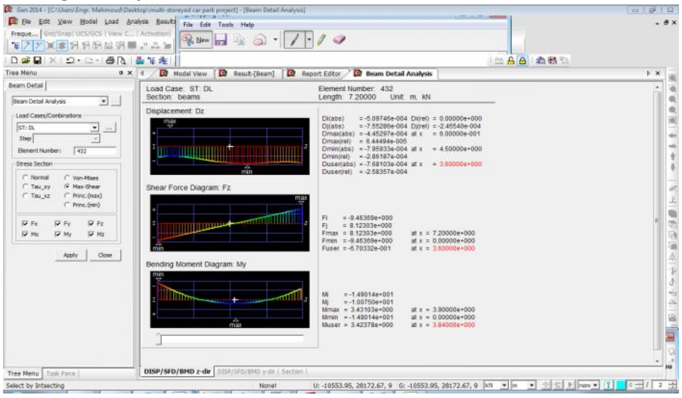


Figure 4: Shear Force and Bending Moment Diagram of a Beam

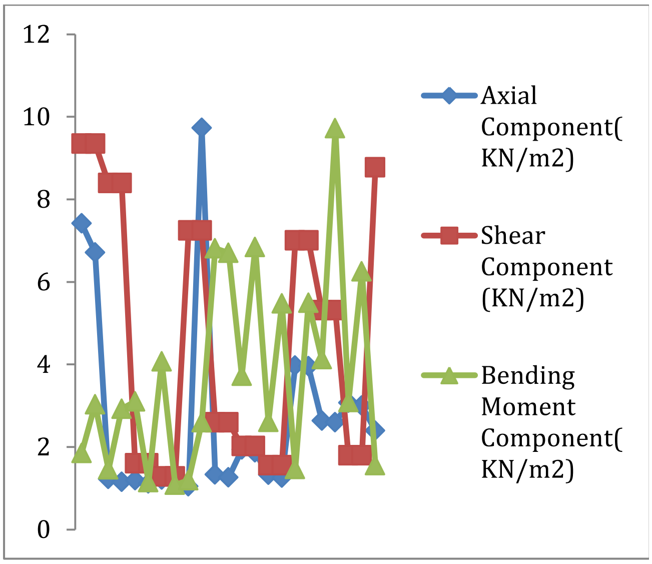


Figure 2: Representation of Axial, Shear and Bending Moment Component

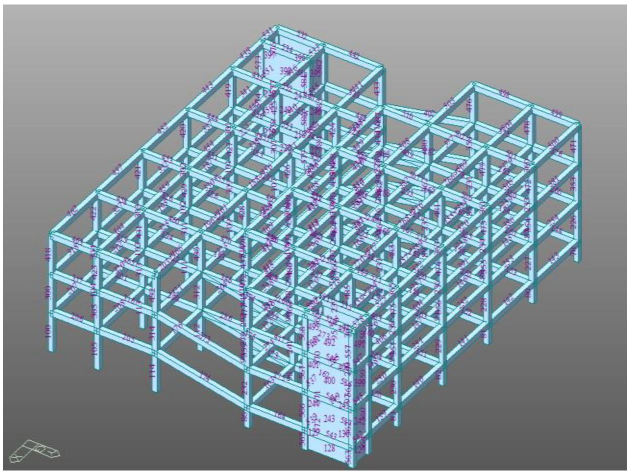


Figure 3: beam detail analysis Results

In table 1, the result of the beam bending moment is shown. It shows the variability of the axial, shear and bending moment component with the structural load/element. The MIDAS GEN provides an accurate method of developing the bending moment of the structural materials in the process of designing a particular structure. It is very useful due to the additional parameters obtained in the process of producing the bending moment for the structure which can be used to improve the design of the structure.

VI. CONCLUSIONS

The use of Computer Aided Design (CAD) tools in structural analysis and design has been proven to be effective base on the results obtained from the program such as the slab design report and the beam reinforcement design report. It was observed that, the computer software application tools (MIDAS GEN) used for the design of the reinforced concrete structures was efficient in reducing the time used in performing the design work significantly. The parking levels are split levels. The storey height is 3m and the rise between levels is half the floor-to-floor height. Since the rise between levels is 1.50m, the ramps slope was kept at 1:6. From the software analysis results, the maximum bending moment was found to be 228.10kNm at the support for selected beam number 231. The maximum and minimum shear forces are 149.57kN and 123.15kN respectively while the maximum and minimum reaction forces for the structure are 4098.79kN and 614.82kN respectively. By comparison, the maximum support bending moment for selected beam was 288.90kNm for the manual approach and 227.50kNm for the software result. The little variation in results is due to the methods adopted for both the manual and software analysis.

VII. ACKNOWLEDGMENT

I gratefully acknowledge the support of the MIDAs Team who provided the software application tool kit which was used for the modeling (analysis and design) of the carpark structure.

REFERENCES

[1] A.N. Amunga, “Multi Storey Car Park Design Project,” A project submitted in partial fulfillment of the requirement for the award of the degree of Bachelor of Science In Civil Engineering at the University of Nairobi, Kenya, 2014.

[2] Arcelormittal, “Carpark in Steel: Economical Sustainable Safe,” A Regular Publication by Arcelomittal, rue de Luxembourg, L-4221 Esch-Sur-Alzette, Luxembourg, 1996.

[3] C. Arya, “Design of Structural Elements: Concrete, Steelwork, Masonry, and Timber Designs to British Standards and Euro codes,” 3rd Edition; Taylor & Francis, London, 2009.

[4] M.O. Bolaji, “Analysis and Design of Multistorey Carpark Structure For University of Ilorin using MIDAS GEN,” An undergraduate Degree Project Work at the University of Ilorin, Nigeria, 2014.

[5] British Standard Code of Practice, 6399 (Part 2, CP3: Chapter V: (1972) Part 2, 1997.

[6] W. Carl and H. Timothy, “Parking Planning,” Published by American Institute of Architects; 2nd Edition, 2006.

[7] A.N. Ede, “Challenges Affecting the Development and Optimal Use of Tall Buildings in Nigeria,” The International Journal Of Engineering And Science (IJES), 3(4), Pp 12-20, 2014.

[8] A.N. Ede, O. Adaramola and O.M Olofinnade, “Modeling, Analysis and Design of a Multistorey Helipad-Carpark: A proposal for CanaanLand,” An International Journal of Innovative Science and Modern Engineering (IJISME) ISSN: 2319-6386, Volume-3 Issue-4, 2015.

[9] A.N. Ede, P.F. Adepoju and P.O. Awoyera, “Challenges of Carpark Design in Nigeria,” An International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-4 Issue-10, 2015.

[10] J.D Holmes, “Wind pressures on tropical housing,” Journal of Wind Engineering and Industrial Aerodynamics, 53, p. 105-123, 1994.

[11] M.D. Khairunnur and L. Nuur, “Multi-storey Carparking,”;http://www.scribd.com/mobile/doc/2194924. Last accessed on 2nd Oct, 2013.

[12] S.B. Osuba, “Appraisal of Parking Problems and Traffic Management Measures in Central Business District in Lagos State of Nigeria,” The Journal of Sustainable Development, Vol. 5, No. 8, 2012.

[13] D. Pike, C.K. Jolly, M. Pundsack, J.N. Stewart and W. Whapples, “Design recommendations for multi-storey and underground car parks” Published by the Institution of Structural Engineers; 4th Edition; London, UK, 2012.