Computer Aided Design Of A Twin Reinforced Concrete Multi-Storey Tower

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***Abstract*—Computer aided design of a twin reinforced concrete multi-storey tower is presented in this work and it entails the use of Midas Gen software for modeling, analyzing and designing of a 25 storey twin tower and comparing the results with STAAD Pro software and manual design. The structural elements of the 10th storey for the twin tower were analyzed and designed using manual computation to ascertain the results from the software packages.**

The moment distribution method of analysis and limit state design method were used to analyze and design the 25 storey twin tower by subjecting it to self-weight, dead load, live load, and wind load in accordance with BS 8110.

From the compared result, it was observed that the results were similar and within range. For the beam design, the number of steel required using the software packages were the same while that of manual computation increased by 1. For the column design, the numbers of steel bars required were the same for both manual and MIDAS while that of STAAD Pro differed a little. For the slab design, the numbers of reinforcement were the same using all the methods.

In conclusion, the use of Midas Gen for structural analysis and design give relatively accurate and reliable results.

Keywords—analysis, computer, design, manual, modeling

I. INTRODUCTION

A structure is a framework of identifiable elements (slabs, beams, columns and foundation) which each element subjected to bending or direct force or the combination of both. A framed structure is that which consists of structural members (slabs, beams, columns and foundation) that are rigidly connected and transfer loads from the roof and all the floors to the foundation such that the induced stresses in the soil do not exceed there allowable bearing capacities. These structural members may be steel or reinforced concrete [1]. Focus is on the reinforced concrete type.
Reinforced concrete (RC) as a construction material that has been used for a wide range of building structures throughout the world, owing to its advantages such as the versatility, low construction cost, excellent durability and easy maintenance [2].
Reinforced concrete is a strong durable building material that can be formed into many varied shapes and sizes ranging from simple rectangular column to slender curved dome or shell. Its utility and versatility is achieved by the best features of concrete and steel. The steel provide the tensile strength and some of the shear strength while concrete, strong in compression protects the steel to give durability and fire resistance[3].
A reinforced concrete structural frame is a combination of beams, columns, slabs and walls, rigidly connected together to form a monolithic frame. Each individual member must be capable of resisting the forces acting on it; the determination of these forces is an essential part of the design process. The analysis must begin with an evaluation of all the loads carried by the structure, including its own weight. Many of the loads are variable in magnitude and position, and all possible critical arrangements of loads must be considered.
Reinforced concrete design is the sizing of structural elements and reinforcement required to give a stable structure of required performance in terms of strength and durability. Design must ensure that:
- Under the worst load, the structure is safe and
- During normal working condition, deformation of member does not detract from the appearance, durability and performance of the structure [3].

A. Review of Literature

Structural design can be integrated with interactive graphics in such a harmony that could prove most beneficial to engineers [4].
STAAD.Pro has the capability to calculate the reinforcement needed for any concrete section as well as giving a precise analysis and design of the structural elements [5].
The use of software in the design of structures reduces the time spent in design work and also improves accuracy [6].
High-rise RC construction is currently used almost exclusively for apartment houses, because of better habitability provided by concrete. Floor plan of these buildings is generally regular, and symmetric with respect to one or two axes [2].
Carrying out a complete analysis and design of the main structural elements of a multi-storey building including slabs, columns, shear walls and foundations using SAFE [7].
In order to make multi-storey structures stronger and stiffer, which are more susceptible to lateral

(earthquake and/or wind) forces, the cross sections of the member (particularly columns) increases from top to bottom, makes the structure uneconomical owing to safety of the structure [8].

B. *Computer Aided Analysis and Design of Structures*

Computer Aided Design-CAD is defined as the use of computer systems to assist in the creation, modification, analysis, or the optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and create a database for construction or manufacturing [9]. The core of a CAD system is the software, which makes use of graphics for product representation, databases for storing the product model and drives the peripherals for product presentation. CAD performs complex design analysis in a short time; implementing Finite Elements Analysis methods the user can perform: Static, Dynamic and Natural Frequency analysis, Heat transfer analysis, Plastic analysis, Fluid flow analysis, Motion analysis, Tolerance analysis, Design optimization etc. CAD software are of different categories varying from 2D drafting tool, 3D modeling software, design and analysis software, simulation software and many more. Examples are AutoCAD, ORION, Prokon, ETAB, STAAD Pro, MIDAS Gen and MIDAS Design etc.

II. METHODOLOGY

The methodology employed by the software packages considered and the manual analysis and designs are:

1) Review of Architectural drawings
2) Structural planning (Building the Model)
3) Load computations (Load combination and estimations)
4) General Analysis, Design and Detailing using MIDAS Gen, STAAD Pro and Manual Approach.

A. *Design Consideration*

Concrete Grade: C25
Steel Grade: 410 N/mm^2
Allowable Soil Bearing Capacity, q_{all} = 190 KN/m^2
Concrete Cover
- Slab = 20mm
- Beam = 25mm
- Column = 25mm
- Foundation = 40mm

Floor to Floor Height = 3m
Height of Plinth = 1m
Depth of Foundation = 1.5m
Height of Slab = 175mm
Size of beam = 600 x 230
Type of wall: 225mm Hollow Blockwall
Type of roof = Steel Roof
Number of Storey = 25

B. *Manual approach of analysis and design*

The procedural steps for the manual design are as follows:

i. Structural planning
ii. Preliminary sizing of members
iii. Computation of loads
iv. Analysis and
v. Design.

C. *Analysis and design using Midas Gen*

The procedural steps involved in the analysis and design of the 25 story building using Midas Gen and Midas Design+ are as follows:

i. Definition of properties;
ii. Importation of the axis line of the architectural plan;
iii. Generation of model and Creation of the elements;
iv. Generating the building storeys;
v. Generating the story data;
vi. Assigning properties;
vii. Definition of the load cases and Generation of the load combinations;
viii. Assigning the loads;
ix. Performing the building analysis;
x. Defining the design code;
xi. Performing beam, column, and shear wall design;
xii. Performing slab design using Midas Design+;
xiii. Viewing and generation of the reports.

D. *Computer modeling and analysis procedure*

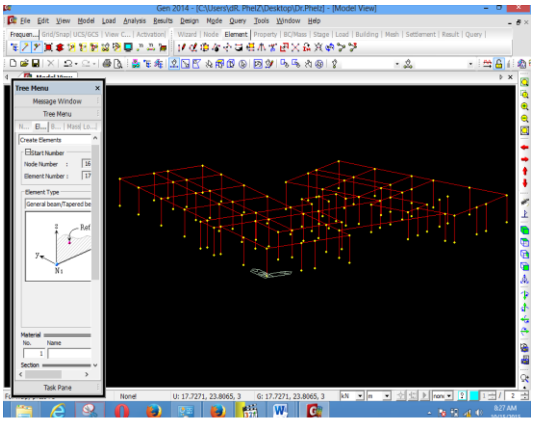

Fig.1.Modelling and Generating the First Floor Plan

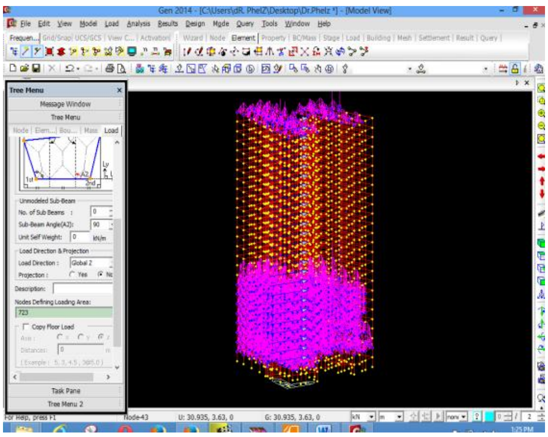

Fig.2. Assigning Floor Load and Roof Load

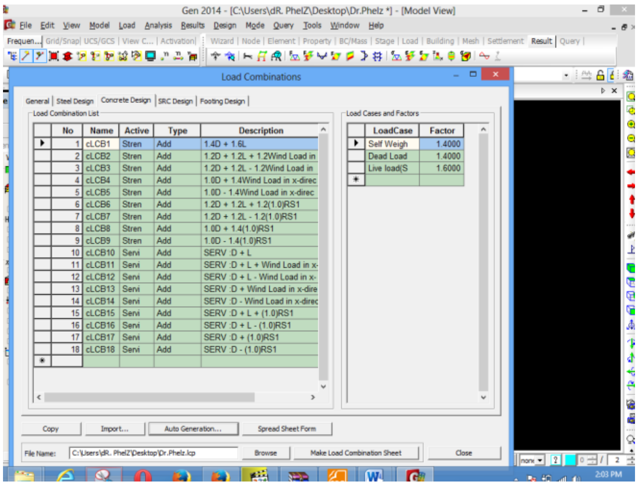

Fig.3. Assigning Load Combination

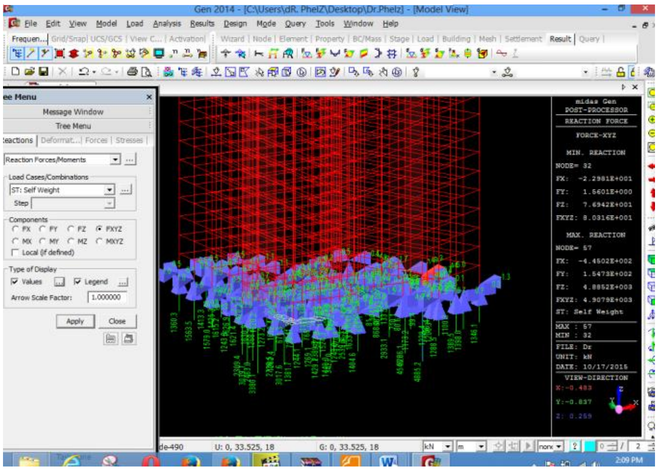

Fig.4. Checking for Reaction Forces and Moments

III. RESULTS

The results and the comparison of the results from both the software packages and the manual computation results are shown in the Tables 1 to 4.

Table 1. Beam Design Results

Method	Member	Section (mm)	Moment (KNm)	Shear (KN)	Steel bar (mm@mm)	Link
STAAD Pro	1654	230 x 600	460	50	4Y20	Y8@300c/c
MIDAS	1654	230 x 600	83.22	62	4Y20	Y10@400c/c
Manual	1654	230 x 600	221.8	32.6	5Y20	Y10@300c/c

Table 2. Column Design Results

Method	Member	Section (mm)	Moment (KNm)	A_s req.	Steel bar (mm@mm)	Link
STAAD Pro	1706	230 x 600	85.52	4919	10Y25	Y10@200
MIDAS	1706	230 x 600	75.43	3490	12Y20	Y10@120
Manual	1706	230 x 600	89.9	4140	10Y25	Y10@300

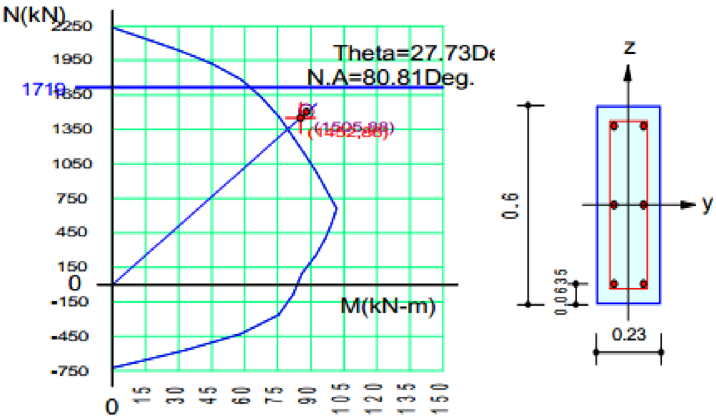

Fig.5. Load Combination Interaction Diagram (For Column)

Table 3. Shear Wall

Method	Load (KN)	Section (mm)	Moment (KNm)	A_s req.	Steel bar (mm@mm)	Link
STAAD Pro	8025	2400 x 230	3992	1003	Y12@200	Y10@250
MIDAS	8434	2400 x 230	4819.19	1130	Y12@200	Y10@250
Manual	2274	2400 x 30	1139	2211	Y12@200	Y10@250

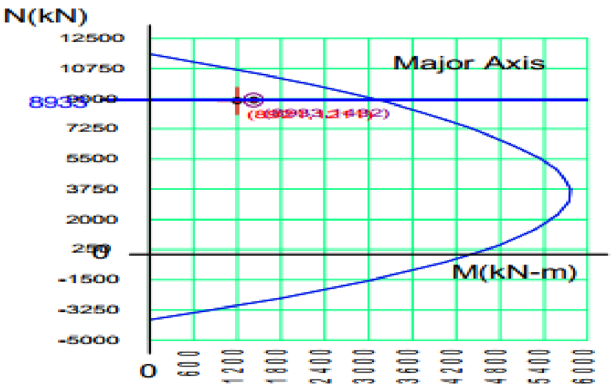

Fig. 6. Major Axis Load Combinations Interaction Diagram (Shear Wall)

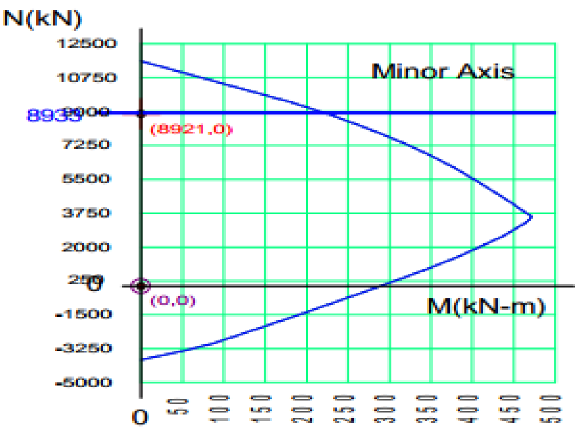

Fig. 7. Minor Axis Load Combinations Interaction Diagram (Shear Wall)

Table 4. Slab Design

Method	Span	Thickness (mm)	Moment (KNm)	Moment (KNm)	A_s req. (mm^2/m)		A_s prov. (mm^2/m)		Steel bars (mm@mm)	
			Midspan	Support	Mid.	Sup p.	Mid.	Sup p.	Mid.	Supp.
Ma-nual	Short span	175	13.81	18.5	250.5	335.7	452	452	Y12@250	Y12@250
	Long span	175	9.99	13.2	197.0	260.8	452	452	Y12@250	Y12@250
MI-DAS	Short span	175	13.42	18.5	248.8	319.7	452	452	P12@250	P12@250
	Long span	175	9.99	13.2	199.6	282.4	452	452	P12@250	P12@250
ST-AAD Pro	Short span	175	13.64	13.22	252.1	226.4	452	452	Y12@250	Y12@250
	Long span	175	18.22	12.01	350.0	256	452	350	Y12@250	Y12@250

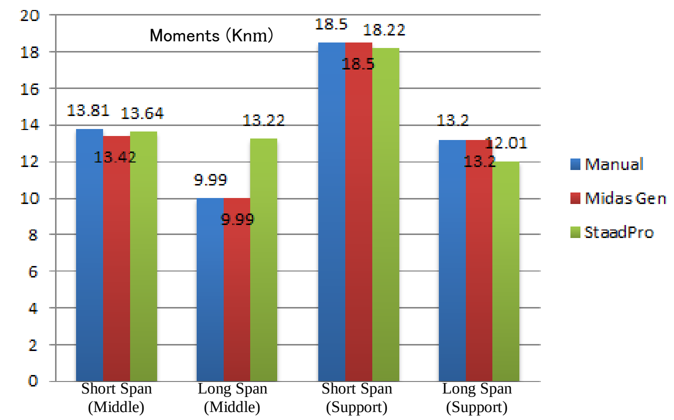

Fig. 8: Slab Moments Comparison Using both CAD and Manual Design

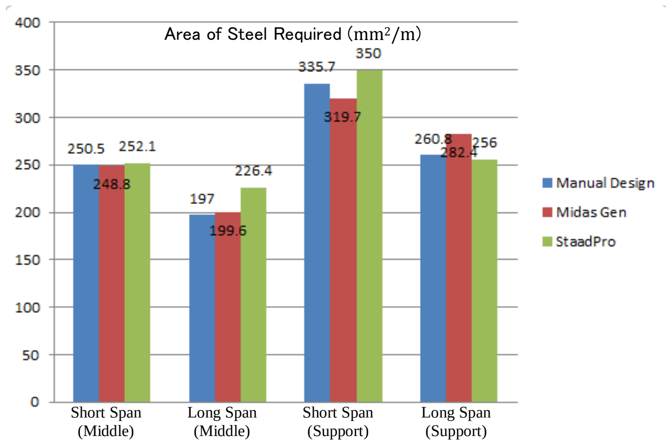

Fig.6. Slab Design Comparison Using both CAD and Manual Design

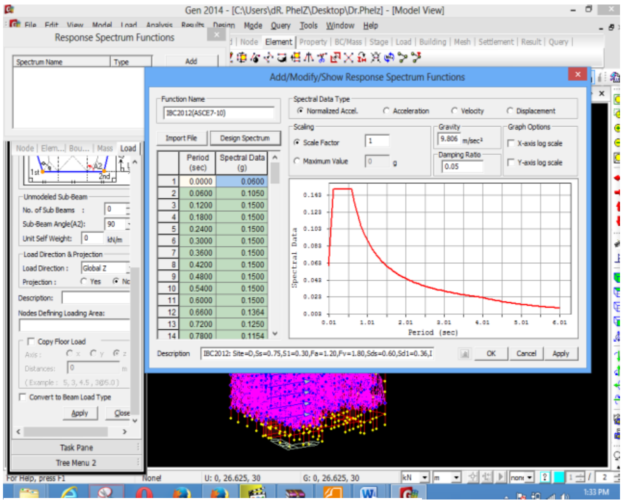

Fig.7. Response Spectrum Analysis

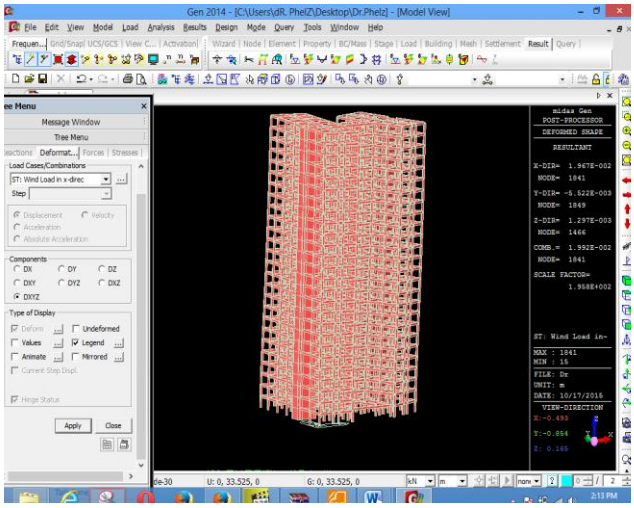

Fig.8. Deformation Caused by the Applied Wind Load

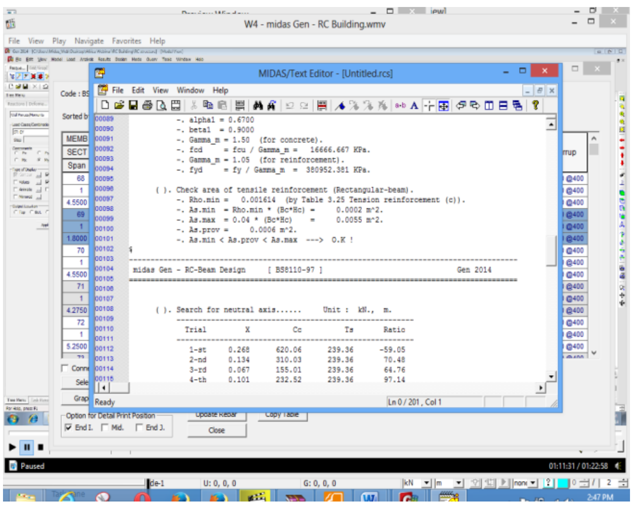

Fig.9. Checking the Design Procedure

IV. DISCUSSION

The comparison of the result obtained by manual computation method and the use of the software programs are shown in Tables 1 to 3. From the compared result, it was observed that the results were similar and within range. For the beam design, the number of steel required using the software packages were the same while that of manual computation increased by 1. For the column design, the numbers of steel bars required were the same for both manual and MIDAS while that of STAAD Pro differed a little. For the slab design, the numbers of reinforcement were the same using all the methods.

V. CONCLUSION

From the comparison result obtained from MIDAS, STAAD Pro and Manual computation, almost all the structural elements passed the checks carried out on them including the deflection, shear forces and bending moment. The list of failed elements was indicated by both MIDAS and STAAD Pro software programs and better section were selected. The analysis and design of the new section were performed again and result came out immediately.

The use of Computer Aided tools in structural analysis and design has been proven to be effective from the results output. It was observed that the time for performing the design work is significantly reduced. However, the software programs can be easily misused without observing proper precautions in the analysis and design procedures which can lead to structural failures, costly disputes and poor performing structures. Thus, this explains the importance of comparison between different software packages and more importantly performing hand calculations for like a floor and comparing for the same floor in the software packages. Therefore, it can be concluded that the structure has fulfilled the Ultimate Limit State and the Serviceability Limit State requirements.

REFERENCES

[1] A. Raji,“Computer aided design of a twin reinforced concrete multi-storey tower”,An undergraduate project submitted to the department of Civil Engineering, University of Ilorin, Ilorin, unpublished.

[2] A. Hiroyuki,“Design of modern high-rise reinforced concrete structures. 1st ed., Imperial College Press: London, 2001.

[3] W. Mosley, H. Ray, and J.Bungey,“Reinforced Concrete Design,”Palgrave Macmillan, 2012.

[4] A. Kwesi,“Computer aided design of precast concrete industrial buildings,” University of Newcastle, unpublished, 1979.

[5] B. Bedabrata,and A. Nagander.“Computer aided analysis and design of multi-storeyed buildings”, National Institute of Technology, Rourkela, unpublished, 2007.

[6] K. Prasad, P.Praveen, S. Kumar and B. Reedy, “Analysis and design of multi-storey (G+6) residential building using STAAD PRO” Institute of Engineering and Technology, Bachupally, Hyderabad, unpublished, 2011.

[7] S. Sultan, K. Sultan, K. Hasher, H.Rasheed, and A.Abdulrahman,“Analysis and design of a multi-storey reinforced concrete building,” A graduation project submitted to department of Civil and Environmental Engineering, United Arab Emirates University, unpublished, 2008.

[8] J. Kulkarni, P. Kore, and B. Tanawade S,“Analysis of multi-storey building frames subjected to gravity and seismic loads with varying inertia,” International journal of Engineering and Innovative Technology, 2013.

[9] M.Sarcar,R.Mallikarjuna, and N.Lalit,“Computer aided design and manufacturing, PHI Learning Pvt. Ltd, 2008.