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Comparative Analysis and Design of Skyscraper in Both ETABS and SAP2000

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ABSTRACT: Structural analysis and design are predominant in finding out significant risk to integrity and stability of a structure with computer aided. This project investigates the efficacy and efficiency of two leading structural analysis and design software Etabs and Sap2000. A skyscraper (G +40) building 144 metre height and subjecting to various loads. Comparing the result of Base shear, Mass participation, Max. displacement, Max. bending moment, Max. Shear force and Max. Torsion. This study provides valuable insights for structural engineers in selecting an appreciate software for skyscraper project, optimizing and enhancing structural reliability.

KEYWORDS: ETABS, SAP2000, Skyscraper, Structural Analysis and Design.

I. INTRODUCTION

"Skyscrapers" means structure with multiple floors, at least 100 meters or 150 meters in height. But there is no universally accepted meaning other than generally mention a very tall high-rise building. They are iconic symbols of modern cities and continue to push the boundaries of height and design. As iconic symbols of urban progress and architectural effectiveness, careful demand for engineering and design considerations. Main reason of high-raised building is less area with more migrate people and settlement. Skyscraper are marvels of engineering and architecture, requiring advanced structural systems to withstand wind, earthquakes, and other forces. Among the leading software applications in this domain, ETABS and SAP2000 have come into view as industry standards, widely adopted by engineers for the analysis and design of high-rise buildings. Both software packages provide comprehensive features for modelling, analysing, and designing complex structural systems. However, they also display different characteristics and capabilities.

The objective of the study to model and analyze a structure in both software to Comparing the result of modal mass percentage, Max. displacement, Max. bending moment, mode participate and base shear etc. Clearly highlight the differences between ETABS and SAP2000 in terms of functionality, results, and user experience. Helping to improve design practices and decision-making between SAP2000 and Etabs.

II. LITERATURAL REVIEW

Brijesh Patel et al. (January-February-2022) (1) modelling and analysis of G 5, G 10 and G 15 RC framed structures using Staad- pro, Etabs & sap2000. They observed results that sap2000 is suitable and furnishing direct results up to G 10 structure but as we raise the height above G 10 it's linked that ETABS is furnishing more precise result. Therefore, it's linked that Etabs is more direct for analysis of altitudinous structures in comparison whereas Staad- pro shows values advanced for same loading condition in comparison. Laxmi Narayan Tiwari et al. (2020) [2] they carried out modelling and analysis of G 5, 10, 15 and 20 story RC framed structure considering seismic zone II and medium soil condition using Staad- pro, sap2000 & Etabs. shear forces, bending moments and reinforcement details for the structural factors of the structure (beams and Columns) and compared the results. observed which software gives more accurate results. In G 5 Storey and G 10 Storey, deflection they observed nearly analogous value in Staad and Etabs. In comparison sap2000 displacement is less. In G 20 Storey, deflection observed nearly analogous value in Staad and

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Etabs output whereas in Etabs (20.15 mm) deflection observed is less in comparison. Bhargav Jyoti Borah et al. (July 2018) (3) they compared to analyses a G 6 structure for chancing the shear forces, bending moments, defections and reinforcement details for the structural components of the building in sap2000 and Staad pro. they justify that sap2000 is more accurate, easier and faster error detection than Staad pro. Varikuppala Krishna et al. (2015) (4) They had planned for stilt with 5 floors residential building designed by Etabs. they used limit state method as Per computation taken in design as per code IS456 & IS875 for all forces and loads. Chuloh Jung et al. (2021&2022) (5) they had analysis and design G 21 building with dead load and live load was applied on the different structural elements like slabs and beams. Vijay Kumar et al. (2020) (6) they probe a high-rise building of (G 10) structure analysis and design as per code (IS 1893:2016) by considering seismic, dead, and live loads. comparing the results of seismic zones 3, 4 and 5. P. Srikanth Reddy et al. (2018) (7) they used architectural planning (G 7), blast resistance analysis (2 loading combinations) and design (IS 4991-1968) of multi-stored RCC building using Etabs.

III. METHODOLOGY

The Etabs and Sap2000 are powerful software tools used for structural analysis and design. They are similar procedure for analysis and design to skyscraper.

3.1 Modeling of skyscraper building in the Etabs and Sap2000

Outline of procedure,
Start New Model (Select units, set up the grids etc.,)
Model⇨ Define > Material (give desired Properties) ⇨Define > Section Properties ⇨Define Element (such as a beam, column, slab and other desired geometry)
Loads⇨ Define > Load Pattern (input the typical / load pattern) ⇨ Assign > Joint/Frame/Area loads (input the typical / load pattern) ⇨ Define > Mass Source (for the dynamic analysis) ⇨ Define > Load Cases (Analysis will run for load cases) ⇨ Define > Load Combination (used for design purpose)
Assign > Joint > Restraints (define the support conditions) ⇨ Analyze > Run Analysis (Select load cases to run)
Display > Results (visualize and extract analysis values)

3.2 Details of structure

G+40 story building is located in seismic zone of IV with plan of building structure 34×32.5m. the total height of structure was 144m. the roof slab was supported by the beam and column having 150mm thickness with M40 grade concrete. The cross section of column was used to support the structure as 1000mm × 1000mm and two type of cross section of beam were used to support the structure as 600mm × 650mm (Ground to 15th floor) and 450mm × 500mm (16th to 40th floor). M50 grade for concrete and HYSD500 grade for steel were used in the modeling of beam and column.

Table no. 01: structural parameter and values

Parameter	values
Structure dimension	34m × 32.5m
Each floor height	3.5 m
Height of ground floor	4 m
No. of storeys	G+40
Column size	1mx1m (1000mm x 1000 mm)
Slab thickness	150 mm
Beam size	0.6m×0.65m (Ground to 15th floor)
	0.45m×0.5m (16th to 40th floor)
Grade of concrete	M40 (for Slab) M50 (for Beam and Column)
Grade of steel	HYSD500

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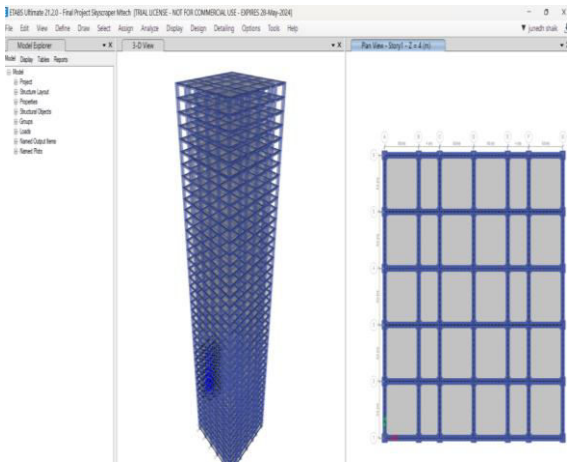

Fig 01(a): The structure view in Etabs.

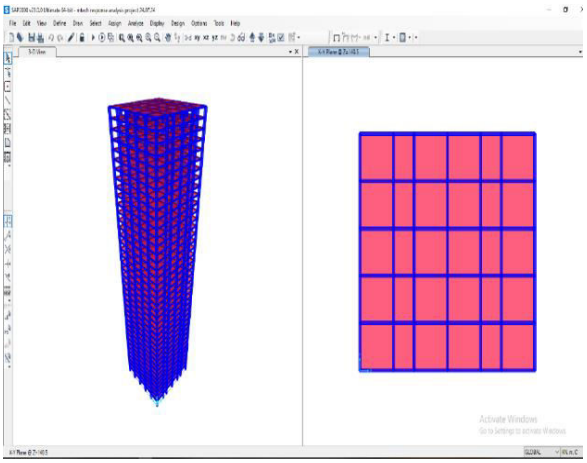

Fig 01(b): The structure view in SAP2000.

3.3 Load assignment on structure

The loads considered were self-weight of beam (9.75k-N/m up to 15th floor & 5.625k-N/m) and column (25k-N/m) uniformly distributed load. slab load as self-weight 3.75kN/m^2, roof slab 3k-N/m^2 in live load condition for the entire floor. The response reduction factor was taken 4 and importance factor 1 with damping ratio as 5%. The zone factor 0.24 was taken for the seismic zone IV as per IS 1893:2016.

Table no.02: applied loads on the structure

Type of loads	Applied
Dead load	Self-weight of slab (3.75k-N/m^2), beam (9.75k-N/m up to 15th floor & 5.625k-N/m) and column (25k-N/m) is taken and modeled within the structure.
Live load (uniform distributed)	3 k-N/m^2
Seismic load	Zone 4 with Reduction factor 4 in the x and y direction
Wind load	44 m/s in the X and Y direction.

Dead load with nonlinear for analysis the complex structure in dynamic condition.
IS 456: 2000 for Beams: Effective moment of inertia taken as 0.7 Ig; Columns**:** taken as 0.9 Ig; Slab: taken as 0.35 Ig.
For seismic analysis the time period value carried out with calculation as per code IS 1893(part-1) :2016 **Clause 7.6.2 (c)**

Time period of oscillation, $T_a = \frac{0.009h}{\sqrt{d}}$

Time period in X- direction, h = 144m and d= 34m $T_a = \frac{0.09\times144}{\sqrt{34}}$; T_a= 2.2226 sec

In the Y- direction, h = 144m and d= 32.5m

$T_a = \frac{0.09\times144}{\sqrt{32.5}}$; T_a= 2.2733 sec

The Indian Standard code commonly used for dynamic analysis, including seismic design, IS1893 (Part 1) – 2016. As

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per **Clause 7.3.1 of IS 1893:2016(Part 1),** Seismic design force computing full dead load and some percentage of the imposed load.

For Imposed load on the floor, 25% of the imposed the load be considered when the live load is up to and including 3.0kN/m^2.

IS 1893 (Part 1): 2016 the base shear calculation **(Clause 7.5.3):** for Scaling and Compliance Building codes often require the base shear V_b obtained from a dynamic analysis (such as a response spectrum method) should not be less than 80% of the base shear. V_B calculated using the equivalent static method.

According to CSI Knowledge Base, scaling factor = $\frac{I}{2R}$ Where, I = Importance Factor R = Reduction factor for Response Spectrum. Ater using the scale to run the analysis to check the base shear EQ X & EQ Y with RSX & RS Y and RS x, RS y must match with Eq x, Eq y, if not matched then it will rescale the scale factor to match the base shear.
Recycle of Scale = $\frac{\text{Obtained Base Shear of EQ X or EQY}}{\text{Base Shear of RS X or RS Y}}$

Obtained the base shear in Etabs, EQ X = 14121.3212 k-N; EQ Y = 14121.3212 k-N; RS X = 5604.3689 k-N; RS Y = 5523.4765 k-N.

The base shear in SAP2000, EQ X = 15213.3212 k-N; EQ Y = 15213.3212 k-N; RS X = 5741.9679 k-N; RS Y = 5734.8461 k-N.

Calculation Of Recycled Scaling factor for Etabs:
For Response spectrum acceleration U1,
SF = $\frac{\text{Obtained Base Shear of EQ X}}{\text{Base Shear of RS X}} \times 9.81$
= $\frac{14121.3212}{5604.3689} \times 9.81 = 24.718$
For U1 in X direction, S.F = 24.718
U2, SF = $\frac{14121.3212}{5523.4765} \times 9.81 = 2.556 \times 9.81 = 25.082$
For U2 in Y direction, S.F = 25.082

Calculation Of Recycled Scaling factor for SAP2000:
For Response spectrum acceleration
U1, SF = $\frac{15213.4283}{5741.9679} \times 9.81 = 25.991$
For U1 in X direction, S.F = 25.991
For Response spectrum acceleration
U2, SF = $\frac{15213.4283}{5734.8461} \times 9.81 = 26.082$
For U2 in Y direction, S.F = 25.02
Give the fixed support and diaphragm for each floor. Then Run analysis with all loads and view results. go to design for concrete structure as per IS 456:2000. Finally start design, it will check each frame and view desired results.

IV. RESULT AND DISCUSSION

Comparing the results in the Etabs and Sap2000

4.1 Base Shear

Comparing the values obtained in both software, Load cases such as earthquake in X & Y direction and response spectrum X & Y.

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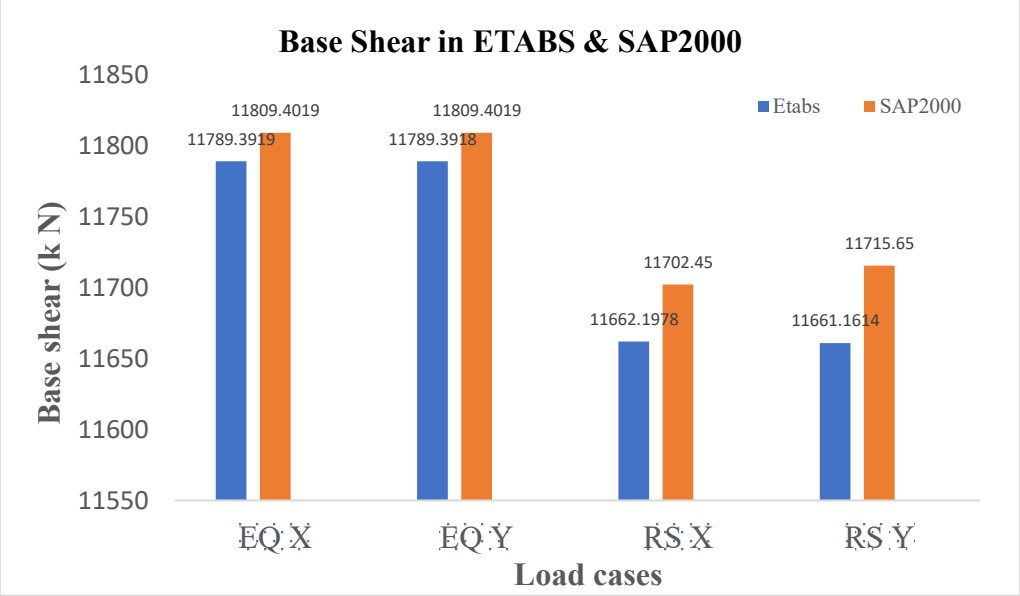
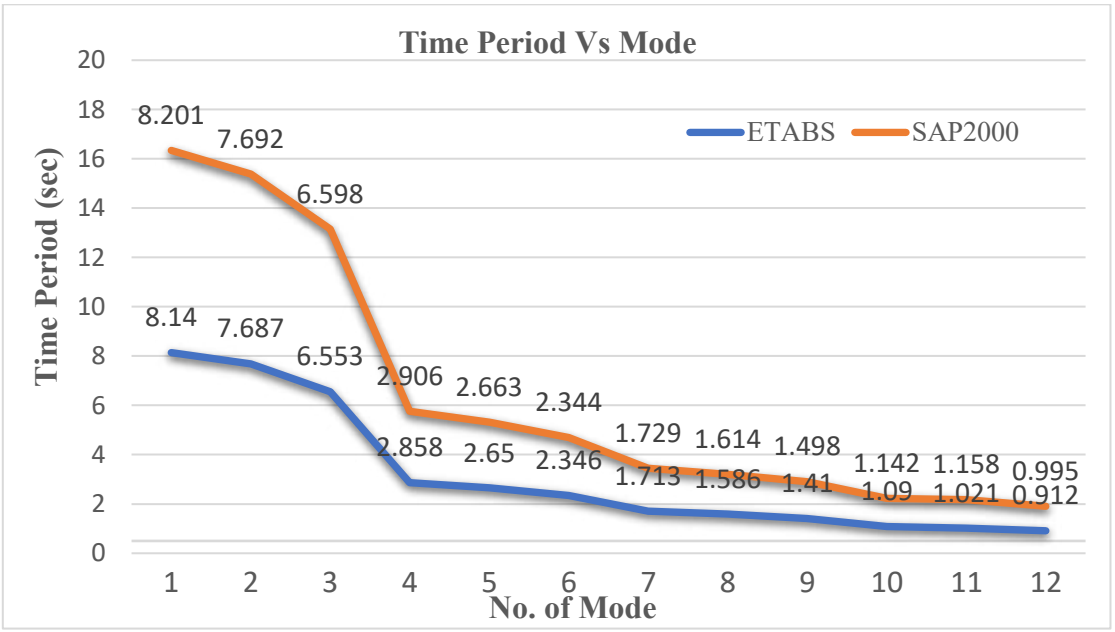


Graph 01: Comparing base-shear with load case in the Sap2000 & Etabs.

A 0.2% difference could be due to slight variations in default settings. This level of discrepancy is generally acceptable in engineering practice, but it might need further investigation if it impacts design decisions.

4.2 Time period in different mode:

In graphs, horizontal axis indicates number of Mode and vertical axis indicates the time period. The values compared in below graph representation.



Graph 02: Comparing Time Period with Mode in SAP2000 and Etabs.

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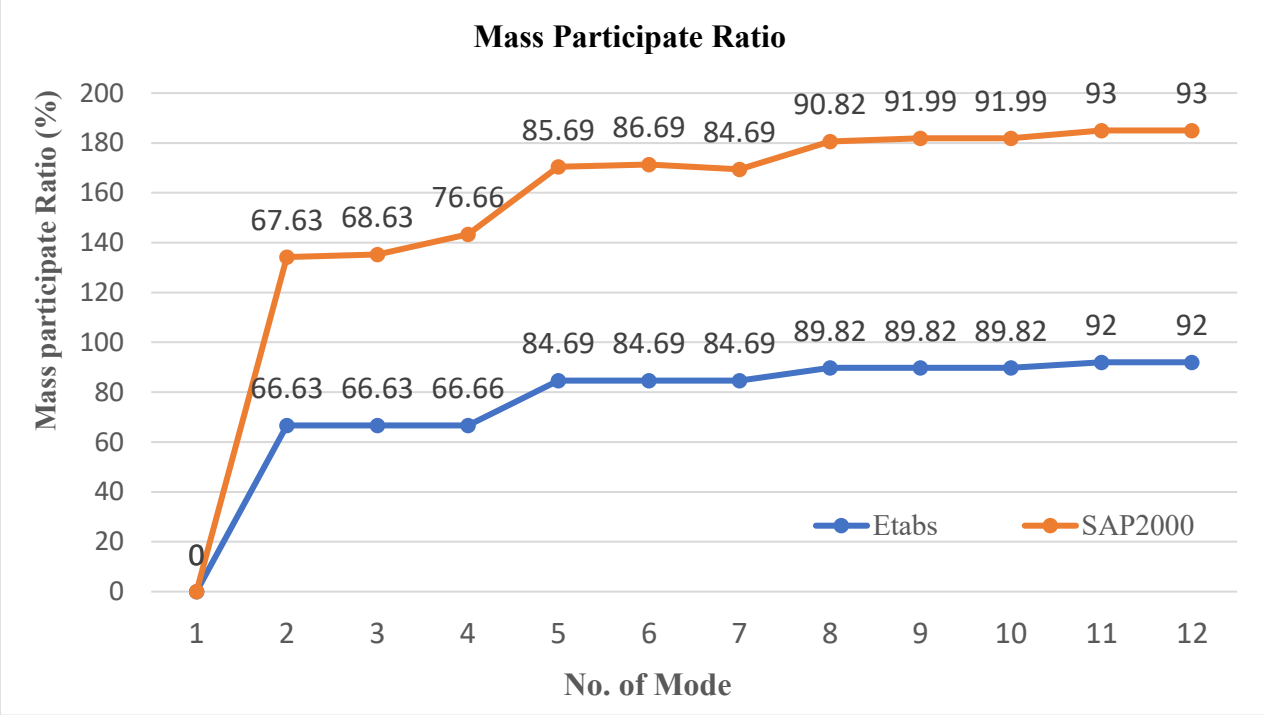
Observed it has small difference with 0.1 Sec. The time period is related to specific mode shapes, which describe how the structure deforms during vibration.

4.3 Mass Participation:

In graphs, horizontal axis indicates number of Mode and vertical axis indicates Mass Participate Ratio. The values compared in below graph representation.



Graph 03: Comparing Mass Participate Ratio with Mode

The code specifies that the sum of the modal masses should account for at least 90% of the total mass of the structure. Here, the Etabs provides 92% of the participate and Sap2000 as 93% with mode. it is okay for better analysis.

4.4 Maximum Displacement:

Displacement data helps in analyzing vibrations and ensuring that they remain within acceptable limits for human comfort and safety. Excessive displacement can cause serviceability issues such as cracking of finishes. In x, y and z direction, the maximum displacement of structure has been compared.

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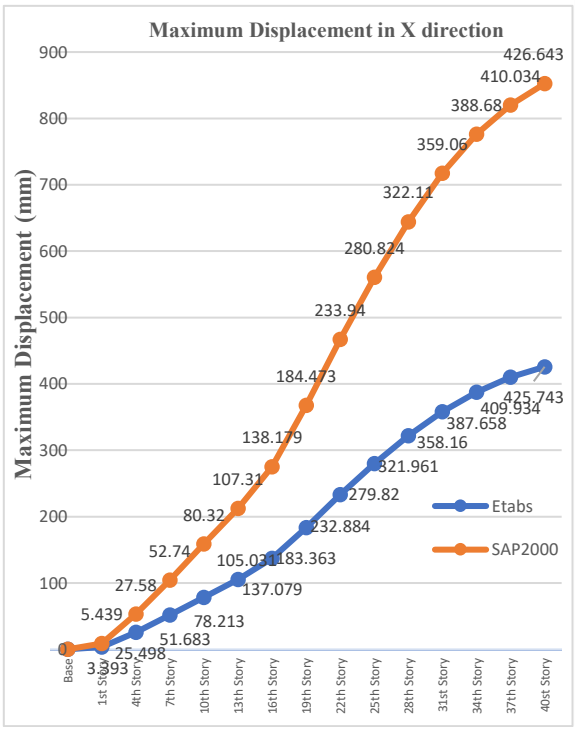
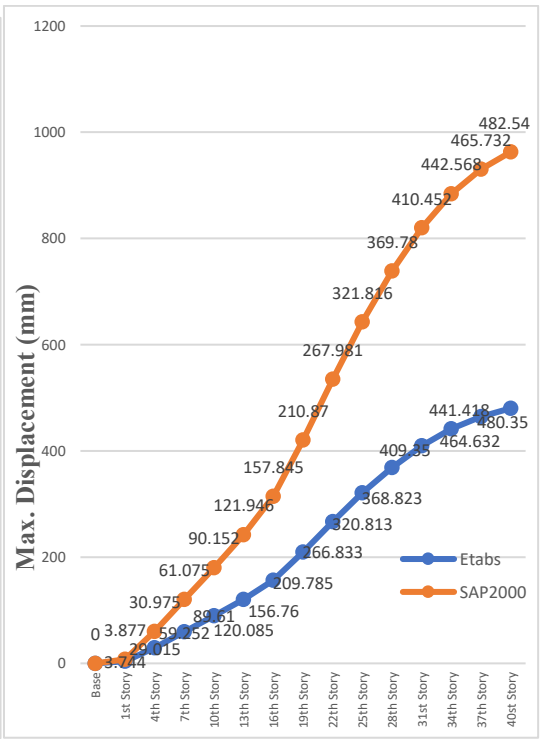
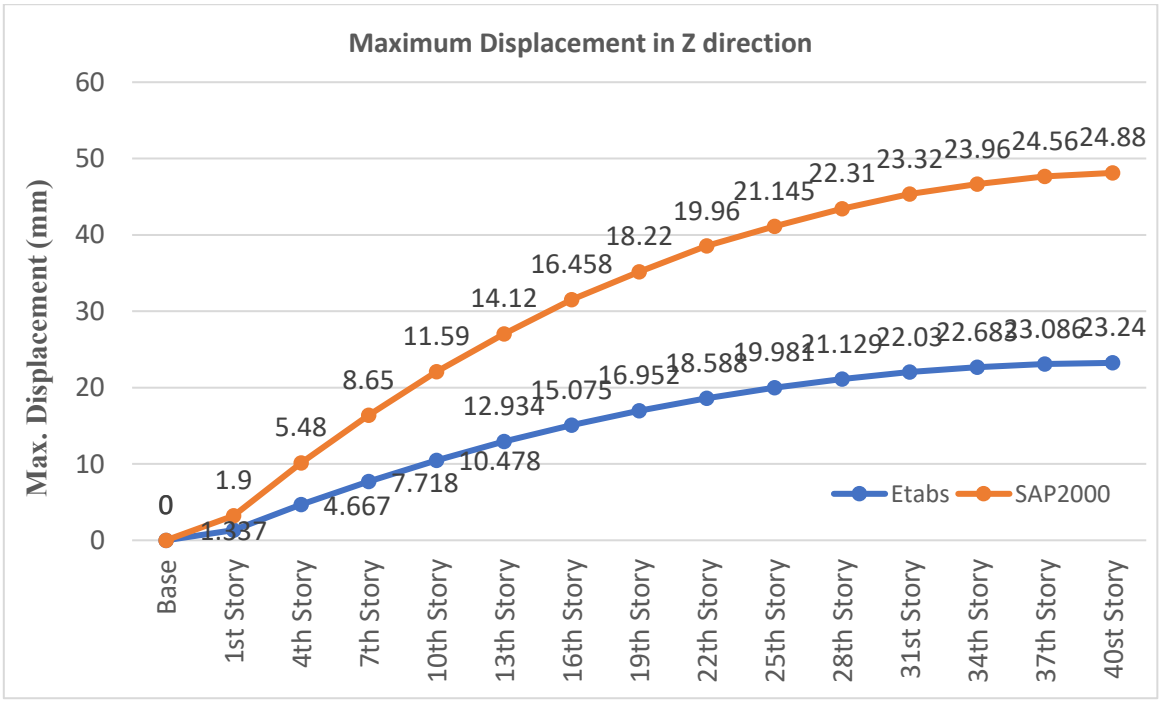


Graph 04(a): Max. displacement in X direction.



Graph 04(b): Max. displacement in Y direction.



Graph 04(c): Comparing Maximum Displacement in Z direction.

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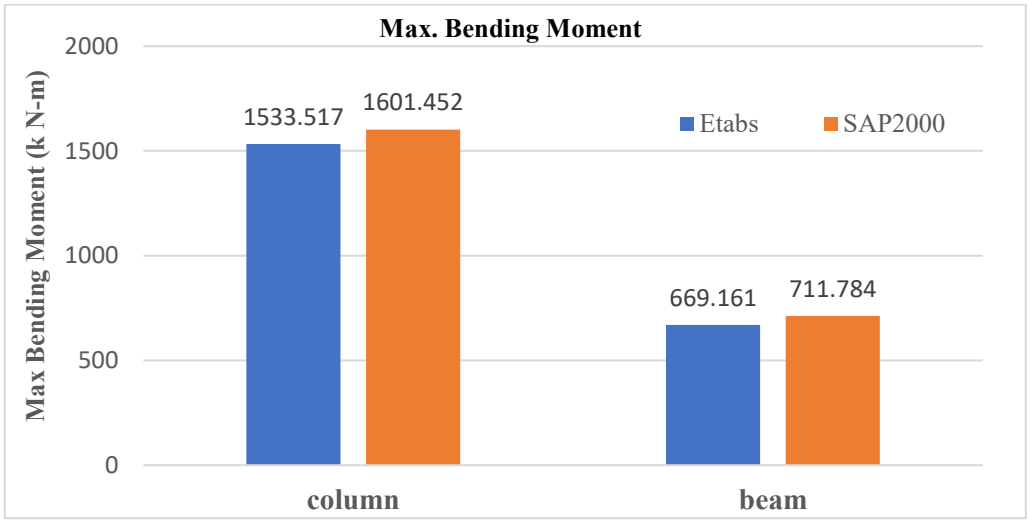
It has observed small difference with the average percentage of 0.02% in the X, Y and Z direction and here the load combination is kept default.

4.5 Maximum Bending Moment:

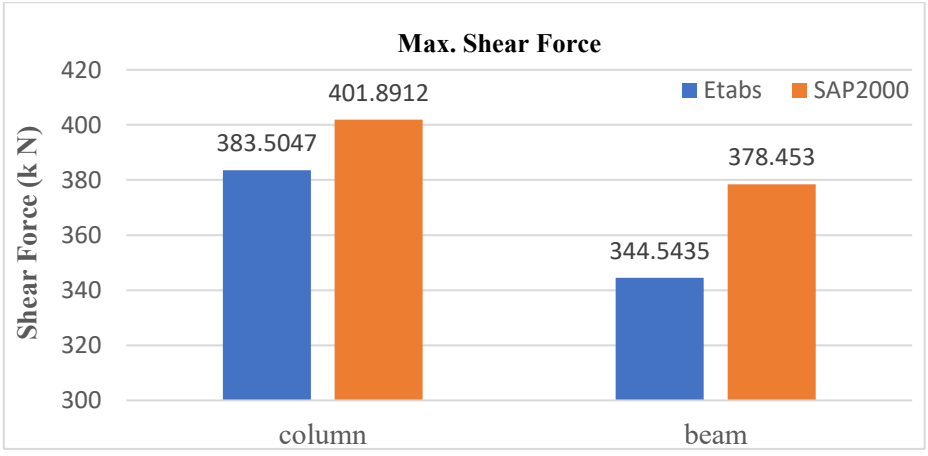
In graphs, it has compared separately with the column and beam which is indicates horizontal axis and vertical axis indicates maximum Bending Moment. The values compared in below graph representation.



Graph 05: Comparing Maximum Bending Moment in the Etabs and Sap2000.

It observed that the maximum bending moment difference between in a column as 67.935% and a beam as 42.623% But, the displacement is observed almost similar values. In the Etabs value is less than SAP2000, the structure serviceability is checked and the sap2000 as giving extra rebar to participate.

4.6 Maximum Shear Force:



Graph 06: Comparing Maximum Shear-force in Etabs and SAP2000.

It observed that the maximum shear force difference between in a column as 18.38% and a beam as 33.9095% But, the displacement is observed almost similar values. Such difference is generally acceptable and indicates that both software

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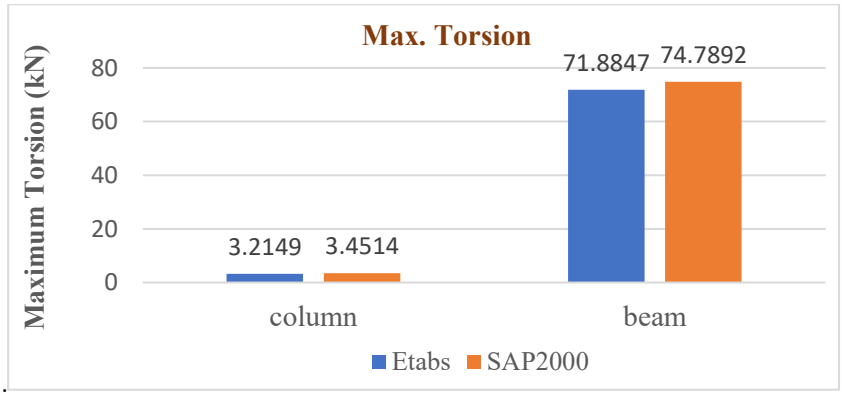
is producing consistent results.

4.7 Maximum Torsion:

In graphs, it has compared separately with the column and beam which is indicates horizontal axis and vertical axis indicates the maximum Torsion. The values compared in below graph representation



Graph 07: Comparing Maximum Torsion in Etabs and SAP2000

It observed that the maximum torsion difference between in a column as 0.2365% and a beam as 2.9045% which is sightly difference. So, it's ignored but shows the Etabs value is less than Sap2000. For the multi-stored structure analysis best to take the Etabs rather than Sap2000.

V. CONCLUSION

Analysis time can by the SAP2000 is within 10 minutes but the Etabs taken 36 minutes. Design process for the Etabs is fast, within 5-6 minutes but the Sap2000 taken 15 minutes. Because software algorithm in the Sap2000 detail properties has been given and the Etabs different aspect of analysis for nonlinear condition. The Etabs integrates building codes and design requirements more Smoothy, which can simplify the design process for skyscrapers Etabs is more efficient and user-friendly. But the Sap2000 is more complex with user defined. Story Drift is available in the Etabs but in the Sap2000 is not showing with graphically. The both Sap2000 and Etabs provide reliable results, Etabs is more specialized for buildings, potentially offering analysis and design processes for skyscrapers. The Sap2000 is handling a wider range of structural types and analysis structure including bridges, dams, and special type structures. For highly complex and nonlinear analysis, Sap2000 offer more advanced capabilities, though this depends on the specific needs of the project.

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