STATIC AND DYNAMIC ANALYSIS OF WIND ENERGY BUILDING UNDER THE ACTION OF WIND LOAD USING ANSYS

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Abstract - *Wind power is a key component of renewable energy utilisation. The execution of building integrated wind turbines contributes positively to the environment as a climate change mitigation option. Built in environment wind turbines are those located in an urban or suburban environment. They can be integrated into a building and included in the building design from architectural, structural, and economic perspectives. The wind power is gaining more importance due to its low price and it's friendly to environment and the wind energy and building integration also becomes a very important mode to develop new energy sources. The application of BEWT systems to high-rise buildings can be done in different ways. Five different ways by which turbine can be installed to buildings are discussed in this paper. Both*

Static and dynamic analysis are done for this models. And the behavior of the buildings are studied. The feasibility of these structures was verified preliminarily by comparing analysis results. Using ANSYS 19.1, both static and dynamic structural analyses were performed. A simplified finite element model that represents the wind turbine tower was created, an ultimate load condition was applied to check the stress level of the tower in the static analysis and for dynamic analysis the rotational velocity of turbine is considered and seismic analysis is also performed along with it. CFD FLUENT is used for the analysis of the building under the action of wind.

Key Words: *Seismic analysis, computational fluid dynamics*

1. INTRODUCTION

Wind turbines can be classified into two categories – macro wind turbines that are installed for large-scale energy generation such as wind farms, and micro wind turbines used for local electricity production. Micro wind turbines are preferred for the application at the buildings and are called building-integrated wind turbines. The developments in building integrated wind turbine technologies involve improving reliability, improving efficiency at low wind speeds and lowering capital cost. The latest wind turbine models have blades which are now designed with lightweight materials and aerodynamic principles, so that they are sensitive to small air movements. Furthermore, the use of permanent magnet generators, based on rare earth permanent magnets, results in lightweight and compact systems that allow low cut-in wind speeds. By this way electricity can be generated with wind speeds as low as a

few metres per second. Buildings integrated wind turbines offer opportunities for local economic development, including:

1. Less financial burden to households due to lower electrical costs

2. Opportunities for households/building owners to sell surplus electricity back to the grid

3. New skills and job opportunities for the local workforce

4. Mechanism to grow the local green economy.

1.1 Objective

- Five cases of building integrated with wind turbine are analysed based on ANSYS finite element software.

- To choose the position of wind turbine, it placed and the structural modifications required in order to make this new structure meet the structural requirements better

- Calculation of deformation of buildings, storey shear, storey axial force and bending moment of building, after installing wind turbines.

- Calculation of results of structure with wind turbines under different wind velocity.

- To study the sudden changes of building occurred due to an earthquake.

- Optimizing the model:

1.2 Scope of work

The scope of the work presented in this thesis is the static and dynamic analysis of building integrated with wind turbine structure subjected to loading due to the dynamic action, external pressure, earthquakes etc.

2. MODELLING

The computational model is a 15-floored frame structure, the floor height is 3m, cross-section size of frame column is 500mm×500mm, cross-section size of frame beam is 200mm×400mm, thickness of slab is 100mm, strength grade

of concrete is M30, steel rebar used HRB335. The beams and columns are of steel members. And the slab is concrete member.

The total height of the building is 45m and 5 different models are taken into study. In the 5 models the position of the wind turbines are changed and its effects are mainly taken to study. In the first model the turbine is fixed at the top floor of the building. In this case the turbines are mounted directly to the building. The turbine is fixed to the building by spot welding technique. In the second model, a steel frame was mounted to the building and the turbine was fixed on this frame. Same spot welding technique was used in this case also. In the third model the turbine is fixed inside the building, the turbine is made to rest in a column and the support was given on other side. In the fourth model the turbine instead of resting on column, it was fixed in the center by giving steel member supports from all the sides and this member's was fixed to the adjacent columns. The 5th case was a different one, here two towers was modeled both of same dimensions and this 2 towers was connected by two bridges like members and this was of steel configuration.
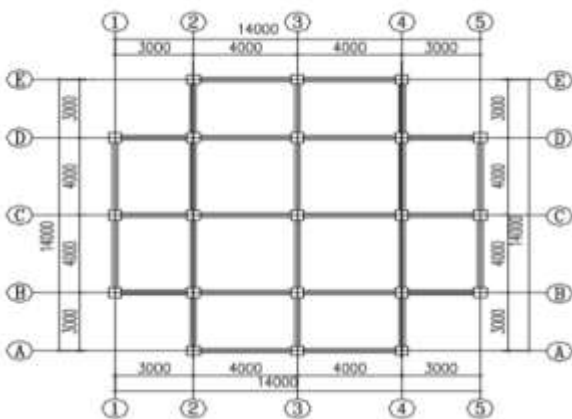
And two turbines was fixed on them, one on each member

Fig -1: Plan of the model

Table -1 Material properties of concrete

Material properties	Value
Density of concrete	2300 kg/m^3
Coefficient of thermal expansion of concrete	1.4 ×10^{-5}/°C
Young's modulus of concrete	3.6×10^4 N/mm^2
Poisson's ratio of concrete	0.18
Bulk modulus of concrete	1.56×10^4 N/mm^2
Shear modulus of concrete	1.27×10^4 N/mm^2
Grade of concrete	M30

Table -2 Material properties of structural steel

Material properties	Value
Density of steel	7850 kg/m^3
Coefficient of thermal expansion of steel	1.2 ×10^{-5}/°C
Young's modulus of steel	2.1×10^4 N/mm^2
Poisson's ratio of steel	0.3
Bulk modulus of steel	1.67×10^{11} Pa
Shear modulus of concrete	7.69x10^10 Pa
Grade of steel	HRB335

2.1 Modelling of different cases

The physical problem was modeled as per the layout. Five models were considered.

In model1, the turbine is mounted at the top floor of the building. The turbine is attached to the structure by connecting steel members of beam sections. The members are connected to the structure by spot welding and these members hold the turbine. The 2nd model is similar to the first one; the main difference is that the turbine is fixed to a frame of steel beam sections. A frame is made outside the building and this frame holds the turbine. This frame is connected to the structure by spot welding technique. In model 3, the turbine is fixed inside the building. The slab in that portion is removed and the turbine is made to rest in the columns. Additional columns and beams to support the turbine is given. In model 4, the turbine is fixed inside the building by the same method of that of model 3. The difference is that, turbine is made in position by the help of several steel members which is of beam cross section. A spider web like design is adopted.
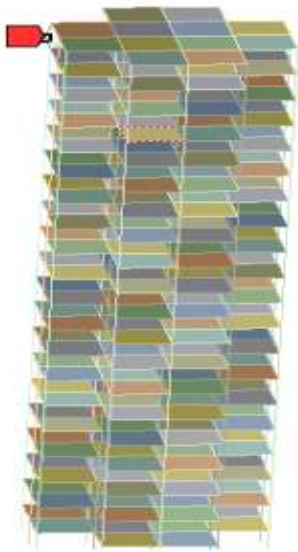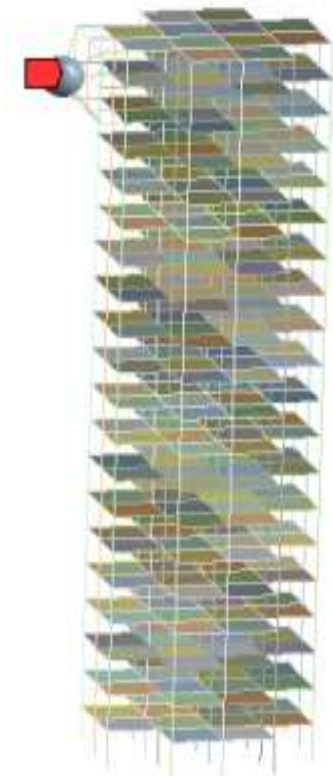
Fig -2: Model 1
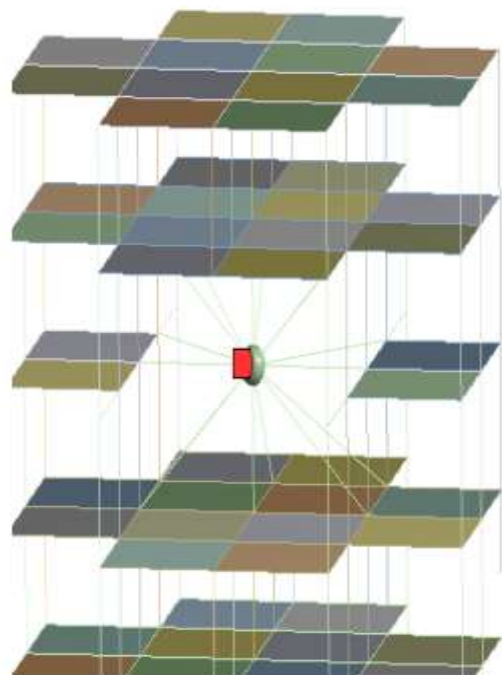

Fig -4: Model 3

Fig -5: Model 4

In addition to these 4 models, another model was designed, this model is different from all other models. Here twin tower is modeled and these towers are connected by bridges in between. The bridges are designed to hold the turbines. Total of two bridges are modeled and each bridge can hold one turbine.
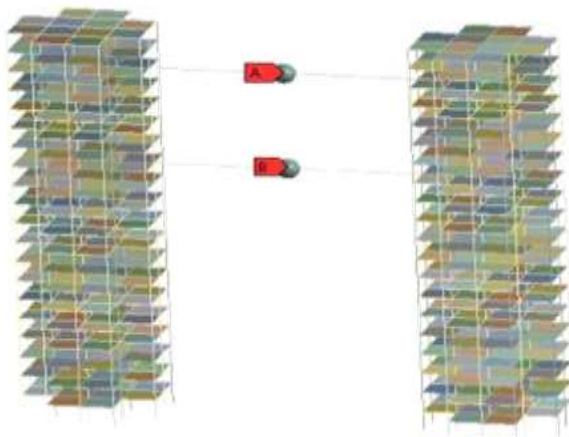

Fig -3: Model 2

Fig -6: Model 5

2.2 Meshing

ANSYS Meshing is a general-purpose, intelligent, automated high-performance product. It produces the most appropriate mesh for accurate, efficient multi physics solutions. A mesh well suited for a specific analysis can be generated with a single mouse click for all parts in a model. Full controls over the options used to generate the mesh are available for the expert user who wants to fine-tune it. The power of parallel processing is automatically used to reduce the time you have to wait for mesh generation.

2.3 LOADING CONDITIONS

The design loads considered for the study primarily include loads of wind turbine (installed in the building structure) and the loads acting on the elements of building structure (dead and live loads of the building). The loads primarily include the Dead Loads (DL), Super Imposed Dead Loads (SIDL) and Live Loads (LL). DL includes the self-weight of building elements, i.e. loads from slab, beams and columns. SIDL denote the dead load on the structure after slab and beams have been casted. This includes loads of floor finishes, wall loads, water proofing, cable wires etc. LL are referred to probabilistic loads which include all the forces that are variable within the structure normal operation cycle not including construction or environmental loads.

The load of the turbine is taken as 2500kg. The turbine is fixed at different position of the building. The turbine portion mainly consists of turbine housing and leaf portion.

2.4 SEISMIC LOADING

Response of the building structure subjected to seismic loading during the phase of turbine movement is observed. Past earthquake response of EI Centro earthquake happened in 1940 was used for time history analysis. The total duration of considered in earthquake response is 30 second. Seismic analysis of the structure considering 30 seconds consumes greater time. Since the maximum response of the earthquake is seen during the first 10 seconds, earthquake

response data of first 10 seconds is considered for the analysis. The turbine moving time in the structure considered is 3 seconds.
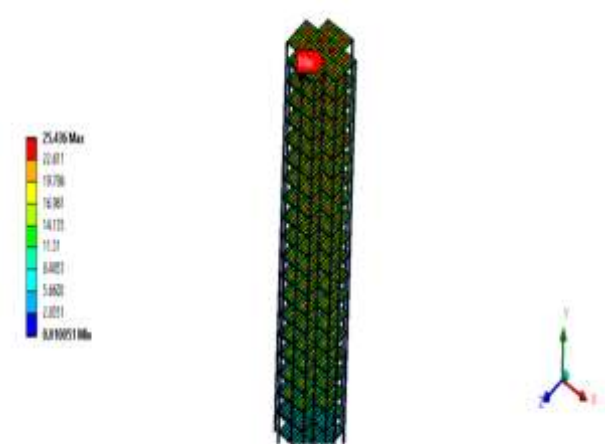

Fig -7: Time acceleration data of EI Centro earthquake

3. ANALYSIS

In this section the analysis like Static analysis, Dynamic analysis, Time History analysis and Modal analysis. Each analysis has a set of loading and boundary conditions that need to be applied for performing the analysis

3.1 Static Analysis

The static analysis of 5 different models has been evaluated and the results of storey deformation, storey shear, storey axial force and bending moment have been found out. We can see that as the position of the turbine changes there is difference in the values of this parameters. The four models was grouped together and there results was compared in-order to find out an optimized model. The model 5 was a different case, as it is a twin tower and the turbines are mounted in between the two towers.
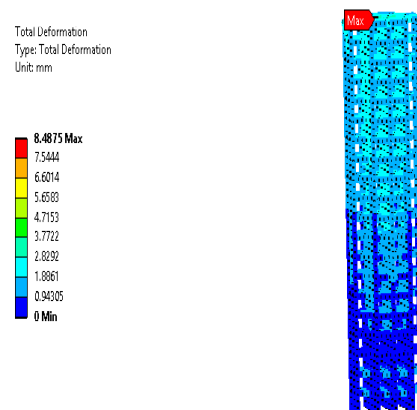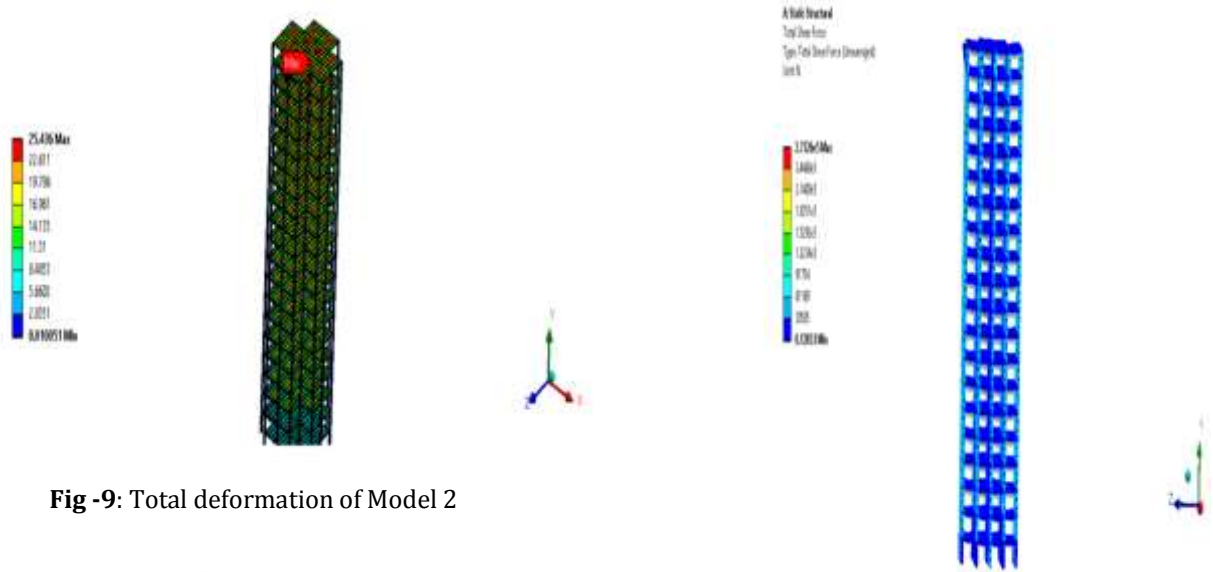

Fig -8: Total deformation of Model 1
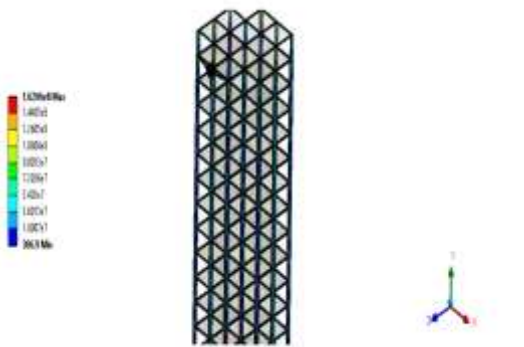
Fig -9: Total deformation of Model 2

Fig -10: Total bending moment of Model 1

Fig -11: Total bending moment of Model 2

Fig -12: Storey shear of model 1

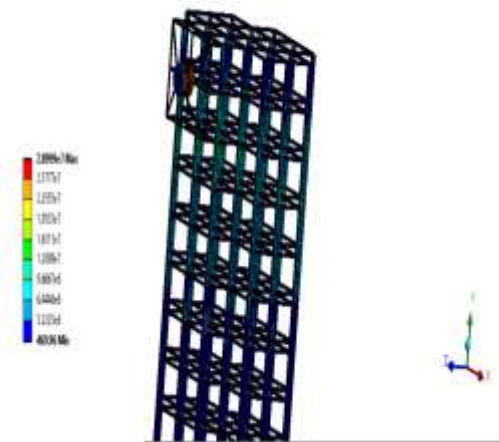**Fig -13**: Storey shear of model 2
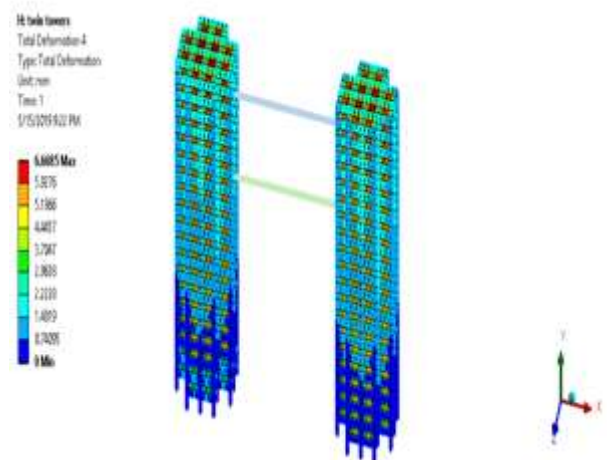
3.2 Static analysis on model 5

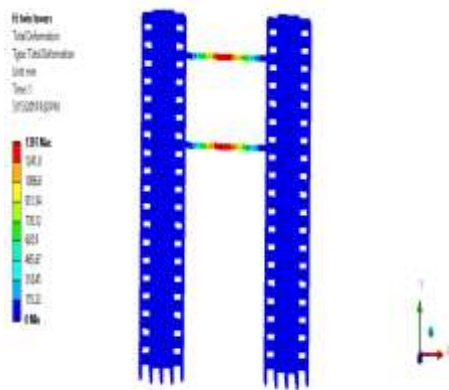**Fig -14**: Deformation of model 5 case1

Fig -15: Deformation of model 5 case2

Here two cases are analysed, in the first case total deformation on the building due to the erection of turbines in the connecting bridges are taken, and we can say that deformation is very negligible in the building. In the second case the deformation occurring on the bridges are taken, and we can see that max deformation occurs on those members. The building is safe in this case.
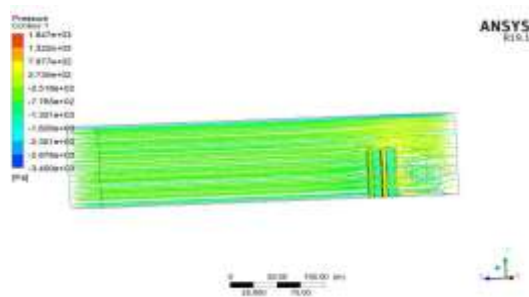
3.3 CFD FLUENT ANALYSIS

Fig -16: Total pressure developed in the building

The CFD analysis was done on model 5 as it will be more prone to the effects of wind especially the bridge which support the turbines. The domain created contains an inlet, outlet, pressure measure, and walls. The pressure measure is used to measure the pressure due to the action of winds. In the result we can see the surfaces which are effected by wind.
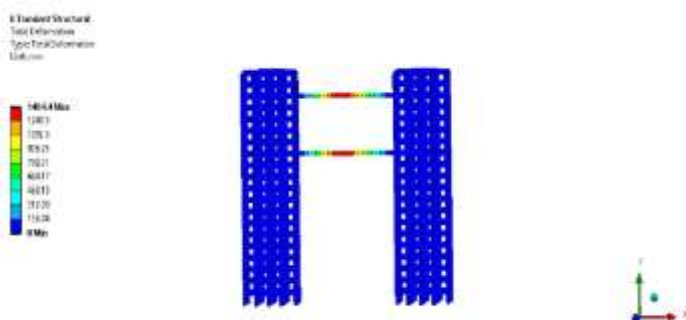
3.4 Seismic analysis

Fig -17: Deformation of model 5

Seismic analysis has been performed for model 5 since the model is considered as the optimized model taking into account the static analysis. Time history analysis has been performed on the model.
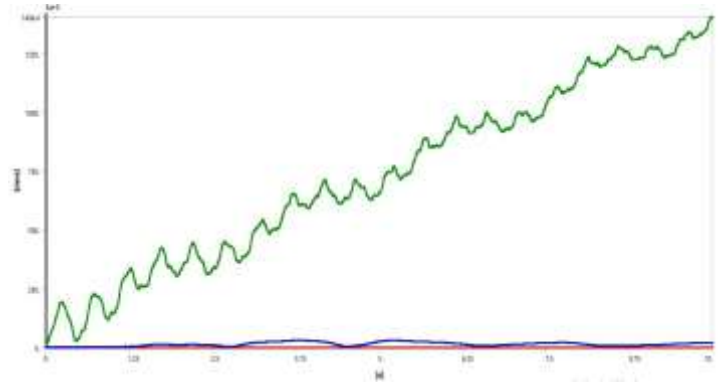

Fig -18: deformation graph of time history analysis

3.5 Vibration analysis

Vibration analysis has been performed for the optimized model, to check for resonance. The natural frequency of the building structure has been determined by performing modal analysis. Modal analysis has been performed for ten mode shapes.

The natural frequency of mode 1 noticed was 0.2346Hz. The modal analysis for mode 1 is shown in figure
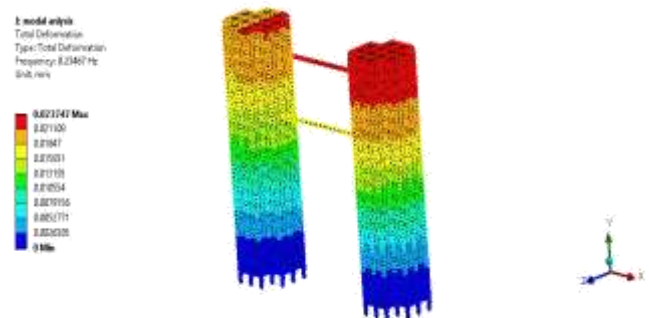

Fig -19: Modal analysis for mode 1

4. CONCLUSIONS

Static, dynamic and seismic analysis has been carried out in this study. Based on the results obtained the following conclusions are made. From the dynamic analysis performed for different cases it was concluded that model 5 is the optimized model.

- From the study its understood that the position of wind turbine is an important factor to be considered.

- The storey shear, deformation and bending moment was evaluated in each cases and the better model among them is suggested.

- Time history analysis was done to evaluate the performance of building under seismic load. Seismic analysis has been carried out for the model 5 and the response of the building structure has been observed

- In addition to that computational fluid dynamics analysis was done to evaluate the response of building under different wind velocities.

- The pressure exerted on the towers was evaluated and this was under permissible limits

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