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DYNAMIC ANALYSIS AND DESIGN OF JACKET TOWERS IN OFFSHORE STRUCTURES

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ABSTRACT

With the increase in demand for offshore wind energy, the need for offshore structures for supporting wind turbine is increasing. As offshore structures produce 50% of more energy compared with on shore structures, our projectis one such design of Jacket tower. The four legged jacket tower is supported by a concrete platform. As the tower is under the action of current and wave loads, the tower is analysed for dynamic conditions using SACS software. X bracings are adopted to resist the lateral loads. The wind and the seismic loads are calculated and analysed using STAADProV8i. The results from the analysis are used for the foundation design using STAAD Pro Foundation. From the analysis and design it is found that the tower seems to be safe under dynamic conditions.

KEYWORDS: *X Bracings, Dynamic Loading, STAAD Prov8i, SACS, Current Load, Load Wave*

Article History

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INTRODUCTION

The Wind turbine can deliver enormous amounts of electricity when contrasted with other vitality sources which are generally placed coastal and seaward. So, there is a need for the offshore structures which supports the wind turbine. Contingent on the profundity of the ocean water and according to the necessity, different sorts of the platform are designed. Offshore wind turbine isolated far from property and buildings, so noise and collapse are insignificant concerns from a human factor and also offshore wind turbines offer many benefits over land-based turbines. It has been observed that relatively low surface roughness of the ocean results in higher wind speeds. So offshore windmills are the best possible options for generating electricity. Wind turbine developed in waterways is more often than not in the sea on the mainland rack, to gather wind vitality to produce electricity. There are two main categories of offshore structures fixed and floating here we are using fixed with pile foundation.

The analysis, design, and construction of offshore structures are s ostensibly a standout amongst the most requesting sets of undertakings looked by the engineering profession. Well beyond the typical conditions and circumstances met via land-based structures, seaward structures have the additional entanglement of being put in a sea domain where hydrodynamic interaction effects and dynamic reaction become real contemplations in their design. Offshore produces 50% more energy than an onshore turbine and it is the tallest among manmade structure on the earth for higher and more constant wind speed. At the point when profound water joins with antagonistic climate condition, vital regular fixed offshore structures require additional physical dimensions to acquire the stiffness and strength. A Jacket is a welded tubular space frame with at least three vertical tubular chord legs with a bracing system between the legs.

The main aim of this project is harvesting wind energy to generate electricity in the off shore

- To study the details and conditions of the proposed location which is Rameswaram
- To design a working platform that supports the wind turbine
- To calculate the various loads that are acting on the structure
- To design a jacket type of offshore structure supporting the wind turbine
- To design a suitable pile foundation for the jacket tower structure.
- A comparative study of analysis by using SACS and STAAD.Pro

Location

About location

This offshore structure is planned to be erected along the coastline of the Indian sea (near RAMESHWARAM) with a water depth of 50metres. The coastline has a maximum wave height of 3.6metres in southwest monsoon and up to 6metres during cyclone period. Along the coastline, the average wind speed of 9.7 m/s and 5.6 m/s was recorded during southwest monsoon and northeast monsoon respectively.

Mean Daily Temperature

Maximum of 29°c to 27°c Minimum of 21°c to17.5°c

Maximum temperature ever recorded was38°c. Minimum temperature ever recorded was16.4°c.

Wind Speed Data

We gathered the monthly average wind speed(2017)which was recorded as,

Table 1: Wind Speed Data

Month	Wind Speed (Mph)
January	15
February	10.2
March	10
April	8.9
May	13.8
June	18.6
July	15.5
August	15.3
September	13.8
October	10.5
November	10.1
December	15

Tidal Variations

Tidal range near Rameswaram was recorded on weekly basis for the month of June(2017),

Table 2: Tidal Range Date

Days	Tidal Range
19th June	0.403
20th June	0.317
21th June	0.317
22th June	0.312
23th June	0.307
24th June	0.293

Rain Fall

The annual average rainfall recorded near Rameswaram was 902mm and monthly average rain fall varies from 4mm(June) to 277mm(November).

Dimensional Parameters

Table 3: Dimensions of the Tower

Components	Dimensions(M)
Jacket Type	X-Braces
Total Height	74.5
Length of Legs	75.5
Length of Top Brace	19.9
Length of Middle Brace	30.49
Length of Bottom Brace	39.21
Length of Top Horizontal Brace	14.67
Length of Middle Horizontal Brace	23.11
Length of Bottom Horizontal Brace	32.8
Thickness of Brace	0.03
Thickness of Leg	0.04
Diameter of Brace	0.09
Diameter of Leg	1.80

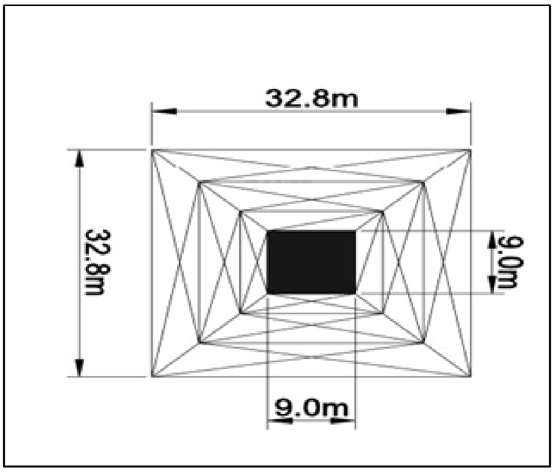

Figure 1: Three Dimensional View Using AUTOCADD

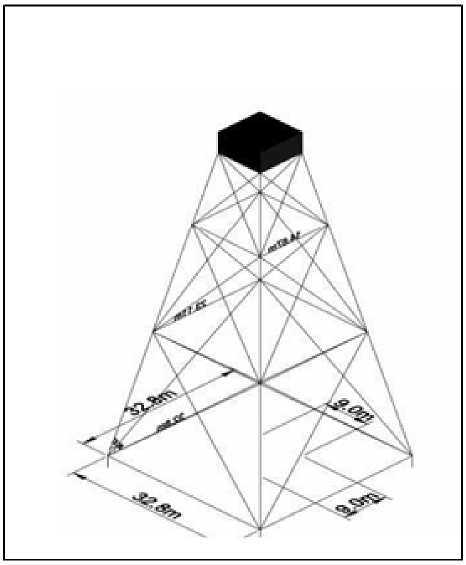

Figure 2: Plan

Load Sacting on the Tower

Loads on offshore structures are gravity loads and environmental loads. Gravity loads are emerging from the dead weight of structure and offices either changeless or brief. Seismic loads are emerging from gravity loads and are a determined sort.

Dead Load and Live Load

Dead load and live load are the vertical loads considered in the structure. Dead loads represent the non-dynamic powers that place persistent and perpetual force on the structure. Live loads are characterized as versatile loads and will be impermanent in nature.

Table 4: Volume Calculation

S. N0	PARTS	CALCULATION	VOLUME
1	Legs	$\left[\frac{\pi}{4} \times (1.8)^2 71.9\right] 4$	731.74m³
2	Bottom Horizontal Brace	$\left[\frac{\pi}{4} \times (0.9)^2 32.8\right] 4$	83.46m³
3	Middle Horizontal Brace	$\left[\frac{\pi}{4} \times (0.9)^2 23.4\right] 4$	58.80m³
4	Top Horizontal Brace	$\left[\frac{\pi}{4} \times (0.03)^2 14.6\right] 4$	39.33m³
5	Bottom X- Bracings	$\left[\frac{\pi}{4} \times (0.03)^2 39.2\right] 8$	0.221m³
6	Middle X-Bracings	$\left[\frac{\pi}{4} \times (0.03)^2 30.4\right] 8$	0.172m³
7	Top X-Bracings	$\left[\frac{\pi}{4} \times (0.03)^2 30.4\right] 8$	0.112m³
		TOTAL VOLUME	911.35m³

Wind Load

The wind load is calculated for the critical wind direction for the whole topside module using the following API recommended formula:

F = (q) (h/10)$^{0.22}$ (C) (A) (sinα)

Where,

C=shapecoefficient h=datumheight,m A=exposedarea,m^2

q = basic wind pressure or suction, N/m^2

α = angle between the direction of the wind and the axis of the

exposed member.

Rameswaram basic winds peed (zoneII)Vb=44.75m/s and the Wind Load acting was evaluated as **641.01kN**

Wave Load and Current Load

The wave-current interaction is significant since the waves propagate on the current. Sea flows instigate drag loading on offshore structures. These flows together with the action of waves create dynamic loads. Wave and current loading can be calculated by the Morison equation was calculated as **961.3kN**

Morison equation can be written as:

□T=1/□□D□W□□|□|+□□2/□□M□W□

Where,

F_T Is the total force, N
ρ_w is the density of water, kg/m^3

CD and *CM* are the drag and inertia coefficients respectively

D is the diameter(m)of the member including marine growth

V is the velocity(m/s) and *a* is the acceleration(m/s^2).

Design of Working Platform

A concrete slab is a common structural element with small thickness supporting mainly transverse load and transferring them into supports primarily by bending in one or two directions. A slab of 9 x 9 m was designed with a depth of 565mm. Six numbers of 25mm diameter bars at 100mm spacing was provided.

Modeling and Analysis

SACS Software

The SACS Program will internally figure the structural mass, water included mass, flooded mass, and mass of marine development for all active members of the structural model. Members will be temporarily designated active or inactive depending on whether computer mass generation or direct input mass is required. For steel mass estimation, dynamic members from the jacket tower will comprise of components in the corner legs, plan levels and frames.

Additional jacket mass due to the nodes will be generated by SACS based on variable sectional properties input for each member so that stick mass and nodes mass add up to the overall steel mass of the jacket. In order to carry out an accurate analysis based on wave loads and current loads the structural analysis computer system (SACS) is used.

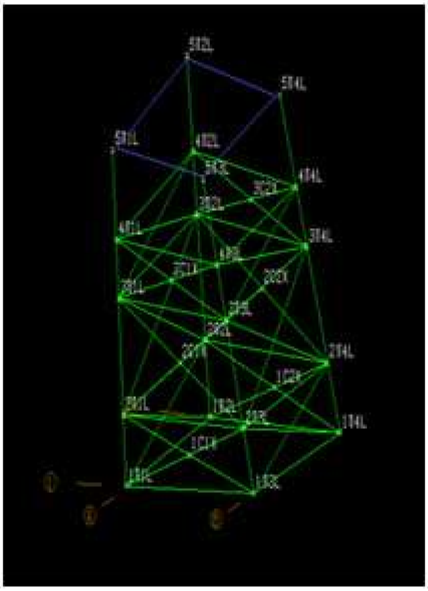

Figure 3: Model of the Structure

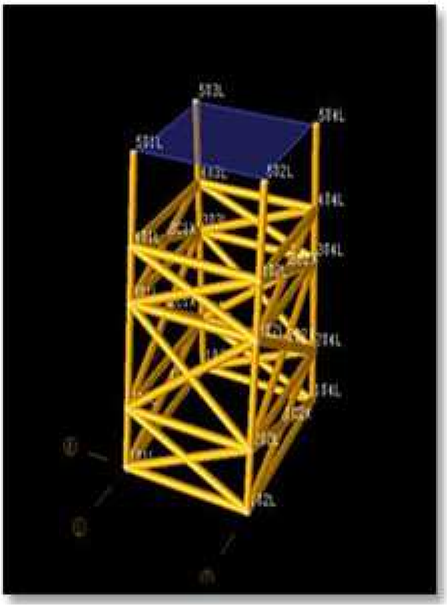

Figure 4: 3-D View

The collected values and the calculated dimensions of the tower are entered. The negative values represent that 50m from the bottom is submerged inside the water.

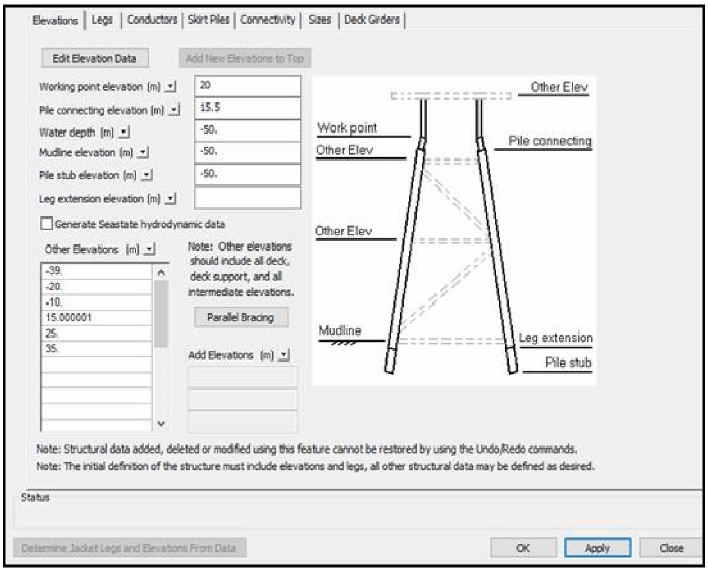

Figure 5: Structure Definition

The main purpose of using SACS is to apply the wave and current loads in cethe jacket tower is a offshore structure. Wave and wind load are applied here.

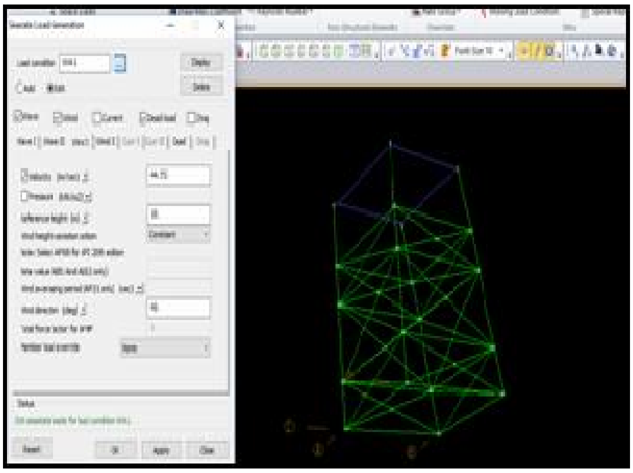

Figure 6: Application of Wave Load

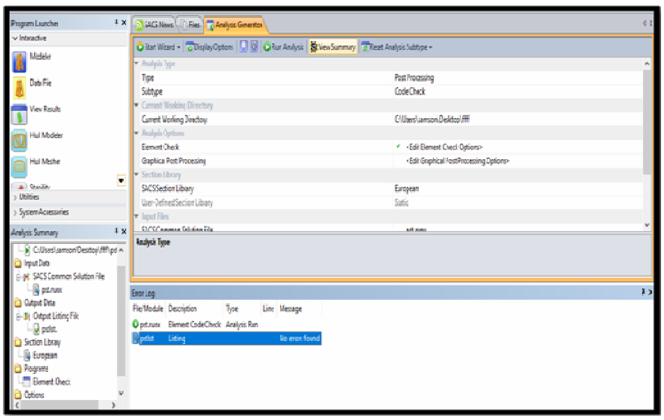

Figure 7: Modeling Check

After the model has been checked for nil errors the analysis of the tower using SACS software is done.

STAAD Pro Software

The model of the tower is created using the nodal value and support and material properties are specified.

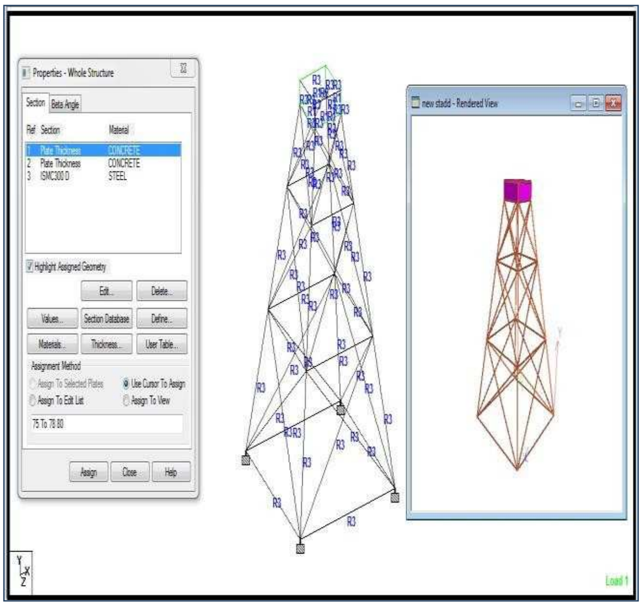

Figure 8: Definition of Member Property

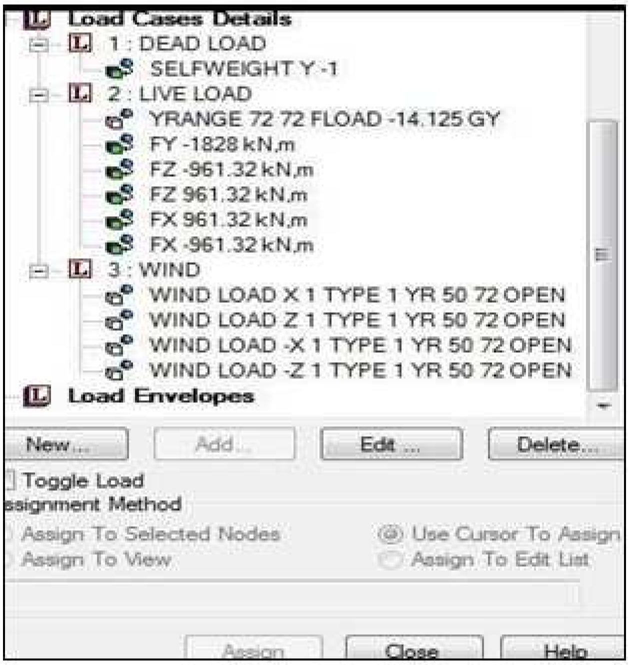

Figure 9: Load Definitions

The wind load specification are given using STAAD Pro. and a minimum of 50m depth to a maximum of 72m depth is entered. This range is adopted because the exposure of the tower is above50m.

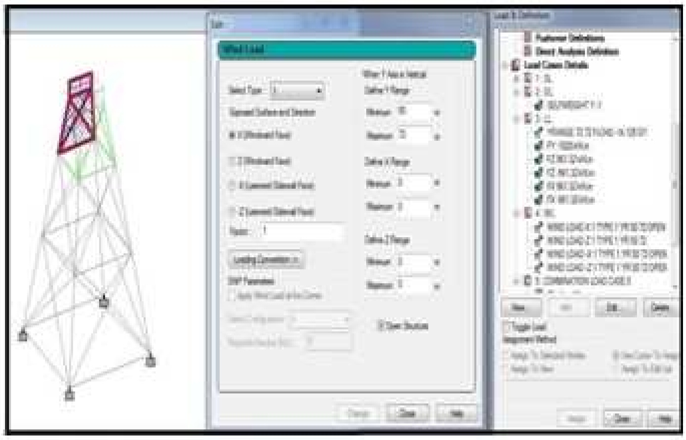

Figure 10: Wind load in X Direction

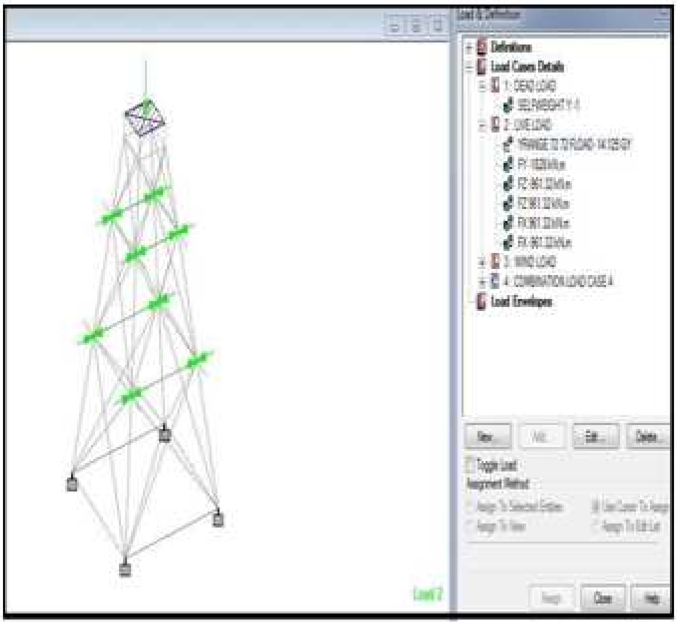

Figure 11: Floor, Wave, and Current Load

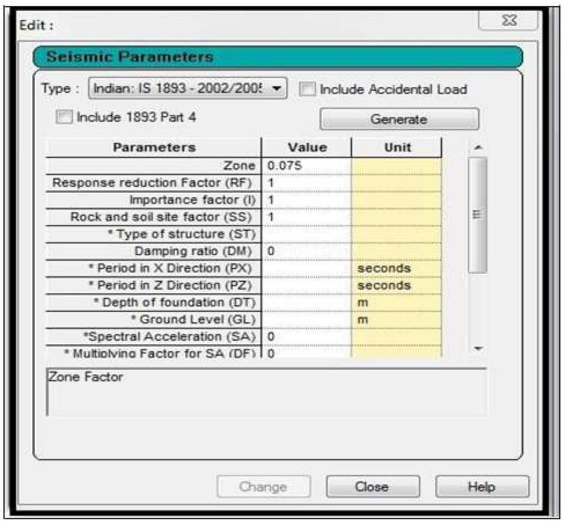

Figure 12: Definition of Seismic Parameter

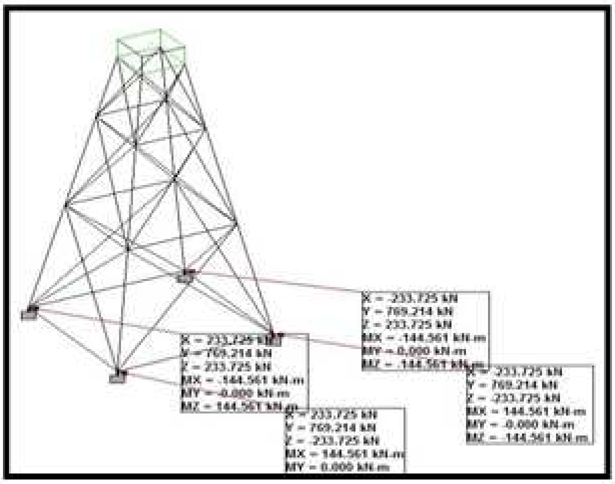

Figure 13: Moments and Reactions at Support

The above results are obtained after the analysis in STAAD Pro. From the above results, it is observed that the assumed sections are safe to carry the load without any failure. Further, these results are used for Foundation design.

Design of Foundation

In an offshore structure, the piles hold them on to the ocean bed. There are various sorts of pile system that can be used in the offshore structures.

Pile Foundation

Table 5: Foundation Parameters

Foundation Data	
Depth	4.75m
Width	15m
Soil Data	
Location	Rameswaram, Tamil Nadu
Soil Type	Cohesionless
Dry Unit Weight	17 kN/m3
Angle of Inclination	22.4
Pile Pattern	Staggered pile pattern

The Pile Foundation for a 22- staggered arrangement is designed. The design includes values of maximum pile load, base resistance, shaft friction, shin friction. The settlement values have also been obtained. Using the results the Foundation Design using STADD Pro. is done.

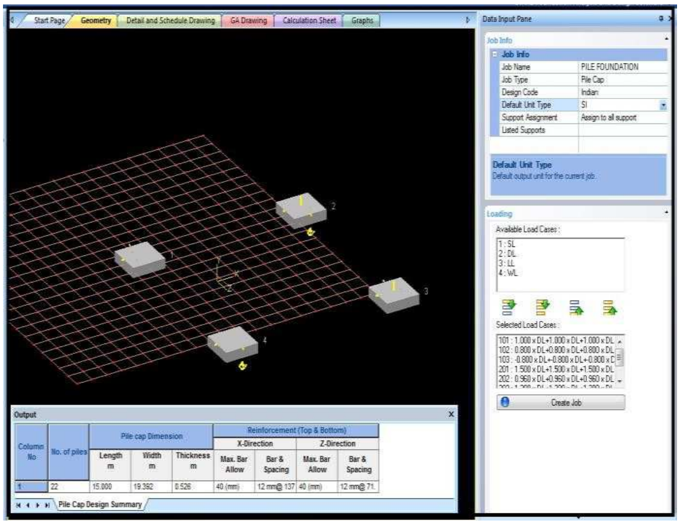

Figure 14: Pile Foundation Design

Figure 15: Load Combinations

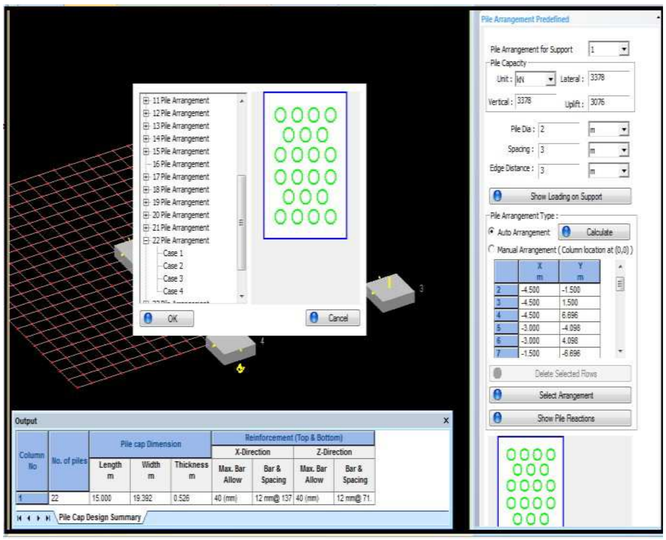

Figure 16: Pile Arrangement

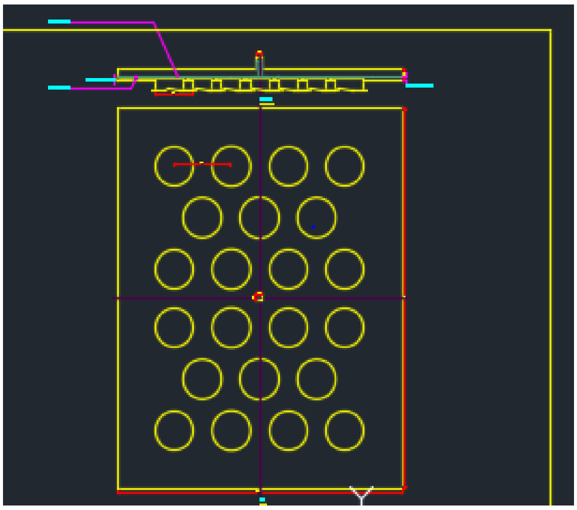

Figure 17: 22- Staggered Pile Arrangement

PILE ARRANGEMENT

Column Dimensions

Column Shape :	Rectangular
Column Length - X (Pl) :	0.305m
Column Width - Z (Pw) :	0.305m

Pedestal

Include Pedestal?	No
Pedestal Shape :	N/A
Pedestal Height (Ph) :	N/A
Pedestal Length - X (Pl) :	N/A
Pedestal Width - Z (Pw) :	N/A

Pile Cap Geometrical Data

Pile Cap Length P_{CL} =	15.000m
Pile Cap Width P_{CW} =	19.392m
Initial Pile Cap Thickness t_i =	0.300m

Pile Geometrical Data

Pile spacing P_s =	3.000m
Pile Edge distance e =	3.000m
Pile Diameter d_p =	2.000m

Pile Capacities

Axial Capacity P_P =	3378.000kN
Lateral Capacity P_L =	3378.000kN
Uplift Capacity P_U =	3076.000kN

Material Properties

Concrete f_c =	25000.004kN/m^2
Reinforcement f_y =	415000.070kN/m^2

Concrete Cover

Bottom Clear Cover CC_B =	0.050m
Side Clear Cover CC_S =	0.050m
Pile in Pile Cap PC_P =	0.075m

Figure 18: Results of Pile Foundation

CONCLUSIONS

Major loads to be considered for the design of jacket tower is wind load and current load which depends upon the zone of construction and the corresponding loads acting on the tower, platform and foundation is calculated as per is code regulations. Standard steel sections are used as tower members depending upon the loads acting on the jacket tower.

software for the calculated seismic and wind loads on the tower, platform, and the corresponding result is obtained. Type of foundation to be adopted for the tower is decided and designed based on the soil type, overturning moment and uplift pressure of the tower as per is code regulations.

From the above analysis, it is inferred that the wind is the predominate factor in the tower modelling than the seismic forces but the seismic effect cannot be completely dismissed as seen from the outcomes. The vertical members are more prominent in taking the loads of the tower than the horizontal and diagonal member, the member supporting the conductors at higher elevation are likely to have large influence on the behavior of the tower.

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5. *Dr.S.Nallayarsu, A book on Offshore Structures, Department of Ocean Engineering, Indian Institute of TechnologyMadras From the determined jacket tower parameters, a tower model is generated and analyzed using STAAD Pro Vi8 and SACS*