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DYNAMIC ANALYSIS AND GEOMETRY DESIGN OF FLOATING OFFSHORE WIND TURBINE (FOWTS)

Mr. Ashitosh Ramesh Sonavane[1], Prof. Dr. C.B. Pol[2]

[1] Student, Civil Engineering Department, walchand college of engineering, Sangli , Maharashtra India
[2] Professor, Civil Engineering Department, walchand college of engineering, Sangli, Maharashtra India

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Abstract –

The dynamic analysis of a floating offshore wind turbine is at the frontier of green energy/renewable energy, and this structure has a big potential to provide clean, inexpensive energy quickly. Offshore wind turbines continue to rise in popularity. The growing use of renewable energy and technology in recent decades has widened the scope of energy study.

The major analyses in this study include the dynamic analysis of a tension legged platform built for wave loading. This paper also includes the methods for designing a 10 megawatt (10MW) triple spar with mooring. While the anchoring mechanism holds the platform in place and prevents drifting. It is also based on experimental fatigue damage and the calculation of fatigue damage and structure service life with a comparison of characteristics of various types of floating offshore wind turbine platforms. Based on strip theory, the bently moses integrated software is employed. A specific line of study seeks to go beyond the technical in order to evaluate the practical, practicable, and actual possibilities for dynamic analysis of offshore floating wind turbines.

1. INTRODUCTION

The advancement of infa in wind power technology has resulted in massive wind turbines. So far, it has only been put on land and in shallow or low water levels. The floating offshore wind turbine outperforms the onshore turbine. The floating wind turbine at sea will not disrupt life on land. Furthermore, there is a better wind efficiency in the sea, which aids in the creation of renewable energy in an inexpensive manner. The tension legged platform is a floating platform that is combined with buoyancy forces as well as tensile pressures generated by tube links, to the Hull and anchor into the seabed.

Unlike the only spar type that requires offshore assembly. Also, to reduce the cost of floating offshore wind turbines. High fidelity design and modeling tools are required for wind energy to establish itself as a dependable technology. Despite being miles distant from the coast, floating offshore wind turbines are more efficient and provide better speed and consistency in any direction. They also have a lower environmental effect. The floating offshore wind turbines continue to be located further away from the local population. It also has greater construction area in the seas and oceans. As a result, we can generate more cleanly sustainable energy.

2. METHODOLOGY

Equation of motion is used for dynamic analysis of floating offshore wind turbine. This equation of motion based on finite element method.

Methodology of analysis and design for floating offshore wind turbine Bently modeler software is used this software is on advanced suite of hydrostatic software that provide for the accurate calculation and simulation of offshore floating system.

2.1 Different types of ocean structures

- TLP (Tension Leged Platform)
- Spar
- Semisubmersibles
- New generation of offshore structure
- Coastal structure

Here articulated tower are showing in below

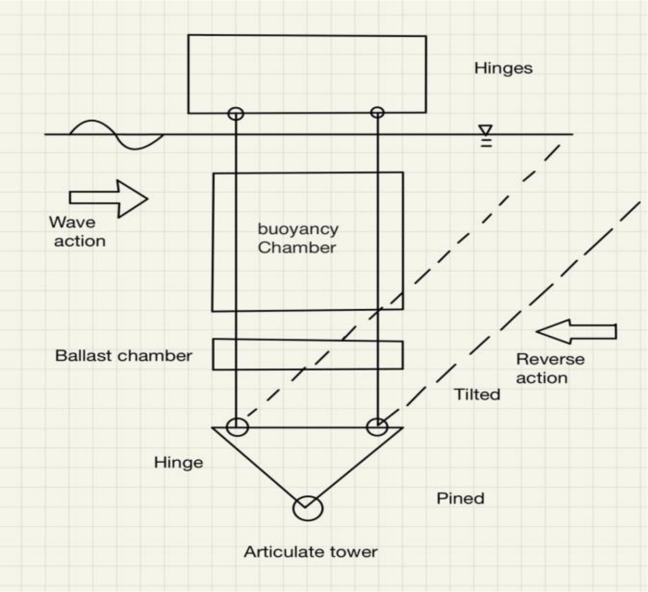

Fig -1: **Articulate Tower**

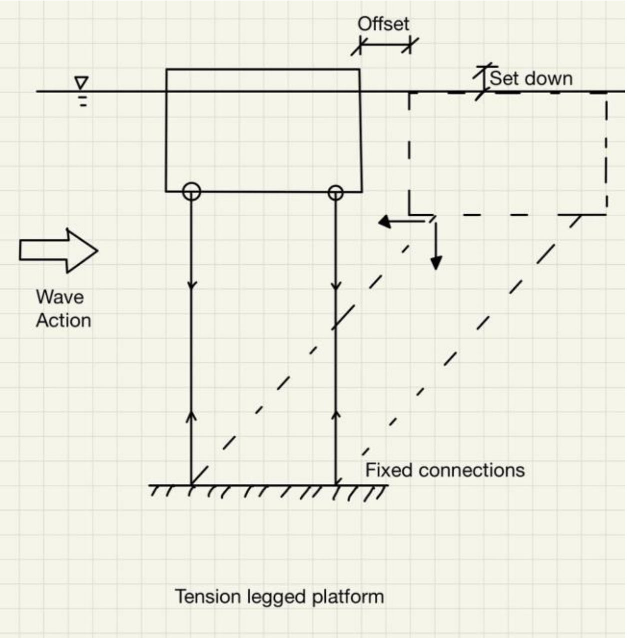

Fig -2: **Tension Leg Platform**

2.2 Dynamic analysis of "TLP"

Equation of motion the of TLP is formulated with classical theory.

$M\ddot{x} + C\dot{x} + kx = [F(t)]$

$[k]_{6\times6}$ = ? .... [derivation of stiffness matrix]

- TLP is a geometric design to suit deep water's
- It is a very special type of system which has got hybrid design capabilities which is otherwise addressed at compliancy,
- because of the classical separation "2 set of Degree of freedom", TLP is able to encounter the environmental loads at deep water depths,
- It has been found effective in terms of cost, and interms of performance.

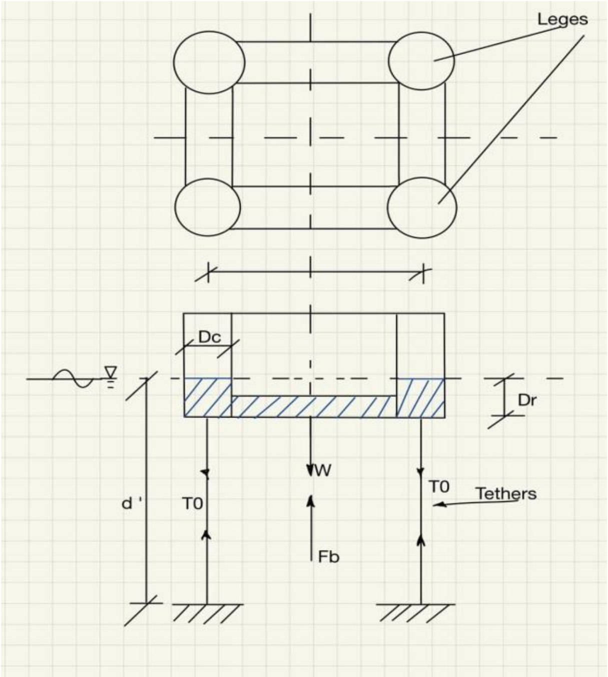

Fig -3: **T Static Equilibrium Diagram of TLP**

Design philosophy :- TLP

FB >> W

↓W + ↓To = FB↑ -static equilibrium

Equation of motion

$[M]\ \{x\} + [C]\ \{x\} + [k]\ \{x\} = \{F(D)\}$

Where,-

i = force in ith dof, due to unit displacement in jth DOF keeping other all DOF restrained

e.g. –

k11 - unit displacement 1 Degree & find force in 1 degree

k12 - unit displacement 2 Degree & find force in 1 degree

ΔT_1 = change in tension in each leg.

$= \{\sqrt{(x_1^2 + l^2)} - l\}\frac{AE}{l}$

$= \{\sqrt{(x_1^2 + l^2)} - l\}\frac{AE}{l}$

$k_{11}x_1$ (force per and displacement) (N/m)

$k_{11}x_1 = 4(T_o + \Delta T_1)\ \text{Sin}\ \gamma x$

$\text{Sin}\,\gamma x = \dfrac{x_1}{\sqrt{x_1^2 + l^2}}$

$k_{11} = \dfrac{1}{x_1}\, 4\,(T_o + \Delta T_1)\,\text{Sin}\,\gamma x$

$= 4\,\dfrac{(To + \Delta T1)}{x^2 + l^2}$ (N/m)

$K_{21} = 0$ (no motion /displacement along y axis)

$K_{41} = 0$ (no moment about x axis)

$K_{41} = 0$ (no rotation about 2 axis due to symmetry)

Equilibrium in “heave direction

$K_{31}\,(\Delta) = \{T_o\,(\text{Cos.}\,\gamma x) + \Delta T_1\ \text{Cos}\ \gamma x - T_0\,\}\,4$

$\text{Cos.}\,\gamma x = \dfrac{l}{\sqrt{x^2 + l^2}}$

$K_{31} = \dfrac{4}{\Delta}\, T_o\,\{(\text{Cos.}\gamma x - 1) + \Delta\ \text{Cos.}\gamma x\}$

K_{51} = K_{11} h (Restring moment)

2) equation of equilibrium in sway direction

$K_{12} = 0$

$K_{52} = 0$

$K_{62} = 0$

$K_{22} = 4\,\dfrac{(To + \Delta T1)}{\sqrt{x^2 + l^2}}$

$K_{32} = \dfrac{4}{\Delta}\,\{T_o\ (\text{Cos.}\gamma x - 1) + \Delta\ \text{Cos.}\gamma y\}$

$K_{42} = K_{22}h$

3) Equation of equilibrium in heave direction heave dof

$K_{13} = 0$

$K_{23} = 0$ No force

$K_{43} = 0$ { · no force along ly $K_{23} = 0$}

$K_{53} = 0$ {∴ $K_{13} = 0$}

$K_{63} = 0$

K_{33} = (draft) (can not be zero)

$K_{33} = (x_3) = 4\left(\dfrac{AE}{l}\right) + \left(\dfrac{\pi\, DC^2}{4}\ \rho w\ \ g\right) 4\}\, x_3$

Roll dof

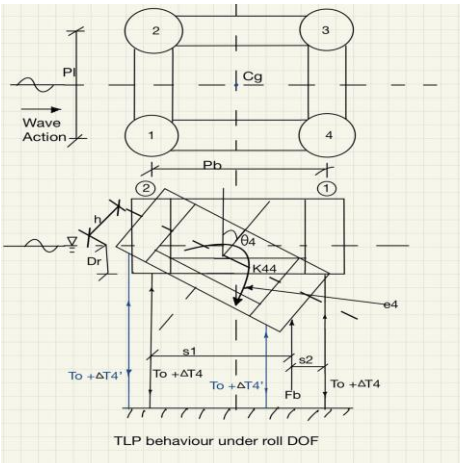

Fig -4: **TLP behavior under roll dof**

e_4 = extensity of Cg initially for perfect balance system the Cg and centre and bouncy remain same

$S_1 = \dfrac{Pl}{2} + e_4$

$S_2 = \dfrac{Pl}{2} - e_4$

$K_{14} = 0$

$K_{24} = 0$

Change in pretension each leg

$\Delta T_4 = \left(\dfrac{AE}{l}\right)\dfrac{Pl}{2}\ \cos\theta 4 = \Delta[T_4c]$

ΔT_4= change in tension or change in pretension in near leg.

$\Delta T_4'$ = Change in pretension in the further leg.

$K_{34} = \dfrac{2\,(\Delta T_0 + \Delta T_4)}{\theta 4}$

$K_{44} = \text{Fb}\, e_4 + 2\,(T_o + \Delta T_4)\,(S_1 - e_4) - 2\,(T_o + \Delta T_4)\,(S_1 + e_4)$

K_{44} = alter native

$\{4\left(\dfrac{\pi D^2}{4}\right)\rho\omega\ g\}\ Pl\ \sin\theta 4 + \dfrac{4}{\theta 4}\, To\,\lambda\ \sin\theta 4 + 4\left(\dfrac{AE}{l}\right)\dfrac{Pl}{2}\ \cos\theta 4$

$K_{54} = 0$

$K_{64} = 0$

5) Pitch dof

$K_{15} = 0$

$K_{25} = 0$

$K_{35} = \frac{2}{\theta 4} (\Delta T\Delta_5 + \Delta T_5)$

$K_{55} = \{4 (\frac{\pi D^2}{4})\rho\omega g\} Pb \sin\theta 4$

$+ \frac{4}{\theta 5}$ To $\lambda \sin\theta 5 + 4 (\frac{AE}{l})$

$\frac{Pb}{2} \cos\theta 5$

Yaw dof -

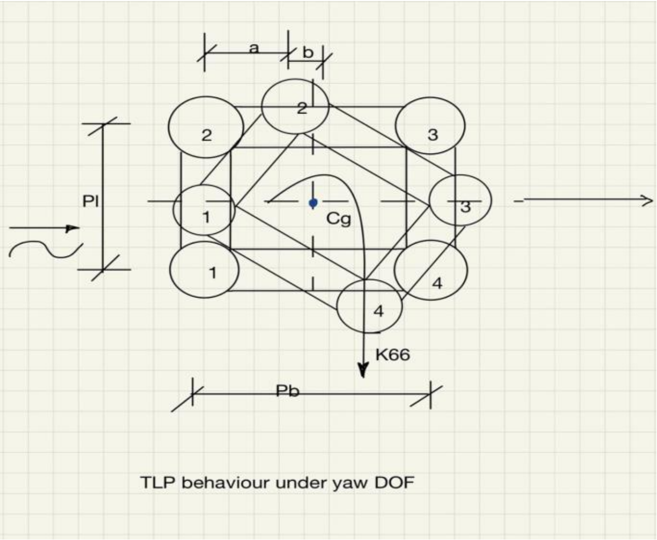

Figure-5 TLP behavior under yaw dof

$l_1 = \sqrt{l^2 + \theta_6^2 (a^2 + b^2)}$

$\Delta T_6 =$ Change in tether length

$\Delta T_6 = \frac{AE}{l} (l_1 - l)$

$K_{16} = 0$

$K_{26} = 0$

$K_{46} = 0$ (∵ K_{26} is zero)

$K_{56} = 0$ (∵ K_{16} is zero)

$K_{36} = (\theta_6) = 4 T_o \left(\frac{l}{l_1} - 1\right) + 4 \Delta T_6 (\frac{l}{l_1})$

$K_{66} = 4 (T_0 + \Delta T_6) (\frac{a^2 + b^2}{l_1}) (\theta_6)$

2.3 Return Period

$\bar{x}$&$\bar{\delta}$ release, which is statwrary stochastic process of f(t).

$f(t) = \{f_i \ f_2 ....\}$

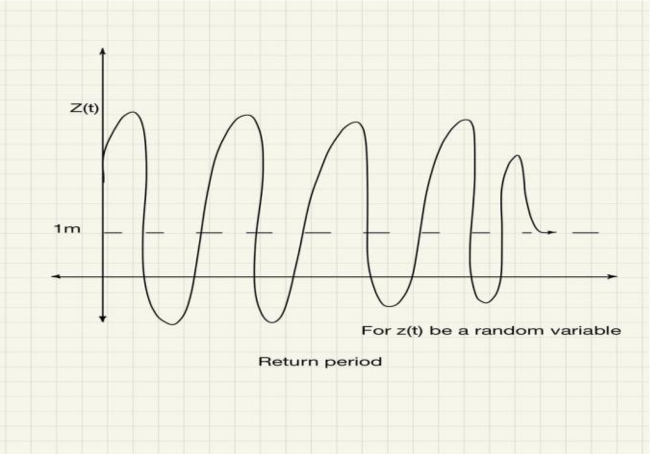

Fig -6: Return Period Diagram

2.4 Fatigue Damage

Fatigue Estimation of off-share platform.

Fatigue Estimate

Triceratops

Dynamic tether tension variation

Fatigue is low amplitude, large cycle issue

Off-share platform- have fatigue issue

Methodology of fatigue damage

Variation of stress time history

↓

Rain flow counting algorithm

↓

Estimated Damage = n/N for total number & stress bins

↓

Service life and structure = 9.47 years

3. RESULTS

Geometric Design

Geometric design of modules are designed in Bently moses modeler and successfully analyzed by Bently moses executive.

Bently modeler is integrated software for FOWT platforms and it is based on strip & FEM (finite element methodology).

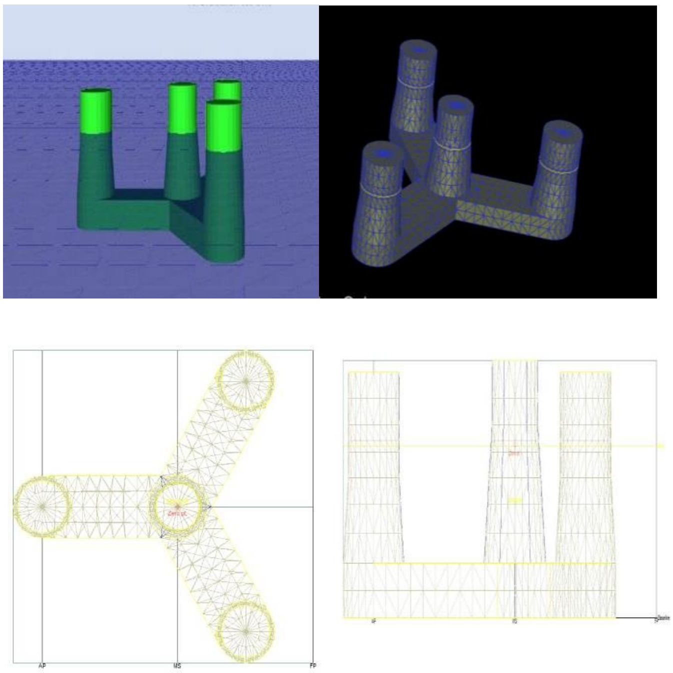

Fig -7: **Geometric design of TLP**

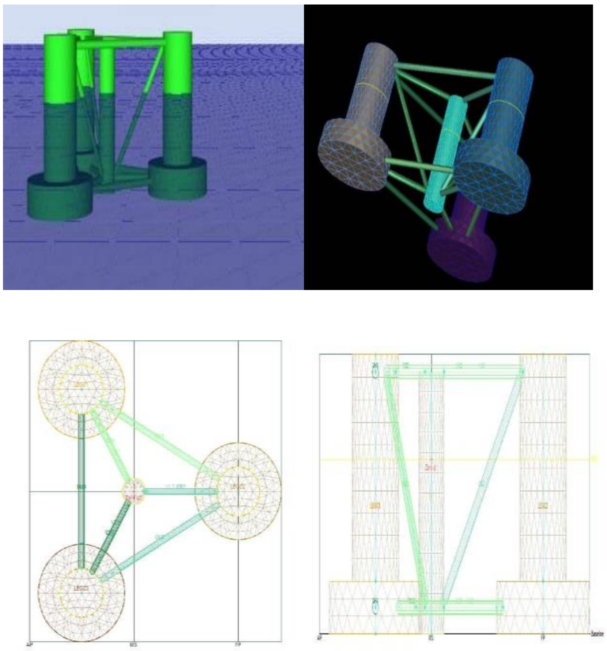

Fig -8: **Geometric design of Semisubmersible platform**

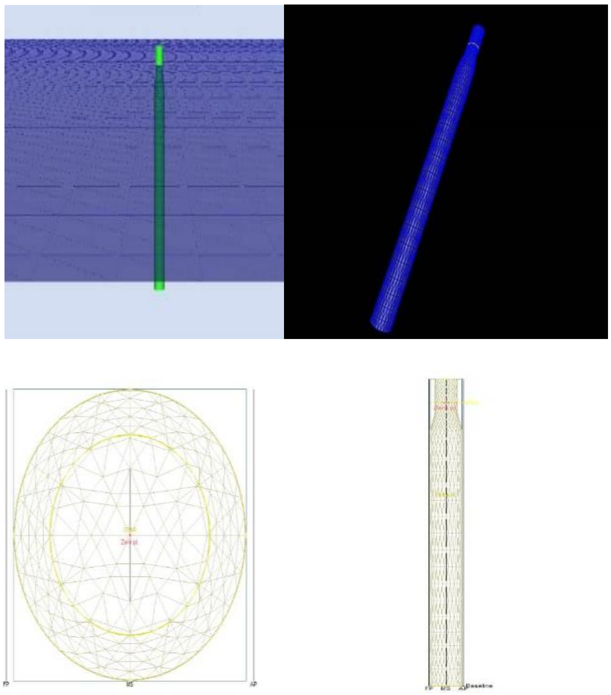

Fig -9: **Geometric design of Spar platform**

Table.1 Comparison Between different parameters of modules

Sr. No.	Parameters	TLP (Tension legged platform)	Semisubmersible Platform	Spar Platform
1	Design	Simple design	Complex design	Simple as compare to TLP
2	Stability	Taut moorings	Hydrostatic	Ballast
3	Motion	Rigid dof Flexible/soft dof surge, sway & yaw	Rigid dof roll and pitch Flexible/soft dof surge, sway, heave & yaw	Rigid dof roll and pitch Flexible/soft dof surge, sway, heave & yaw
4	Mooring	Tout mooring	Catenary mooring or semi-tout mooring	Catenary mooring or semitout mooring
5	Fatigue	Lower fatigue loads	Lower fatigue loads	Higher fatigue loads in tower

6	Transportation	easy to tow	easy to tow	spar buoy platform is loaded in ship then transport to the site location
7	Installation	more complex	Easy Installation	Installation as compare to Semisubmersible
8	Commissioning & decommissioning	Easy	Easy	Hard as compare to TLP and Semisubmersible
9	Advantage	Lower wave induced motion	Most viable in deep waters	Lower wave induced motion
10	Disadvantage	Higher mooring cost	Higher wave induced motion	Higher fatigue loods in tower not suitable for shallow water
11	Cost	Costly	Less costly as compare to TLP	Costly as compare to Semisubmersible
12	Fabrication	More complex	More complex	Potentially simple

3. CONCLUSIONS

In past decodes years static analysis is used to analyzed floating offshore platforms (W + To = FB) This equilibrium equation is used to analyzed structure but it gave accuracy results, then after further studies and researches "Dynamic analysis gives more accurate results it is a classical theory based on finite element method. Any type of platform like TLP (Tension leged platform), spar and semisubmersible platforms response analyzed in terms of 6 dof displacements and rotation surge, sway, heave, roll, pitch and yaw.

From the results

i. Stiffness matrix it is fundamental derivation for the development of geometry.

ii. Mass matrix it is assumed as structure mass is lumped at each dof.

iii. Damping matrix applied uniformly distribution for the entire structure by using bently moses software.

iv. Design of floating offshore wind turbine platforms is designed by using bently moses software.

v. This software is based on hydrostatic, hydro dynamics strip theory and by using STANDARD DNVGL-ST-0119 that provides for accurate calculation and simulation of offshore floating system.

vi. From studies and researches comparison in different parameter's of different types in floating platforms the most suitable type of platform for wind turbine is semisubmersible platforms compare to spar & TLP.

vii. Important Feature that must be considered is effect of wind on the turbine, that provide on inclination of the turbines tower and reduction of energy produced.

viii. One- diamensional model for an a ideal rotor considered aerodynamic thrust is force acting perpendicular on the rotor.

ix. One-diamensional model for an a ideal rotor considered aerodynamic thrust is force acting perpendicular on the rotor.

x. Because of this action of inclination and aerodynamic thrust platform requires higher stability

xi. Higher stability platforms are TLR, SPAR and semisubmersible. TLP stability is very as compare to semisubmersible & spar but cost of mooring system is very higher which is not suitable for floating offshore wind turbine.

xii. Spar type platform also have good stability but higher loads in tower.

xiii. The most suitable type of platform is semisubmersible platform, this platform also have good stability which is depend upon hydrostatic and by using new mooring system like semi-taut mooring.

xiv. Semi taut mooring it is a combination of category and taut mooring which gives higher stability to the platform as compare to only category type mooring.

xv. Semisubmersible platform we can easily low, transportation, installation, commissioning, decommissioning easily and also low fatigue damage acts on the structure.

FUTURE SCOPE

More work can be done in future to improve the understanding of turbine and they are listed below.

1. Trying to change the ocean structure can lead to amazing results.

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About the Authors

Mr. Ashitosh Ramesh Sonavane.

Student, Civil Engineering Department, walchand college of engineering, Sangli , Maharashtra India

Prof.Dr. C.B. Pol

Professor, Civil Engineering Department, walchand college of engineering, Sangli, Maharashtra India