# Fatigue Life of Wind Turbine Foundation from Elastic Fem Considering Multiaxial Plasticity

**Sincy Andrews[1] Shwetha Saju[2]**
[1]PG Student [2]Assistant Professor
[1,2]Department of Civil Engineering
[1,2]Christ Knowledge City

*Abstract*— Steel embedded rings were commonly used in turbines foundation which are given at onshore. This embedded steel rings help to resist the uplift force as well as the compressive force. Mainly the properties of the concrete at the interface of embedded ring varies with respect to time. Also the strength will affect. This is commonly due to the effects of cyclic load which act on the structure. In this paper, the numerical study of fatigue life of onshore concrete wind turbine foundation is done. The major study is based on the different grades of concrete and the thickness of the embedded ring.

***Key words:*** Fatigue, Wind Turbine Foundation, Cyclic Loading, Finite Element Model

## I. INTRODUCTION

Steel embedded rings were commonly used in turbines foundation which are given at onshore. Generally the wind turbine is designed so that it can retain for almost 20 years. When considering the economy, it would be the best. The fatigue of concrete in the compressive zone have more importance. Also the effect of fatigue in the compressive zone reflects the overall performance of the structure. The embedded ring attached to the concrete as specially designed so as to resist the compressive as well as the uplift force. Due to several mechanisms like shrinkage and repeated cyclic loading, crack is emerged in the concrete on both side of the bottom flange. The initial crack remains in the structure even after the load is removed. This may leads to a reduction in the shear resistance capacity. The sum of bearing capacity of concrete in the compressive zone above and under the bottom flange is assumed as the uplift capacity of the structure.

## II. FINITE ELEMENT ANALYSIS

Mainly there are several types of damages are present in existing foundation. Fatigue damages in structure is generally due to the connections in the structure .Here the fatigue damage is caused by the connection provided in between the embedded ring and concrete. The basic method of evaluating structural fatigue behaviour involves S-N curves, plots of stress range S against the number of cycles to fatigue N [1]. They only apply to fatigue life estimation of a single concrete element subjected to a constant-amplitude stress level. Based on the location of wind turbine weather it is onshore or offshore stress as well as strain changes along the periphery of bottom flange of embedded ring. Implementing design method of S-N curves, which ignores radial and circumferential stress gradients, would result in conservative results in fatigue assessments of wind turbine foundations [1]. Moreover, information on strain is not included in S-N curves, and therefore the evolution of strain and stress of foundations over the lifetime of the structures cannot be obtained [2]. The fatigue behaviour of concrete is reflected by the increase of plastic strain and the reduction of modulus. The aim of this study was to develop, validate and utilize an analytical tool for predicting the structural response of wind turbine foundations in the long term. Numerical modelling based on the commercial software ANSYS is used to define the initial stress state of the foundation at the section level [3]. The resultant stress distributions are compared with those yielded by fatigue analysis in the loading phase of the first cycle. The dimensions of the foundation and the embedded ring. The entire FE model comprises concrete, reinforcing bars and an embedded ring [1]. The purpose of FEM is to calibrate the fatigue algorithm; therefore, the foundation should be modelled with defects. Many studies have reported that, after several years of operation, cracks emerge on both sides of the bottom flange and propagate over a considerable length towards the outside [2]. It is assumed that concrete in the anchorage zone loses tensile resistance and the reinforcing bars carry anchor tension forces [5].

The discontinuity, is created as a failure surface located beneath the bottom flange of the embedded ring. The reinforcing bars arranged in the foundation are large in quality and low in stress level [1]. Thus, the fatigue calculation for reinforcing bars is not necessary. Overall, the model is simulated in light of the nonlinearity of the material [5]. The pedestal, spreading footing and embedded ring are modelled with solid 65 elements. The reinforcing bars are embedded in the concrete assuming a perfect bond between the steel and the concrete [2]. The interaction between the discontinuity surfaces and that between the concrete and the embedded ring are modelled as surface-to-surface contact [1]. Displacements and rotations in all directions at the nodes of the bottom concrete surface were prevented concerning it would not influence the results. Loads and displacements of tower are constrained to prevent any effect on the results. The embedded ring and reinforcing bars are modelled as elastic materials [3]. The density q of steel is 7850 kg/m3, the elasticity modulus E is 206 GPa, and Poisson's ratio t is 0.2 [4]. A damage plasticity model is used for the stress-strain relations in the concrete. The compressive strength fc is 23.4 MPa, the tensile strength ft is 2.2 MPa, the young modulus E is 31.5 GPa, the density q of concrete is 2400kg/m3 [1]. The concrete used are of grade M20, M25, M30.

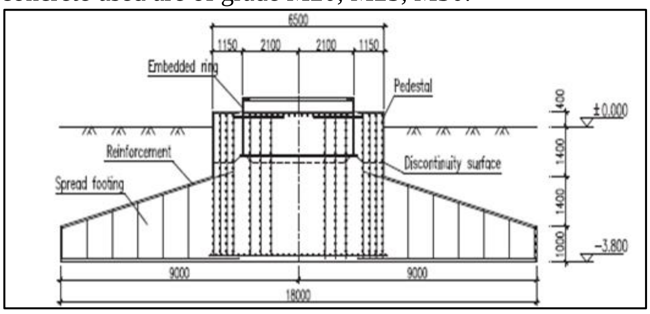


Fig. 1: Cross section of the foundation.

 

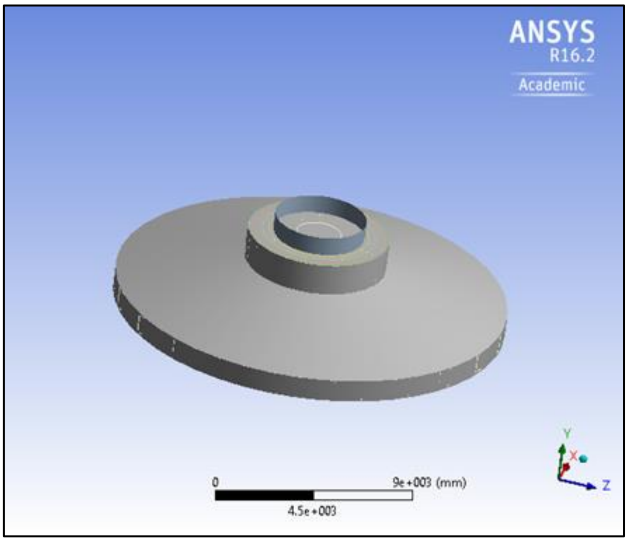


Fig. 2: Model of machine foundation

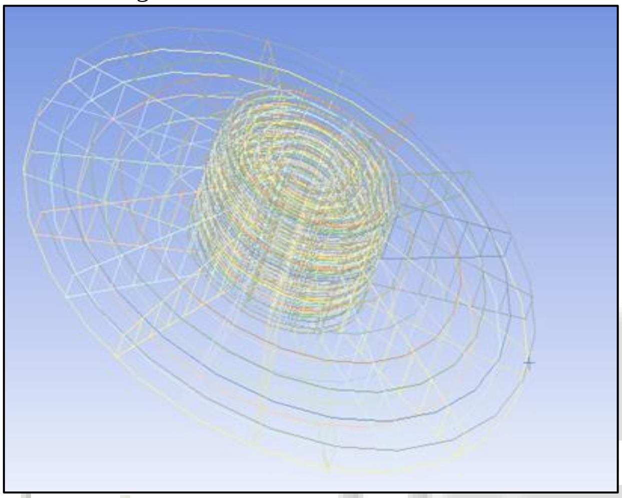

Fig. 3: Reinforcement of the foundation

## III. CONCRETE M20

The analysis were done by considering ordinary Portland cement concrete with a grade M20 where it has a compressive strength of 20N/mm2. The mix proportion for M20 concrete is 1:1.5:3 (cement: fine aggregate: coarse aggregate). Also the S-N curve varies with the grade of concrete.

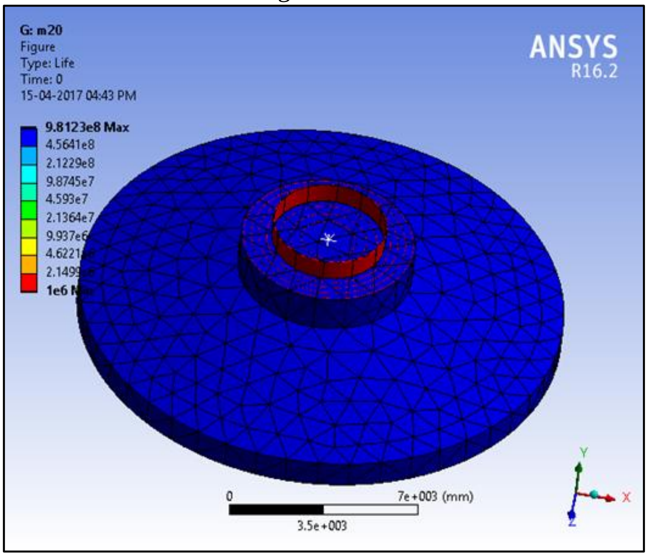


Fig. 4: Fatigue Life

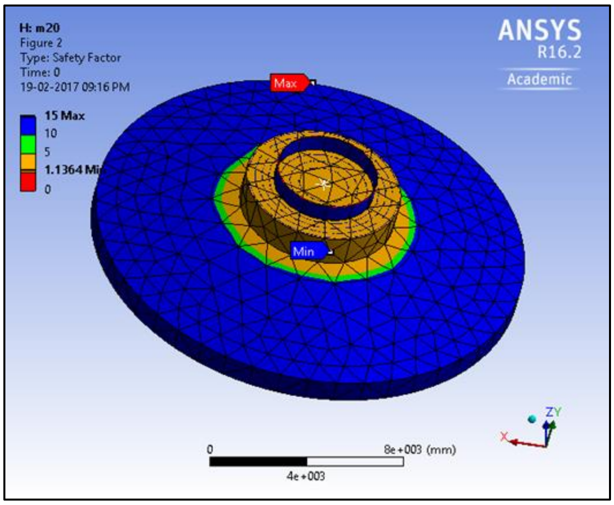


Fig. 5: Safety Factor Of The Model

The fatigue life of the M20 grade concrete is obtained as 9.8123e8 no of cycles as the maximum life and 1e6 no of cycle as the minimum life and maximum value for safety factor is 15.

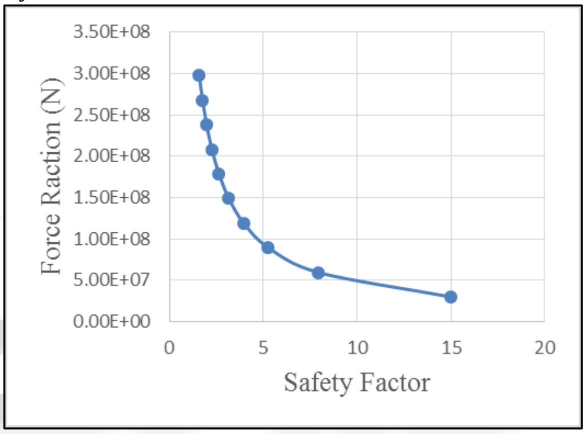


Fig. 6: Force vs safety factor

The force vs safety factor it can be visualized that safety factor goes on decreasing when force reaction increases.

## IV. CONCRETE M25

The analysis were done by considering ordinary Portland cement concrete with a grade M25 where it has a compressive strength of 25N/mm2. The mix proportion for M25 concrete is 1:1:2 (cement: fine aggregate: coarse aggregate). Also the S-N curve varies with the grade of concrete.

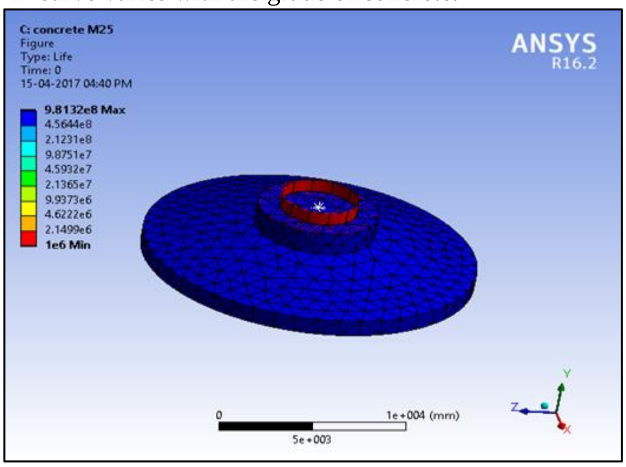


Fig. 7: Fatigue Life

 

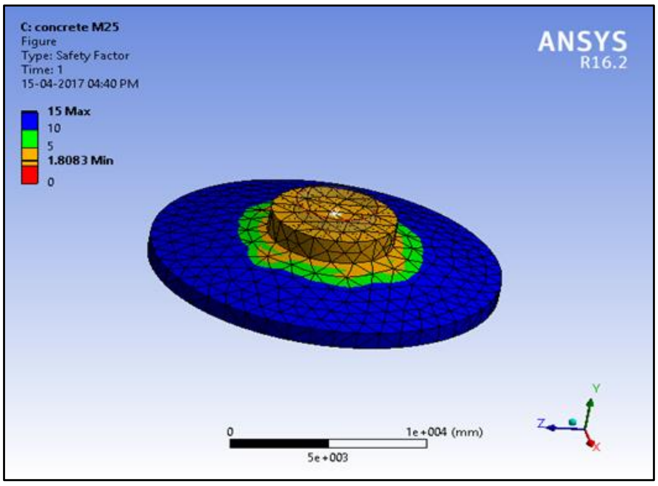


Fig. 8: Safety Factor Of Model

The fatigue life of the M20 grade concrete is obtained as 9.8132e8 no of cycles as the maximum life and 1e6 no of cycle as the minimum life and maximum value for safety factor is 15.

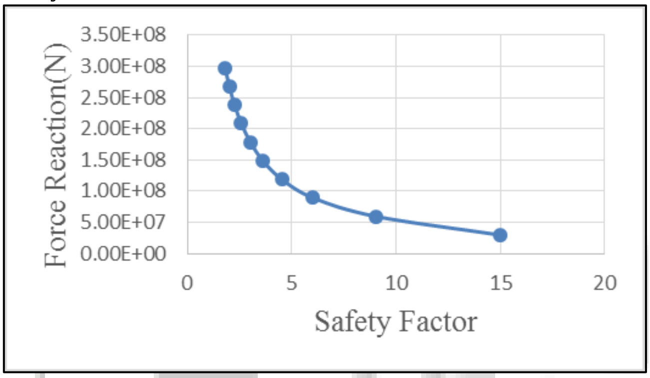


Fig. 9: Force Vs Safety Factor

It can be visualized that safety factor goes on decreasing when force reaction increases.

## V. CONCRETE M30

The analysis were done by considering ordinary Portland cement concrete with a grade M30 where it has a compressive strength of 30N/mm2. The mix proportion for M30 concrete is 1:1:2 (cement: fine aggregate: coarse aggregate). Also the S-N curve varies with the grade of concrete.

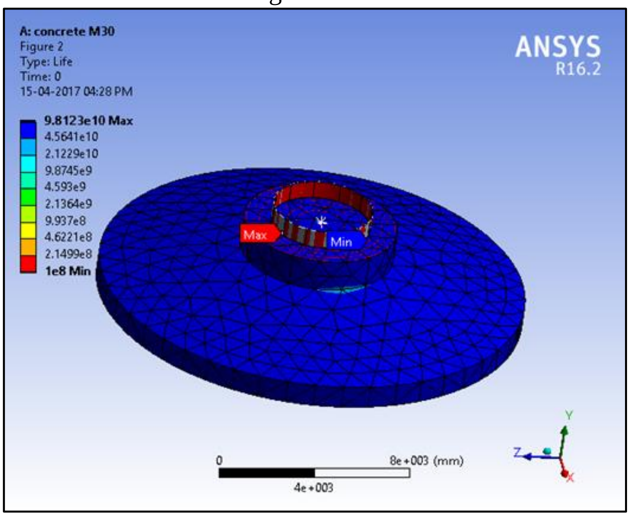


Fig. 10: Fatigue Life

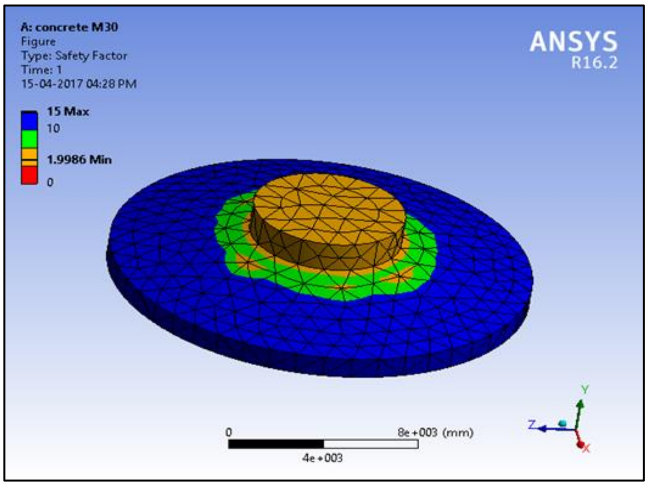


Fig. 11: Safety Factor

The fatigue life of the M30 grade concrete is obtained as 9.8132e10 no of cycles as the maximum life and 1e8 no of cycle as the minimum life and maximum value for safety factor is 15.

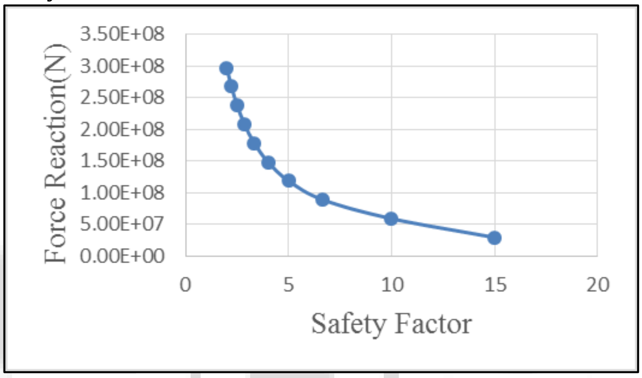


Fig. 12: Force Vs Safety Factor

It can be visualized that safety factor goes on decreasing when force reaction increases.

## VI. CONCLUSION

The fatigue behavior of concrete in the anchorage zone of a wind turbine foundation subjected to a combination of equivalent fatigue loads is studied in this paper. The maximum fatigue life is for M30 grade concrete.

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