International Journal of Engineering Research and Development
e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 12, Issue 10 (October 2016), PP.34-39

Design of Shallow Foundation under Downward, Uplift and Side Thrusts Loadings for Transmission Lines Tower.

Prof. R.G. Bade[1], Mr. Zeeshan Qureshi[2], Mr. Shrikant Yadav[3].
[1]*Assistant Professor At Anjuman College Of Engineering And Technology, Department Of Civil Engineering, Nagpur (India).*
[2]*Student Of Graduation Programme In Department Of Civil Engineering At Anjuman College Of Engineering And Technology, Nagpur (India).*
[3]*Student Of Graduation Programme In Department Of Civil Engineering At Anjuman College Of Engineering And Technology, Nagpur (India).*

Abstract:- India has a large population all over the country and the electricity supply is need of this population creates requirements of a large transmission and distribution. In transmission line towers, the tower legs are usually set in concrete which generally provides good protection to the steel.

In transmission line towers, foundation plays an important role in safety and satisfactory performance of the structure as it transmits the load from structure to earth. In present study, a typical 220 KV double circuit transmission tower is considered, for designing the foundation manually with respect to loadings viz downward, uplift and side thrusts. A proposed site was considered situated on the banks of river analyzed and design the transmission tower in STAAD PRO and on the basis of analysis results and soil investigation reports the three forces are validated in the designing of foundation manually.

In this paper, the tower foundation is designed manually with reference to CBIP manual (central board of irrigation and power) and a methodology is obtained for designing the foundation as per conditions malleably.

Objectives
- To study the types of foundation as per the desired loadings on different types of soil
- To study the designed parameters and checks required for designing the transmission tower foundation as per CBIP manual.
- To designed the safe and durable foundation on the proposed site near kanhan river, Nagpur, India.

Keywords:- transmission lines, foundation.

I. INTRODUCTION

Foundations of any structure plays on important role in safety and satisfactory performance of the structure as it transmits the loads from structure to earth. The towers legs are usually set in concrete which generally provides good protection to the steel. Without having a sound and safe foundation, structure cannot perform the functions for which it has been designed. Therefore, the importance of foundation need not to be over emphasized.

The sizes of transmission line tower are increasing because of the present day high, extra high and ultra-high voltage transmission, resulting in heavier loads and as such requiring bigger and heavier foundations. A large number of foundation are normally required in any transmission line project. Thus, the total cost of foundation in a transmission line project becomes quite substantial. Apart from the financial aspects, past records show that failures of tower foundations have also been responsible for collapse of towers. These failures have usually been associated with certain deficiencies either in the design which certainly depends on the types of loadings on the foundation or classification or construction of foundation. Many times, foundations cast are over safe because of inappropriate classification, resulting in wastage of resources. From engineering point of view, task of design and selection of most suitable type of tower foundation is challenging because of the variety of soil conditions encountered enroute the transmission line and remoteness of construction sites. The foundations in various types of soil have to be designed to suit the soil conditions of particular type.

A. Types of Loads on Foundations:

The foundations of towers are normally subjected to three types of forces. These are:

- **i.** The compression or download thrust;
- **ii.** The tension or uplift;
- **iii.** The lateral forces or side thrusts in both transverse and longitudinal directions.

B. Basic Design Requirements:

To meet the varying needs in respect of soil conditions and loadings quantum several types of foundations have been used for the transmission line towers. Design philosophy of tower foundation should be closely related to the principles adopted for the design of the tower which the foundation has to support. A weak or unsound foundation can make a good tower design useless. Functionally, the foundation should be strong and stable. It should take care of all the loads such as dead loads, live loads, wind loads, seismic loads, erection loads, etc. causing vertical thrust, uplift as well as horizontal reactions. For satisfactory performance, it should be stable and structurally adequate and be able to transmit these forces to the soil such that the limit soil bearing capacity are not exceeded.

C. Soil Parameters:

For designing the foundations, following parameters are required:

i. Limit bearing capacity of soil;
ii. Density of soil; and
iii. Angle of Earth frustum.

These soil properties are normally obtained either by conducting in-situ or laboratory test on soil samples collected from the field during Soil Investigation or from available testing record of the area.

D. Soil Investigation:

The design of tower foundation is fully dependent upon condition of soil that will support the foundation and the nature of loadings. It is, therefore, necessary to investigate the soil for engineering properties. There are number of procedures for collection of soil data covered in various Indian Standard Codes of practice like IS: 1892, IS: 1888, IS: 2131 etc. and standard books on Soil Mechanics and Foundation Engineering. Selection of anyone of these depends on the suitability and merits of the procedure for a given soil condition.

E. Types of Foundation:

Depending upon the ground water table and type of soil and rock, the foundation can be classified as follows:

i. **Normal Dry Soil Foundations:**
ii. When water table is below foundation level and when soil is cohesive and homogeneous up to the full depth having clay content of 10 – 15%.
iii. **Wet Soil Foundations:**
iv. When water table is above foundation level and up to 1.5m below ground level. The foundations in the soils which have standing surface water for a long period with water penetration not exceeding 1.0 m below ground level (e.g. paddy fields) are also classified as wet foundations.
v. **Partially Submerged Foundation:**
vi. When water table is at a depth between 1.5m and 0.75m below ground level and when the soil is normal and cohesive.
vii. **Fully Submerged Foundation:**
viii. When water table is within 0.75m below ground and the soil is normal and cohesive.
ix. **Black Cotton Soil Foundation:**
x. When the soil is cohesive having inorganic clay exceeding 15% and characterized by high shrinkage and swelling property (need not be always black in colour).
xi. **Partial Black Cotton Foundations:**
xii. When the top layer of soil up to 1.5m is Black Cotton and thereafter it is normal dry cohesive soil.
xiii. **Soft Rock/Fissured Rock Foundations:**
xiv. When decomposed or fissured rock, hard gravel or any other soil of similar nature is met which can be executed without blasting. Under cut foundation is to be used at these locations.
xv. **Hard Rock Foundations:**
xvi. Where chiselling, drilling and blasting is required for excavation.

II. LITERATURE REVIEW

2.1 Experimental study on corrosion of transmission line tower foundation and its rehabilitation ISSN 2010
2.2 Reliability based design of foundation for transmission line structures (New York) (drilled and spread foundation)
2.3 Analysis and research for uplift mechanism on foundation of transmission line towers in expansive soil.

II. TEST CONDUCTED

A. SOIL TEST REPORT

Site Proposed- Kanhan (Niri), Nagpur

Properties	Sample identification & test results	
	Core cutter 1	Core cutter 2
Moisture content - %	12.34	9.36
Bulk density – gm/cc	1.660	1.683
Dry density – gm/c	1.477	1.538
Unconfined compressive strength – Mpa	0.2	-
Cohesion – kg/sq.cms C	-	0.446
Angle of internal friction – degree	-	14.4
Initial void ratio	-	0.714
Compression index - cc	-	0.215
Specific gravity	-	2.622

B. Net Safe Bearing Capacity (IS 6403 : 1981)

Qd = C. Nc. Sc. Ic. dc + q(Nq-1). Sq. dq. iq + 0.5. B. Y. Sy. Ny. Dy. Iy. w

Where,

Qd	Net Ultimate Bearing Capacity
C	Cohesion = 4.46 tons / sq.m
Ø	Angle of internal Friction = 14.4 degree
Y	Average Density of Overburden 1.6105 tons / Cu.m
Nc, Nq, Ny	Bearing Capacity Factors on Ø (10.664, 3.7636, 2.4784 respectively)
Sc, Sq, Sy	Shape Factors (1.3, 1.2, 0.8 respectively)
ic, iq, iy	Inclination Factors 1for each
dc, dq, dy	Depth Factors (1.0702, 1.0351, 1.0351 respectively)
q	Effective Surcharge at 3.5m below G.L. = 8.0525 tons / sq.m
w	Water table Corrections 0.5
B	Width of footing 2m assumed

Qd = 4.46 x 10.664 x 1.3 x 1 x 1.0702 + 8.0525 x (3.7636-1) x 1.2 x 1.0351 x 1 + 2 x 1.6105 x 0.8 x2.4784 x 1.0351 x 1 x 0.5

Qd = 95.46496 tons / sq.m

III. RESULTS AND DISCUSSIONS

A. Design of Foundation (CALCULATIONS)

220 KV D/C Transmission lines (all the calculations are on the basis of CBIP manual)

Tower type: “DB”

Design loads (limiting/ultimate) (inclusive of overload factor 1.2)

Description	Normal Condition (Reliability) (Kgs)	Broken Wire Condition (Security) (Kgs)
Down thrust	16604	17255
Uplift	14194	14982
Side thrust (t)	2693	3018
Side thrust (l)	2695	2999

Tower slope:

Θ = 9.22

Tan θ = 0.16225

True length = 1.013

Soil/ rock data:

Unit weight of dry fissured rock = 1700 kg/cu,m

Specification	Quantity	Checks			
Volume of concrete (cu.m)	9.868	Uplift		Bearing capacity	
Dry soil volume (cu.m)	95.832	NC	BWC	NC	BWC
Wet soil volume	Nil	11.32	11.29	2230.1	3277.75

Over load due to concrete (kg)	Compression	Uplift			kg/m^2	kg/m^2
	7069	6299	>1 Hence safe		< 95469.6 kg/m^2 Hence safe	

Limit bearing capacity (fissured rock locations): 62500 kg/sq.m

B. Design of dry type foundation

C. Design of chimney

Sr.no	**Specification**	**Conditions**			
		Normal		**Broken wire**	
		Mux1	Muy1	Mux1	Muy1
1	Compression with bending	659.1 kN-m	659.1 kN-m	659.1 kn-m	659.1 kn-m
1.1	Moment at the root of chimney	Mux	Muy	Mux	Muy
		49.22 kn-m	49.27 kn-m	57.61 kn-m	57.12 kn-m
		$\left(\frac{MUX}{MUX1}\right)^{\alpha n} + \left(\frac{MUX}{MUX1}\right)^{\alpha n}$ $\left(\frac{49.22}{659.1}\right)^{1} + \left(\frac{49.27}{659.1}\right)^{1}$ =0.15 < 1 Therefore, ok		$\left(\frac{MUX}{MUX1}\right)^{\alpha n} + \left(\frac{MUX}{MUX1}\right)^{\alpha n}$ $\left(\frac{57.61}{659.1}\right)^{1} + \left(\frac{57.12}{659.1}\right)^{1}$ = =0.17 < 1 Therefore, ok	
2	Tension with bending	700.3 kN-m	700.3 kN-m	700.3 kN-m	700.3 kN-m
2.1	Moment at the root of chimney	49.22	49.27	57.61	57.12
		$\left(\frac{MUX}{MUX1}\right)^{\alpha n} + \left(\frac{MUX}{MUX1}\right)^{\alpha n}$ αn = 1 (for tension bending always) = $\left(\frac{49.22}{700.3}\right)^{1} + \left(\frac{49.27}{700.3}\right)^{1}$ = 0.14 < 1 Therefore, ok		$\left(\frac{MUX}{MUX1}\right)^{\alpha n} + \left(\frac{MUX}{MUX1}\right)^{\alpha n}$ αn = 1 (for tension bending always) = $\left(\frac{57.61}{700.3}\right)^{1} + \left(\frac{57.12}{700.3}\right)^{1}$ = 0.16 < 1 Therefore, ok	

D. Design of Base Slab

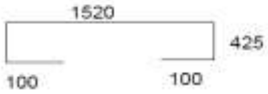
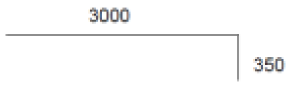
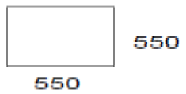
Design Bearing Pressure

=0.0197 N/mm^2

Sr.no	**Specification**	**At section XX**	**At section YY**
1	Effective depth	476 mm	276 mm
2	Compression reinforcement		
	Bending moment	188.5 kN-m	108.85 kN-m
	AST required	2931.83 mm^2	1121.75 mm^2
3	Uplift reinforcement		
	Bending moment	13.26 x 10^6 N-mm/m	7.65 x 10^6 N-mm/m
	AST required	1.25 m^2	1.25 m^2
4	Check for one way shear	0.28 N/mm^2	0.35 N/mm^2
5	Check for two way shear	0.968 N/mm^2	0.968 N/mm^2
6	Check for uprooting	Design uplift = 14194 kg Stub section = 200 × 200 × 16 Stub depth below GL = 2800 mm Ult. Load resisted by stub in slab due to bond **Us = [D × {X×2.0+(X-T) × 2.0}-Npx {X+(X-Ts)} × K] × s** Ultimate permissible bearing Stress in concrete = 68.84 kg/cm^2 Use outer cleat = 3 nos. 110 × 110 × 8 – 440 mm long Use inner cleat = 3 nos. 110 × 110 × 8 – 250 mm long Provide 4 nos. of 16 dia. Bolts per cleat pair of 5.6 grade	

7	Load resisted by cleat in bearing	136923 kg
8	Ultimate shear strength of bolts	152438 kg
9	Ultimate bearing strength of bolt in stub or cleat	159744 kg
10	Effective strength of stub and cleat	154971 kg which is more than ultimate uplift = 14194 kg (Hence safe)
11	Check for Bond	Design bearing pressure = 0.0197 N/mm^2 1.32 N/mm^2 < 1.6 N/mm^2 Therefore OK
12	Check for sliding	F.O.S in Normal condition = 10081/2693 = 3.74 > 1 F.O.S in broken wire condition = 10081/3018 = 3.34 > 1 Hence Ok
13	Check for overturning	Total Overturning Moment Under (NC) 25656.51 kg-m Under BWC 28284.84 kg-m Total resisting moment 318361.89 kg-m Factor of safety Under NC = 318361.89 / 25656.51 = 12.40 > 1 Under BWC = 318361.89 / 28284.84 = 11.25 > 1 Hence Ok

E. Reinforcement Details

Sketch	Length (mm)	Bars (mm)	No. of bars	Unit wt. (kg/m)	Wt./length (kgs)	Wt./tower (Kgs)
	4590	16	16	1.58	116.04	464.16
		12	10	0.89	40.85	163.40
	2570	10	4	0.62	6.38	25.52
	4852	10	4	0.62	6.38	25.52
	3350	20	20	2.47	165.49	661.96
	2307	6	13	0.22	6.60	26.39

Quantities per Tower
Concrete volume : 47.44 m^3(M15) + 4.4 m^3(M10)
Excavation volume : 361.68 m^3
Reinforcement : 1366.95 kgs

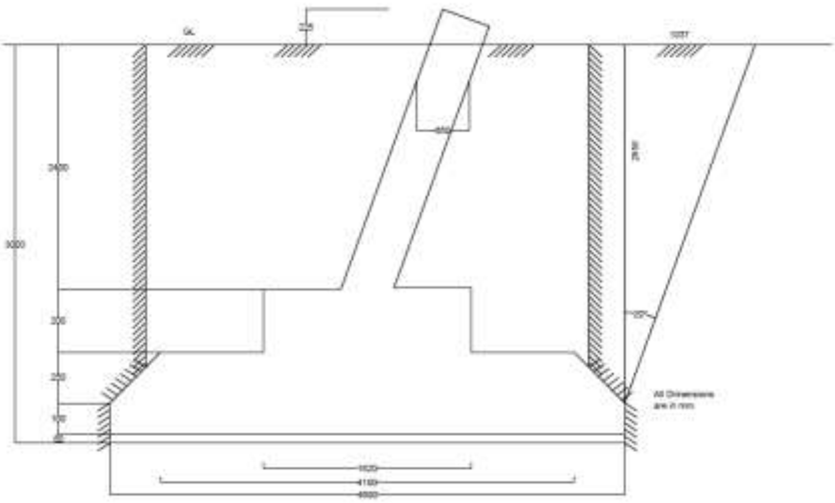


Fig. no. 1 dry fissured type of foundation design

IV. CONCLUSIONS

i. This study shows us how to design the foundation of a transmission lines tower as per the loadings and also as per the soil investigation reports. It reveals the action of forces acts on the foundation of tower and what parameters to be taken into account for the safe and stable foundation which satisfactorily supports the towers to the designed life period.

ii. Through the design we also get enough knowledgeable about the design of the transmission line tower foundation in the worst condition near or on the banks of river.

iii. It revealed the actual action of forces which is accompanied by downward, uplift and side thrust.

REFERENCES

[1]. Experimental study on corrosion of transmission line tower foundation and its rehabilitation ISSN 2010

[2]. Reliability based design of foundation for transmission line structures (New York) (drilled and spread foundation)

[3]. Analysis and research for uplift mechanism on foundation of transmission line towers in expansive soil.

[4]. Central board of irrigation and power of transmission line tower (CBIP) manual.