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COMPARATIVE STUDY ON DESIGN OF TRIANGULAR TOWER USING SCHIFFLERIZED ANGLES

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ABSTRACT

Telecom industry is growing rapidly which require more number of towers. Triangular towers are being used as an alternate to square towers due to their lesser wind resistance which results in significant weight reduction compared to square towers. Hot rolled 90^0 steel equal angle sectional are generally used in lattice towers for both leg and bracing members since the 60^0 angles are not readily available. In triangular based towers, the included angle between the two flanges of the main leg member shall be 60^0 for a smooth connection between the leg and bracing members. The bracing members are connected to both the flanges of the leg members (made of 90^0 angle section) using 15^0 bent gusset plates. The gusset plate thickness shall be 2mm higher than the bracing member that it connects with the leg member based on code recommendations, resulting in a heavier tower. The required included angle of 60^0 between the two flanges of a leg member can also be achieved by 'schifflerized' hot-rolled 90^0 Angle.The current paper focuses on the effect of schifflerized angles in overall structure weight compared to towers with hot rolled 90^0 angle towers of same configuration and antenna loading. During this study, two different height of tower are considered i.e., 40m and 60m height and performed analysis with 90^0 angles and schifflerized angles. Comparative summary is obtained between two cases and conclusions are drawn on overall impact of structural weight.

I. INTRODUCTION

The Rapid growth in the telecommunication system requires a slender and light weight structures supporting antenna equipment at elevated heights. Lattice steel towers have provided an economic solution for the communication industry over many years. Typically lattice towers vary in face width from top to bottom and depending on the form of structure; different bracing patterns are adopted appropriate to the loading to be carried. The main advantage of self-supporting lattice structures lies in their good torsional rigidity. The design problems are relatively straight forward and are amenable to well-established principles although a relatively large number of secondary members are used, to reduce the effective length of primary load-carrying members in wide faced towers. Towers which are generally square in plan and constructed of bolted angle sections are popular due to their easy of material, fabrication and installation. The design of such structures evolved rapidly with the advent of transmission line, whose towers were designed for maximum efficiency – that is the lowest weight of steel. Wind is predominant load in slender and light weight structures of telecom towers, whereas wire loads are major in design of transmission line towers. Wind speed is depending on site condition based on IS 875 (part 3) – 2015. Wind pressure on structure is greatly influenced by – structural characteristics, size and shape, surrounding terrain features and topographical features of site condition. It is recognized from wind loading standards that square tower attracts more wind resistance due to their adjacent faces exposed to wind compared to triangular lattice towers. Triangular towers are being used as an alternate to square towers due to their lesser wind resistance which results in significant weight reduction compared to square towers.

Hot rolled 90^0 steel equal angle sectional are generally used in lattice towers for both leg and bracing members since the 60^0 angles are not readily available. In triangular based towers, the included angle between the two flanges of the main leg member shall be 60^0 for a smooth connection between the leg and bracing members. The bracing members are connected to both the flanges of the leg members (made of 90^0 angle section) using 15^0 bent gusset plates. The gusset plate thickness shall be 2mm higher than the bracing member that it connects with the leg member based on code recommendations, resulting in a heavier tower. The required included angle of 60^0 between the two flanges of a leg member can also be achieved by 'schifflerising' hot-rolled 90^0 Angle.The current paper focuses on the effect of schifflerized angles in overall structure weight compared to towers with hot rolled 90^0 angle towers of same configuration and antenna loading. During this study, two different height of tower are considered i.e., 40m and 60m height and performed analysis with 90^0 angles and schifflerized angles. Comparative summary is obtained between two cases and conclusions are drawn on overall impact of structural weight

II. GEOMETRICAL PROPERTIES

Seshu Madhava Rao Adluri&Murty K.S. Madgula (1990) focused on calculation of section properties for schifflerized angles, the geometrical properties of schifflerized angles have been calculated by idealizing the cross section in to rectangular elements. While the calculation of properties such as moments of inertia and Saint-venant's torsion constant pose no difficulty, the computation of warping constant is quite involved and is presented in paper of 'Geometrical properties of schifflerized angles.

Every 60^0angle will have a 90^0 unchanged root portion of length ranging from 24 to 54mm, depending up on the leg thickness and are listed below for various size of angle.

Table 2.1: Width of Unbent portion of schifflerized Angle legs

Leg thickness (mm)	Width of Unbent Portion of Leg – a (mm)
30	54
25	44
20	38
16	34
13	29
10	26
8	25
6	24
5	24

Table 2.2 Comparison of salient properties of equal 90^0angle and schifflerized angle

Property	90^0 Angle	Schifflerized Angle
Area	Same	Same
Torsional constant	Same	Same
Shear Centre	Intersection of Centre lines of legs	Further away from the centroid
I_{max}	-	Approx. 20-45 % smaller
I_{min}	-	Approx. 20-50% larger
Warping Constant	Small	Approx. 30-100% larger

III. METHODOLOGY FOR CALCULATION OF COMPRESSION CAPACITY

There has been little or no published information through formal study on the strength and behavior of these angles until very recently. Various design procedures that deal with shcifflerized angles have thus far depended on knowledge extrapolated from the published literature on regular 900 angle. Among other things, the compressive strength of schifflerized angles depends on the slenderness ratio and width-thickness ratio. There is no unanimity about the width of the leg plate to be used in the computation of width-thickness rations for schifflierized angles. Because of substantial increase in the strength of these angles for flexural buckling and a reduction of strength for torisonal-flexural buckling from that of 900 angles, they are susceptible to torsional-flexural buckling even at significantly high slenderness ratios.

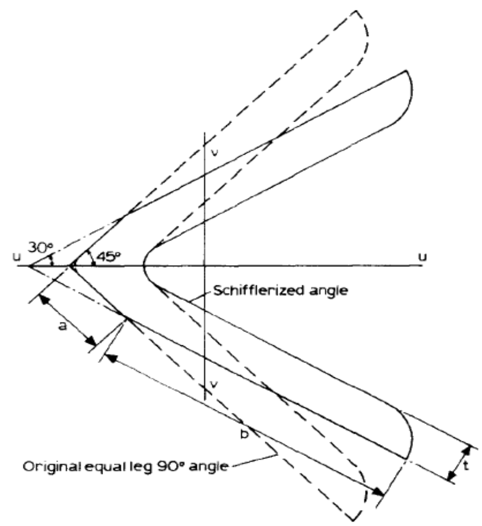

Fig. 2.1: Typical Cross Section showing original equal leg 90^0 angle and schifflerized angle

SeshuMadhavaraoAdluri, Murty K.S. Madugula (1992) proposed two alternate design recommendations for schifflerized angles. Both recommendation give reasonably good results for designing schifflerized angles using the provisions of ASCE Manual. Alternative one is easy to apply compared with alternative two. However, alternatiee two is more rational and may not prove to be difficult to apply if embedded in to design software.

Alternative one:

- Compute the width-thickness ratio of the schifflerized angles using the normal leg width (a+b) instead of (a+b-t-c)
- Use this ratio to compute the design compressive strength which are using for 90^0 angles

Alternative Two:

- Use dimension (b) instead of (a+b-c-t) to compute the width-thickness ratio
- Compute the flexural and the equivalent torsional-flexural radii of gyration of the member
- Select the minimum of the two radii of gyration to compute the slenderness ratio of the member
- Using the width-thickness ration (of step 1) and the slenderness ratio (of step 3), compute design compressive strength which are using for 90^0 angles.

IV. CASE STUDY SPECIFICATIONS

Self-Supporting tower with two different heights are considered to understand the overall advantage of using schifflerized angles in view of weight of structure. 40m and 60m high triangular lattice towers considered to be placed in 44m/s (3 second gust) to support antenna at top 5m portion. Tower geometrical details for each tower configuration are is mentioned below.

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Table 4.1: Tower Geometry and specifications

Description		40m Tower	60m Tower
Height	(m)	40	60
Bottom Base Width	(m)	4	6
Top Base Width	(m)	1.5	1.5
Height of Sloped Portion	(m)	30	50
Height of Vertical Portion	(m)	10	10
Yield stress – Members	(Mpa)	250	250
Loading Standard		IS 875 (Part 3) – 2015	
Design Standard		IS 802 (Part 1 / Sec 2) – 1992	

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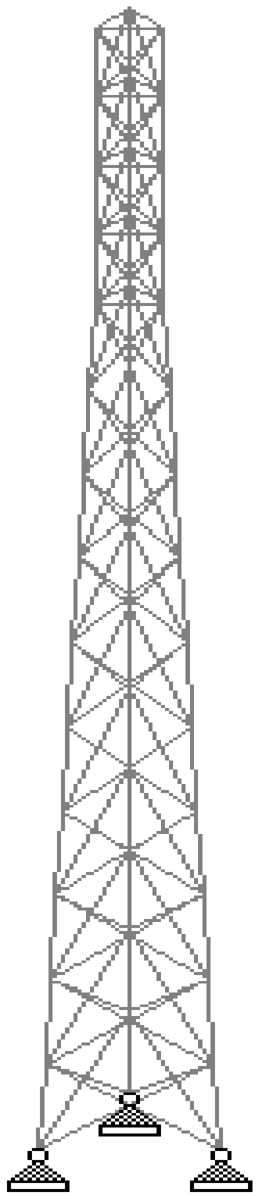

Fig: 4.1a 40m Tower – 90^0 Profile

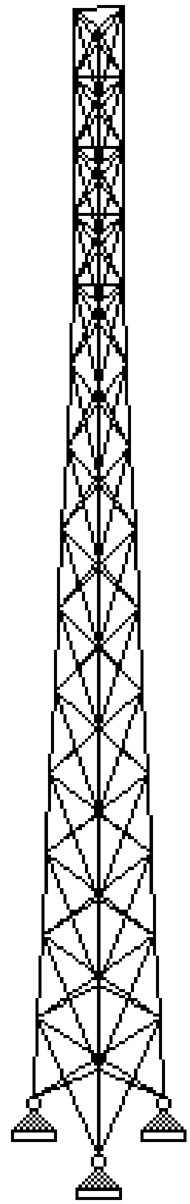

Fig: 4.1b 40m Tower – Schifflerized Profile

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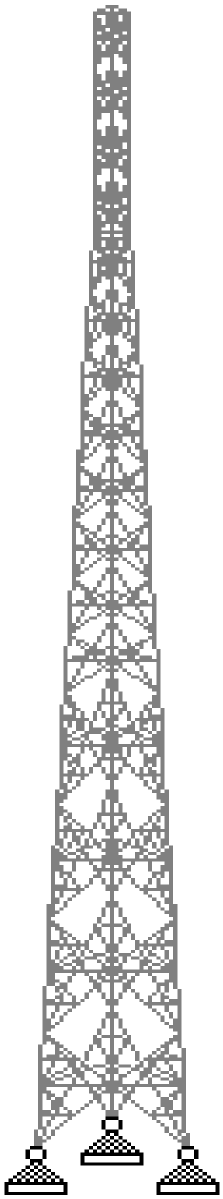

Fig: 4.2a 60m Tower – 90^0 Profile

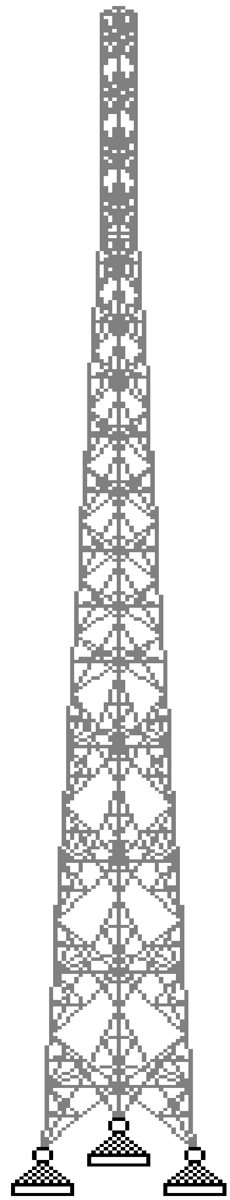

Fig: 4.2b 60m Tower – Schifflerized Profile

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V. LOAD CALCULATIONS

The Basic wind speed (V_b) shall be modified to include the effects of Risk level, Terrain roughness and height of structure, Local Topography and Importance factor for the cyclonic region to get design wind speed (V_z) at any height z which can be expressed mathematically as follows.

$$V_z = V_b\ k_1\ k_2\ k_3\ k_4 \qquad (5.1)$$

k_1 – Risk coefficient
k2 - Terrain and Height Factor
k3 - Topography Factor
k4 - Importance factor for cyclonic region

The design wind pressure at any height (z) is given by

$$\bar{p}_d = K_d\ K_a\ K_c(0.6\, V_d^2) \qquad (5.2)$$

Table 5.1: Wind Load – 60m tower using 90^0 angle profiles

Panel Ht.(m)	Cum. Ht. (m)	Height (m) - K_2	K_2	$P_d(kN/m^2)$	Wind Resistance (m^2) Tower	Ladder & Cables	Total	Wind Load (kN)
2.5	60	58.75	1.21	1.95	1.92	0.69	2.61	5.08
2.5	57.5	56.25	1.21	1.94	1.92	0.69	2.61	5.06
2.5	55	53.75	1.20	1.93	2.06	0.69	2.75	5.31
2.5	52.5	51.25	1.20	1.92	2.06	0.69	2.75	5.28
2.5	50	48.75	1.20	1.91	2.36	0.69	3.05	5.81
2.5	47.5	46.25	1.19	1.89	2.37	0.69	3.06	5.76
2.5	45	43.75	1.18	1.87	2.59	0.69	3.28	6.12
2.5	42.5	41.25	1.18	1.85	2.71	0.69	3.40	6.27
2.5	40	38.75	1.17	1.83	3.04	0.69	3.73	6.81
2.5	37.5	36.25	1.17	1.81	3.16	0.69	3.85	6.95
2.5	35	33.75	1.16	1.79	3.74	0.69	4.43	7.91
2.5	32.5	31.25	1.15	1.77	3.87	0.69	4.56	8.07
2.5	30	28.75	1.15	1.75	4.01	0.69	4.69	8.20
2.5	27.5	26.25	1.14	1.72	4.14	0.69	4.82	8.32
2.5	25	23.75	1.13	1.70	4.26	0.69	4.95	8.43
2.5	22.5	21.25	1.12	1.68	4.39	0.69	5.08	8.53
5	20	17.5	1.11	1.62	9.12	1.38	10.49	17.04
5	15	12.5	1.07	1.52	9.69	1.38	11.07	16.85
5	10	7.5	1.05	1.47	11.48	1.38	12.85	18.85
5	5	2.5	1.05	1.47	12.01	1.38	13.39	19.63

Table 5.2: Wind Load – 60m tower using Schifflerized Profiles

Panel Ht.(m)	Cum. Ht. (m)	Height (m) - K_2	K_2	P_d(kN/m^2)	Wind Resistance (m^2)			Wind Load (kN)
					Tower	Ladder & Cables	Total	
3	60	58.5	1.21	1.95	2.39	0.83	3.22	6.26
3	57	55.5	1.21	1.94	2.26	0.83	3.08	5.96
3	54	52.5	1.21	1.94	2.07	0.83	2.90	5.61
3	51	49.5	1.20	1.91	2.07	0.83	2.90	5.54
3	48	46.5	1.19	1.89	2.78	0.83	3.60	6.80
3	45	43.5	1.18	1.86	2.82	0.83	3.65	6.80
3	42	40.5	1.18	1.84	3.58	0.83	4.40	8.10
3	39	37.5	1.17	1.82	3.77	0.83	4.59	8.34
3	36	34.5	1.16	1.79	3.94	0.83	4.77	8.55
3	33	31.5	1.15	1.77	4.11	0.83	4.94	8.74
3	30	28.5	1.15	1.75	4.55	0.83	5.37	9.38
3	27	25.5	1.14	1.72	4.71	0.83	5.54	9.52
6	24	21	1.12	1.68	9.97	1.65	11.62	19.50
6	18	15	1.09	1.58	10.83	1.65	12.48	19.72
6	12	9	1.00	1.33	11.55	1.65	13.20	17.56
6	6	3	1.00	1.33	13.68	1.65	15.33	20.38

VI. ANALYSIS RESULTS

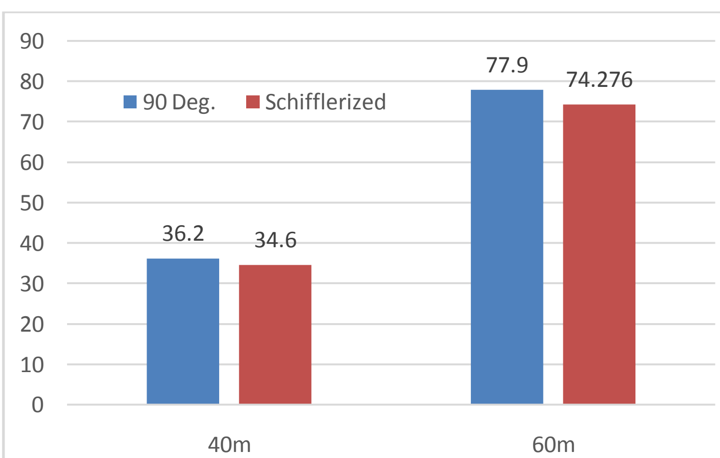

Table 5.1: Weight Comparison Table

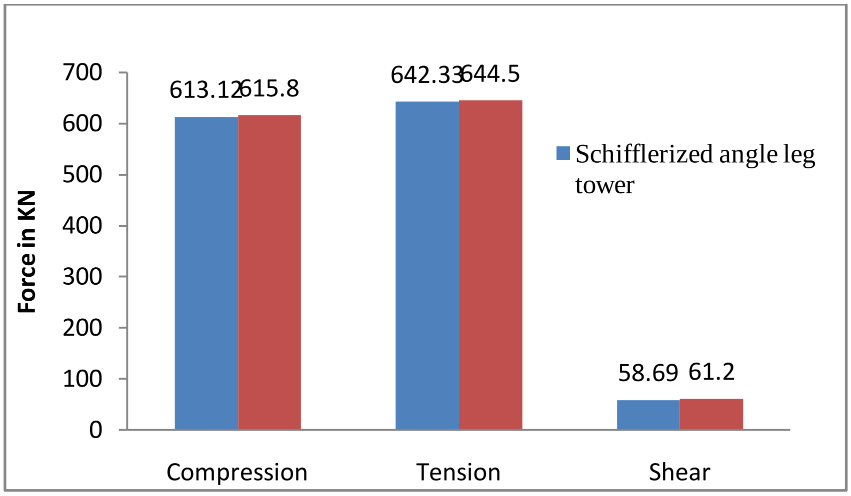

Table 5.2 : Base Reaction Comparison(40m Tower)

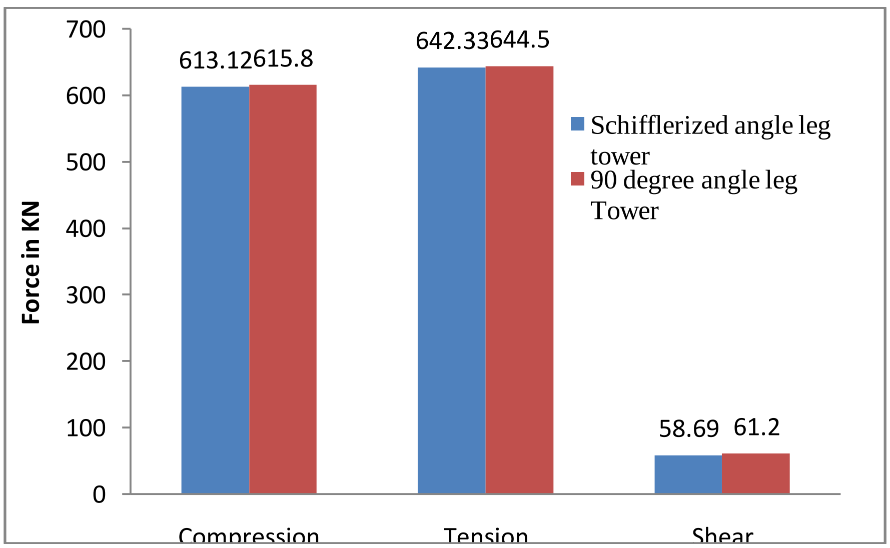

Table 5.3 : Base Reaction Comparison(60m Tower)

VII. CONCLUSION

- An increase of 14-17% radius of gyration in minimum axis observed for schifflerized angle
- Due to above, tower optimization is possible by increase effective length of member there by reduces number of redundant members resulted in tower weight.
- An average of 5-8% of tower weights is reduced in two tower heights (40m & 60m) and further gusset plate weights also eliminate due to schifflerized profiles
- Foundation reactions are reduced by 6% in 60m tower and negligible increase in 40m tower observed, due to fact that wind on tower body major contribution in more tower heights.
- Therefore, an 10-12% of tower weights can be reduced using schifflerized angles inplace of Hot Rolled 90^0 Angle Profiles.

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