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Study on the Effect different materials in Traffic signal pole using numerical simulation approach

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Abstract

Traffic signal poles play a role of mitigating traffic congestions in cities. It slender structure which is usually characteristics with high deformation. It is exposed to load, various environmental factor and natural hazards. The aspiration of modal analysis in structure mechanics is to negotiate the natural frequency of an object or structure in times of free vibration. Conventional poles are replaced with I and T section by applying various material such as structural steel (SS), stainless steel (STS) and grey cast iron (CI). By predicting the ultimate section with low deformation. The ultimate material is endowed and fracture behaviour is prompt, substitute crack is inserted in the maximum stress spot and life cycle of the ultimate material section is deliberate.

Key words: traffic poles, modal analysis, natural frequency, fracture analysis, crack, life cycle

1. Introduction

Traffic signals can lead to a standard distribution of traffic flows [1]. It structure is usually characteristic with high deformation [2-6]. It may have exposed to various load and environmental factor especially wind factor such as hurricane [7],[8]. It leads to the failure and so the conventional structure is replaced to I and T sections [09-11]. Predominantly, I and T section offer a high strength long span structural beam. Various material such as SS, STS and CI is applied to the section [12-14] to found the minimum deformation by modal analysis [15]. Modal analysis is the process of determining the characteristics of a system in for of natural frequencies and mode shapes and formulates a mathematical model of its behaviour [16-18]. The aspiration of modal analysis in structure mechanics is to negotiate the natural frequency of an object or structure in times of free vibration [19]. The natural nodes of vibration are inherent to a system and are determined by its physical properties such as mass, stiffness, damping and the spatial distributions [20]. Each mode is described in terms of its modal parameter such as natural frequency, modal damping factor and characteristics displacement pattern which are called mode shape [21-25]. In this paper, analytical calculation and numerical calculation for each section with various material is carried out and the section with minimum deformation with preferred material is concluded. So alternatively we could increase the life span of signal poles. In protrusion to the modal analysis, the preferred section is terminated and the fracture behaviour and crack analysis is constituted [26-30] and the life cycle of the component is calculated.

2. MATERIAL PROPERTIES:

Steel is an alloy of iron, with carbon the primary alloying element. Carbon, other elements, and induced within iron act as hardening agents. Varying the number of alloying elements, their form in the steel either as solute elements, or precipitated phases, retards the movement of those dislocations that make iron so ductile and so weak, and so it controls qualities such as the hardness, ductility, and tensile strength of the resulting steel. Steel can be made stronger than pure iron, but only by trading away ductility, of which iron has an excess.

Grey cast iron is a type of cast iron that has a graphitic microstructure. It has the alloying element of carbon 2.5 to 4 %, silicon 1 to 3% and graphite 6 to 10 %. It also has high damping capacity.

Table 2.1 Mechanical Properties of different materials

Material	Elastic modulus (E) N/mm^2	Shear modulus (G) N/mm^2	Poisson's ratio (V)
Structural steel	210,000	81,000	0.30-0.31
Stainless steel	180,000	74,000	0.27-0.30
Grey cast iron	100,000	69,000	0.21-0.26

3. MODELLING AND ANALYSIS

Modelling is the 3D representation of the object. W27*178 I section and 6*100 truss T section are modelled by modelling software. ANSYS is general-purpose Finite Element Analysis (FEA) software package.

Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user designed size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole.

The ANSYS Workbench environment is an intuitive up-front finite element analysis tool that is used in conjunction with CAD systems and Design Model. ANSYS Workbench is a software environment for performing structural, thermal, and electromagnetic analyses. The Workbench focuses on attaching existing geometry, setting up the finite element model, solving, and reviewing results.

Table 3.1 Dimensions of Hollow Pipe

Section	Outer diameter (mm)	Thickness (mm)
Hollow pipe	114.30	6.30

Table 3.2 Dimensions of various section of Pipe

Section	Height (inches)	Length (inches)	Width (inches)
I section	27.8	14.09	1.19
T section	7	6	1

Wind pressure calculation:

Normal wind speed in India = 39 m/s

Wind Pressure (p) = 0.00256 * V^2 (1)

V = Speed of the wind in Mph

01 metre = 2.2337 miles per hour

V^2 = 7611.34 Mph (2)

Wind Pressure (P) = 19.485 psf

1 Pascal = 0.021 pounds per square foot

Wind Pressure = 0.4901 Pa

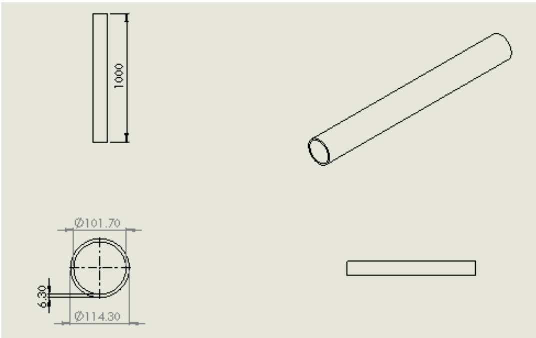

Fig.1.sectional views of hallow cylindrical bar

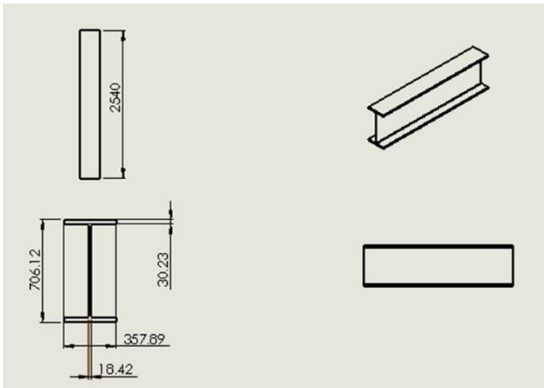

Fig.2. Sectional views of I section beam

3. NUMERICAL CALCULATION

Table.1 Dimensions of components

Component	Area	Centroid distance	Ay
Top flange	l*b = 16.767	27.205	456.146
Web	l*b = 18.556	8.235	152.808
Bottom flange	l*b = 16.767	0.595	9.9763

= 8369.342 inch

y = 0.0404 (structural steel)

y = 0.0470 (stainless steel)

y = 0.0848 (grey cast iron)

$$f = \frac{1}{2\Pi}\sqrt{g/\delta}$$

f_n= 78.46 (structural steel)

f_n = 72.74 (stainless steel)

f_n = 54.15 (grey cast iron)

T section

Table.2 Dimensions of T section

Compo nent	Area	Centroid	Ay
1	l*b = 6	6.5	39
2	l*b = 6	3	18

$$\bar{y} = \frac{\sum ay}{\sum a} = 11.881$$

$I_{xx} = I_{top} + I_{web} + I_{bottom}$

= 8369.342 inch

$$y = \frac{wl^3}{3EI}$$

$$y = \frac{pl^4}{8EI}$$

y = 0.0404 (structural steel)

y = 0.0470 (stainless steel)

y = 0.0848 (grey cast iron)

fn= 78.46 (structural steel)

fn = 72.74 (stainless steel)

fn = 54.15 (grey cast iron)

4. Result And Discussion

Modal analysis of I and T section is done by finite element method with ANSYS 17 software to calculate the natural frequencies and maximum deformation of section and comparisons are done with the selected materials and the best material for the I and T section is analysed. Results obtained from this analysis are shown in the following tables according to materials. Table

Thus, by comparison of Natural Frequency and Total Deformation obtained for the default Modes for all three Material, Structural Steel, Stainless Steel, Grey Cast Iron, both SS and STS are suitable for the traffic light poles. The deformation results with respect to modes are show below.

Modal analysis for three different materials (structural steel, stainless steel, grey cast iron) is carried out. The accept value of deformation is noted by this we can made a conclusion structural steel has minimum deformation. So structural steel is more preferable for T section and it is strong for section traffic signal poles.

Life time prediction:

In protrusion to the modal analysis, the best material for the I and T section is terminated and the fracture behaviour and crack analysis is constituted and the life cycle of the component is calculated as the prediction process. That the component wants to be change within that life time for the safety proposes. Crack is formed with difference of 0.005 and the major and minor radius the crack is increased. The fracture behaviour is analysed through the results obtained in SIFS k1 and k2.

$\Delta K = K_{max} - K_{min}$

ΔK- stress intensity

C, n – material data

da/dN – growth rate

Hollow bar:

Table 3 Mode Value of different structures

Modes	1	2	3	4	5	6
Structural steel	106.12	106.12	600.34	600.34	782.59	1263.3
Stainless steel	104.93	104.93	593.35	593.36	770.76	1249.1
Grey Cast Iron	82.169	82.169	465.3	465.3	610.73	978.12

Comparison of three materials:
Structural steel:

Table 4 Mode Value of structural steel

Modes	1	2	3	4	5	6
Frequency	106.12	106.12	600.34	600.34	782.59	1263.3
SS- Deformation	0.48444	0.48444	0.46996	0.46996	0.36476	0.34542

Stainless steel:

Table 5 Mode Value of Stainless Steel

Modes	1	2	3	4	5	6
Frequency	104.93	104.93	593.35	593.36	770.76	1249.1
STS- Deformation	0.48756	0.48756	0.47288	0.47288	0.36711	0.34766

Grey cast iron:

Table 6 Mode Value of Cast Iron

Modes	1	2	3	4	5	6
Frequency	82.169	82.169	465.3	465.3	610.73	978.12
CI- Deformation	0.50586	0.50587	0.49094	0.49094	0.38087	0.36066

Table 7 I – Section Modal Analysis of Steel and iron

Modes	1	2	3	4	5	6
Structural steel	35.26	43.837	88.933	105.23	131.73	175.42
Stainless steel	34.865	43.321	88.065	103.94	130.16	173.88
Grey Cast Iron	27.298	33.977	68.67	81.633	102.14	135.18

Table 8 I – Section Modal Analysis of Structural Steel

Modes	1	2	3	4	5	6
Frequency	35.26	43.837	88.933	105.23	131.73	175.42
SS - deformation	0.084177	0.094583	0.09949	0.072184	0.12977	0.11114

Table 9 I – Section Modal Analysis of Stainless Steel

Modes	1	2	3	4	5	6
Frequency	34.865	43.321	88.065	103.94	130.16	173.88
STS-deformation	0.084743	0.095219	0.10022	0.072609	0.13103	0.11196

Table 10 I – Section Modal Analysis of Grey Cast Iron

Modes	1	2	3	4	5	6
Frequency	27.298	33.977	68.67	81.633	102.14	135.18
CI–Deformation	0.087843	0.098704	0.1037	0.07545	0.13466	0.11583

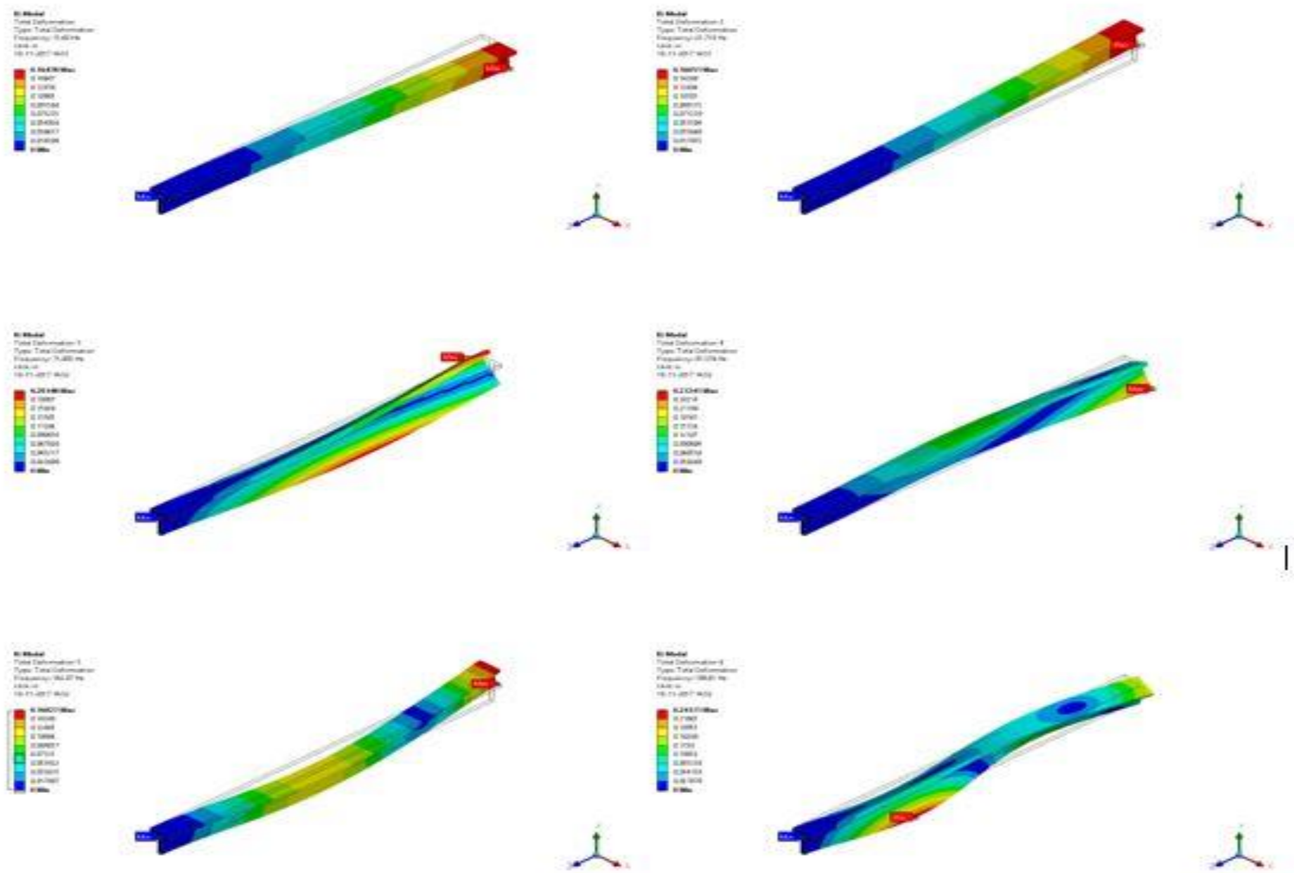

Fig.3. Modal analysis of different material with different cross section

Table 11 life time calculation for crack formed at maximum stress area – I section.

crack length		**change in crack**	**STRESS INTENSITY FACTORS**		**Delta K**	**Paris constant**		**Initial**	**Cumulative**
ai	af	af-ai	Kmax^2	Kmax^3	K	C	m	life cycles	
0.0035	0.004	0.0005	22.959	48.199	35.579	1.00E-11	3	1110.168223	1110.168223
0.004	0.0045	0.0005	25.271	43.826	34.5485	1.00E-11	3	1212.501866	2322.670089
0.0045	0.005	0.0005	26.323	40.138	33.2305	1.00E-11	3	1362.571738	3685.241826
0.005	0.0055	0.0005	28.453	38.067	33.26	1.00E-11	3	1358.949348	5044.191175
0.0055	0.006	0.0005	29.808	36.246	33.027	1.00E-11	3	1387.914219	6432.105393
0.006	0.0065	0.0005	31.293	34.938	33.1155	1.00E-11	3	1376.816475	7808.921869
0.0065	0.007	0.0005	32.762	33.505	33.1335	1.00E-11	3	1374.573799	9183.495668
0.007	0.0075	0.0005	33.683	32.498	33.0905	1.00E-11	3	1379.939404	10563.43507
0.0075	0.008	0.0005	36.005	31.491	33.748	1.00E-11	3	1300.845991	11864.28106
0.008	0.0085	0.0005	36.932	30.606	33.769	1.00E-11	3	1298.420621	13162.70168
0.0085	0.009	0.0005	38.569	30.063	34.316	1.00E-11	3	1237.314285	14400.01597
0.009	0.0095	0.0005	40.548	29.102	34.825	1.00E-11	3	1183.849865	15583.86583
0.0095	0.01	0.0005	41.581	28.832	35.2065	1.00E-11	3	1145.780553	16729.64639
0.01	0.015	0.005	45.862	34.854	40.358	1.00E-11	3	7606.433913	24336.0803
0.015	0.02	0.005	59.604	43.96	51.782	1.00E-11	3	3601.086415	27937.16672

Table 12 life time calculation for crack formed at maximum deform area – I section.

crack length		**change in crack**	**STRESS INTENSITY FACTORS**		**Delta K**	**Paris constant**		**Initial**	**Cumulative**
ai	af	af-ai	Kmax^2	Kmax^3	K	C	m	life cycles	
0.0035	0.004	0.0005	0.11981	-0.00836	0.055725	1.00E-11	3	2.88945E+11	2.88945E+11
0.004	0.0045	0.0005	0.25983	-0.00068	0.129578	1.00E-11	3	22981650432	3.11927E+11
0.0045	0.005	0.0005	0.36449	0.03546	0.199975	1.00E-11	3	6252344336	3.18179E+11
0.005	0.0055	0.0005	0.26722	0.008347	0.137783	1.00E-11	3	19115241314	3.37294E+11
0.0055	0.006	0.0005	0.29883	-0.05119	0.12382	1.00E-11	3	26339217376	3.63633E+11
0.006	0.0065	0.0005	0.49978	0.087167	0.293474	1.00E-11	3	1978168718	3.65612E+11
0.0065	0.007	0.0005	0.11509	0.043142	0.079116	1.00E-11	3	1.00966E+11	4.66578E+11
0.007	0.0075	0.0005	0.1951	0.006442	0.100771	1.00E-11	3	48861470351	5.15439E+11
0.0075	0.008	0.0005	0.41758	0.046756	0.232168	1.00E-11	3	3995424458	5.19435E+11
0.008	0.0085	0.0005	0.30237	-0.01371	0.144331	1.00E-11	3	16630130450	5.36065E+11
0.0085	0.009	0.0005	0.33649	-0.00714	0.164673	1.00E-11	3	11196978229	5.47262E+11
0.009	0.0095	0.0005	0.34573	-0.03215	0.156792	1.00E-11	3	12971866171	5.60234E+11
0.0095	0.01	0.0005	0.30213	0.015114	0.158622	1.00E-11	3	12527942173	5.72762E+11

0.01	0.015	0.005	0.28152	-0.06518	0.108172	1.00E-11	3	3.95026E+11	9.67788E+11
0.015	0.02	0.005	0.61506	-0.02098	0.29704	1.00E-11	3	19077760341	9.86865E+11

Table 13 life time calculation for crack formed at maximum deform area – T section.

crack length		**change in crack**	**Stress Intensity Factors**		**Delta K**	**Paris constant**		**Initial**	**Cumulative**
ai	af	af-ai	Kmax2	Kmax3	K	C	m	life cycles	
0.0015	0.002	0.0005	0.1611	0.6779	0.41949	1.00E-11	3	677337572.9	677337572.9
0.002	0.0025	0.0005	1.2246	1.1136	1.1691	1.00E-11	3	31290681.56	708628254.5
0.0025	0.003	0.0005	0.8179	0.8836	0.85076	1.00E-11	3	81198651.46	789826905.9
0.003	0.0035	0.0005	1.3933	1.0322	1.21275	1.00E-11	3	28032133.61	817859039.5
0.0035	0.004	0.0005	1.2745	0.7661	1.02029	1.00E-11	3	47075952.29	864934991.8
0.004	0.0045	0.0005	1.8293	0.5607	1.19501	1.00E-11	3	29299174.59	894234166.4
0.0045	0.005	0.0005	0.3339	0.7835	0.55871	1.00E-11	3	286688762.9	1180922929
0.005	0.0055	0.0005	1.7024	0.2034	0.95289	1.00E-11	3	57788536.54	1238711466
0.0055	0.006	0.0005	0.6334	0.5012	0.5673	1.00E-11	3	273869164.5	1512580630
0.006	0.0065	0.0005	0.7444	0.2254	0.48486	1.00E-11	3	438666398.1	1951247028
0.0065	0.007	0.0005	1.7719	0.2755	1.0237	1.00E-11	3	46607762.91	1997854791
0.007	0.0075	0.0005	1.9261	0.3212	1.12363	1.00E-11	3	35245674.33	2033100466
0.0075	0.08	0.0725	0.4441	0.4339	0.439	1.00E-11	3	85692822153	87725922619
0.008	0.0085	0.0005	1.1173	0.2147	0.66598	1.00E-11	3	169276326.1	87895198945

CONCLUSION:

I – section is most probably suited for all traffic light poles than the hollow bar and material selection and finds the main part over here, so we analysed the beam with three commonly used materials, and in that structural steel is better.

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