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Preliminary Estimation of Structural Steel for Industrial Steel Structures

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ABSTRACT:
This study covers the various methods for preliminary estimation of structural steel for industrial steel structures by using various methods that are commonly adapted in Industrial practices. Some existing real time samples were considered for this study and the results would be compared by calculating the steel quantity by the automated method based on stability design of steel structures as described in AISC specification 360 - 2010. The research work primarily focuses on the design optimization of pre engineered buildings due to the salient characteristics of light weight, faster erection and enduring strength. The results arrived from different methods and that of the stability analysis of steel structures are tabulated and compared with final quantities which are available from database and the applicability of more suitable method for the preliminary steel estimation would be recommended. In this juncture, the literature review and manual calculation of some of the stability methods are presented in this report.

***Keywords*: estimation of steel, stability methods, comparative study**

INTRODUCTION:

The project is based on the preliminary estimation of industrial steel structure by the help of various methods which are used in checking the stability and weight of the structure. The preliminary estimation of steel quantities and stability analysis is done by the manual calculation according to the stability design of steel structures AISC specifications 360 -2010. The comparison between different methods of stability analysis is done for making the structure more stable.

GENERAL

In this project the preliminary estimation of steel for industrial steel structures is done by using different estimation methods and for stability checking direct stability analysis method is used .In this study we are comparing the results of different methods for knowing best by which effect of stability can be reduced in the steel structures.

There are four methods for estimation of structural steel:

1. GIFA
2. GEFA
3. Volume based method
4. Member based method

GIFA(Gross internal floor area):-

GIFA value is used for obtaining the value of internal floor area excluding the external floor area.

For eg. The school contains three floor each with internal floor area $1.5m^2$ and according to the definition the gross internal area amounts to be $4.500m^{2.}$

Assume the range of the structure=$200kn/m^2$

Than the weight of structure wiil be = range×area

$=200kn/m^2\times4.500m^2$

=900kn

The value for GEFA will be also related to GIFA

Volume based method :-

Consider a cylindrical column of size =3.8m×0.250m×0.300m

=l×b×h

$=0.285m^3$

Assume range of structure $=200kn/m^2$

Than the weight of structure will be $= 200kn/m^2\times0.285m^3$

=57kn/m

Member based method :-

Strucrural steel is normally priced by weight. For example the standard method for specifying the dimensions of an wide flange beam W6×23, in which 6inch i.e (0.15 m) deep with weight of 23lb/ft i.e (75.44m)

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Computing the structural steel weight:

Section	Number	Length(m)	Total length	Weight/m	Total weight
W14×132	1	6.09	6.09	40.24	245kn
W14×120	1	9.14	9.14	36.58	334kn
W16×40	5	6.09	30.45	12.19	371kn
W27×94	1	9.14	9.14	28.65	261kn
W18×50	2	9.14	18.28	15.24	278kn
W14×43	1	6.09	6.09	13.1	80kn
W18×84	3	4.57	13.71	25.6	350kn
W14×109	8	4.57	36.56	33.23	1215kn
W24×68	1	10.36	10.36	20.73	214kn
W16×20	1	7.62	7.62	7.92	60.3kn

A Comparison of Frame Stability Analysis Methods:-

There are three methods which are used for finding the comparison of frame stability. These three methods helps the readers in understanding the differences between them

1. The 1st-Order Analysis Method
2. Direct Analysis
3. Effective length method

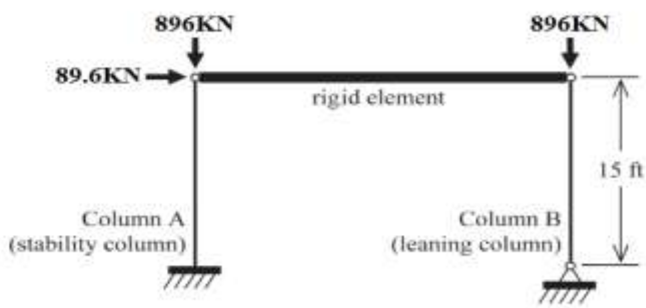

Figure no.1. *One-bay unbraced frame*

First-Order Analysis:

Design of first order analysis:

The first-order analysis method is:

$\alpha = 1.0$

$K = 1.0$

Calculations:
The given frame the additional lateralload is based on the fi rst-order drift ratio, Δ/l *and* ,gravitational load Yi.

$\Delta = \Delta 1st,$

$\Delta 1st / l = (34.036)/(4572mm)$

$= 0.00744$

$Yi = 896kn+896kn$

$= 1792kn$

$Ni = 2\,(\Delta 1st / L)Yi \geq 0.0042Yi$

$= 2\,(0.0075)*(1792kn) \geq 0.0044*(1792kn)$

$= 27.99kn \geq 7.52kn$

$= 27.99kn$

The 2^{nd} order drift is less than 1.5 time the fi rst-order Additional

$\alpha p_r = 1(896kn)$

$= 896kn$

And for steel frame

$0.5Py = 0.5Fy\,Ag$

$= 0.5(50\ ksi)(26.5\ in.2)$

$= 2970.24kn$

Because $\Delta 2nd < 1.5\Delta 1st$ and $\alpha Pr < 0.5Py$, the use of this method is permitted.The loading for this method is the same as that shown in Figure 1, except for the addition of a notional load of 28kn coincident with the lateral load of 89.6kn shown, resulting in a column moment, *Mu*, of 5789knm

$K1 = 1.0.$

$P_{e1} = \pi 2EI/(K_1L)*2$

$= 39558.4kn$

The column moment at 1 axis is zero , so moment gradient :

$Cm = 0.6 - 0.4(m_1/m_2)$

$=0.6$

From Equation C2-2,

$\alpha Pr / Pe_1 = 1(896kn)/(39558.4kn)$

$= 0.0236$

$B_1 = \frac{Cm}{1-\frac{\alpha Pr}{\alpha Pe1}} \geq 1$

$=0.623 \geq 1$

Axial loads and design perimeters are :

$Mrx = B_1 Mu$

$= 1.0\ (5789knm)$

$= 5789knm$

$c_b = 1.68$

$L_b = 4.57m$

Base on the design perimeters, the axial loads :

$p_c = \varphi c p_n = 4480kn$

$M_{cx} = \varphi b * M_{nx} = 8419.89knm$

The ratio of axial load:

$P_r/P_c = \frac{896\,kn}{4480\,kn} = 0.200$

becoz $P_r / P_c \geq 0.2$ and eqn is fine

$P_r/P_c \quad \frac{8}{9}\left(\frac{Mrs}{Mcx}\right) = 0.277 + \frac{8}{9}\left(\frac{5789.59knm}{8419.89knm}\right)$

$= 0.823$

since $0.823 \leq 1$

Design of direct analysis :

Nodal load = $0.002Y$

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EA^* and EI^* are reduced stiffness.

Thus the notional load can be applied as min. lateral load:

Yi = 896kn + 896kn

= 1792kn

Ni = 0.002Yi

= 0.002(1792kn)

= 3.58kn

For Col. A,1st-order :

P_{nt} = 896kn, Plt = 0 kn

Mnt = o knm, M_{lt} = 4408.3knm

To determine the second-order amplifi cation, the reduced stiffness, EI^*, must be calculated.

αPr = 1.0(896kn)

= 896kn

and

0.5Py = 0.5$Fy\ Ag$

=2970.24kn

Thus, because $\alpha Pr < 0.5Py$, $\tau b = 1.0$ and

$EI^* = 0.8\tau bEI$

= 0.8EI

For P-δ amplification there are no moments and no need to calculate B_1.

For P-Δ amplification. $EI^* = 0.8EI$,

$\Delta 1st$ = 1.25(34.036)

= 42.545

The fi rst-order drift ratio is determined from the amplified drift of 42.545

$\Delta 1st/L$ = (42.545)/(2160.57mm)

= 0.00933

, R_m = 0.856

$\Delta H = \Delta 1st$ and Σh = 89.6kn

$\Sigma P_{e2} = R_m \frac{\Sigma H}{(\Delta 1st/L)}$

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$=0.856\frac{896kn}{0.00933}$

=81629kn

thus,

$\alpha\Sigma P_{nt}$ / ΣP_{e2} = 1(896kn+896kn)/81629kn

= 0.220

The amplification is :

$B_2=\frac{1}{1-\frac{\alpha\sum Pnt}{\sum Pe2}} \geq 1$

$=\frac{1}{(1-0.220)} \geq 1.0$

= 1.28≥1.0

= 1.28

The amplified axial load and parameters :

$P_r = P_{nt} + B_2P_{lt}$

=896kn + 1.28(0 kips)

= 896kn

$K_x = K_y = 1.0$

$L_x = L_y = 4.57$m

Moment and design perimeter are :

$M_{rx} = B_1M_{nt} + B_2M_{lt}$

= 0 + 1.28(4408.32knm)

=5642.64knm

$C_b = 1.67$

$L_b = 4.57$m

Flexural strength:

$P_c = \varphi cP_n = 4480$kn

$M_{cx} = \varphi b{*}M_{nx} = 8419.89$knm

Compressive load :

$P_r/P_c=\frac{896\,kn}{4480\,kn}$

= .200

$P_r /P_c \geq 0.2$

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$P_r/P_c + \frac{8}{9}\left(\frac{Mrs}{Mcx}\right) = 0.200 + \frac{8}{9}\left(\frac{5642.64knm}{8419.89knm}\right)$ = 0.796 The W14×90 is adequate since 0.796≤1.0.

Effective length method:

Calculations for effective length method:		
P_u=896kn M_u=(896×4.57) =409.47kn I_{st} order drift(Δ_1t)=(89)/(2.64) =34.036mm		
Y_i=896+896 =1792kn	P_{nt}=896kn M_{nt}=0	P_{lt}=0 M_{lt}=409.47kn
Nodal load= N_i N_i= 0.002Y_i =3.58 kn M_r=B_1M_{nt}+B_2M_{lt} Finding B_1 P_r=P_{nt}+P_{lt}		
Thus P_r= 896kn	I=28.3m	
$P_{e1}=\frac{\Pi^{\wedge}2EI}{(KL)^{\wedge}2}$ =383.77kn α =0.6	C_m=0.6-0.4(M_1/M_2) =0.6	
$B_1=\frac{Cm}{1-\frac{\alpha Pr}{Pe}}$ =0.6 use 1 $B_2=\frac{1}{1-\frac{\alpha Pnt}{Pe}}$ =1.1 Calculate amplified axial load: P_r=896kn		
P_r=P_{nt}+B_2P_{lt} =896+(1.1)×0 =896kn	K_x=K_Y=1.0 L_x=L_y=4.57m	

Moment and design parameters are: C_b=1.67

$M_{rx}=B_1M_{nt}+B_2M_{lt}$ L_b =4.57m

=452.5kn

Flexural strength:

$P_c=\varphi_c P_n$=4480kn

$M_{cx}=\varphi_c X M_{nx}$=8419.89kn

$$=\frac{Pr}{Pc}+\frac{8}{9}\left(\frac{Mrx}{Mcx}\right)$$

$$=\frac{896}{4480}+\frac{8}{9}\left(\frac{452.5}{8419.89}\right)$$

=0.200+0.88(0.053)

=0.25≤1

RESULTS

All methods illustrated in the foregoing sections produce similar designs. The results are tabulated here for comparison ,where the result of the beam-column interaction equation is given for each method. A lower interaction equation result for the same column shape signifies a prediction of higher strength.

Method Interaction Equation:

First-Order	0.82
Direct Analysis	0.79
Effective length method	0.25

In this example effective length method predicts the higher strength , while first order method predicts the lowest strength. The designs compared here are based on strength with no consideration of drift limitation, except to the extent that the actual drift impacts the magnitude of the second-order effects. The usual drift limits of approximately *L*/400 will necessitate framing members and configurations with more lateral stiffness than this frame provides.

CONCLUSION:

The stability analysis for a steel frame was done using the following three methods:

1.The 1st-Order Analysis Method

2. The Direct Analysis

3. Effective length method

The results for stability of the frame was calculated manually using all the above three methods. Effective length method showed better results for stability than other two methods.

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