EFFECT OF EXPANSION RATIO ON DEFLECTION OF CASTELLATED BEAM

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ABSTRACT: ***As we know that, though there is no provision for the castellated beam in Indian standard, the use of castellated beam is increased day by day mainly for the industrial buildings because of the advantage of the castellated beam like decrease the weight of the beam cause decrease floor weight. And decrease of floor weight causes decrease in size and weight of the columns and ultimately considerably reduction in cost of the substructures. A study on the effect of the expansion ratio on the deflection of the castellated beam is described in this paper. Finite element method is used using ANSYS 11 to determine the behavior of the castellated beam with change of the expansion ratio. In this paper, the expansion ratio of different values for the ISMB 500 is used for which, the depth is ranging from 700 to 800 with expansion ratio of 1.4 to 1.6. Here two support conditions one is both ends are fixed and other is both ends are pinned are used and various parameters are found out like maximum von misses stresses, deflections, strain etc. Here there is variation have seen in deflection with change in the expansion ratio. With increase in expansion ratio, there is a decrease in deflection up to certain limit and, then there is a increase in deflection. It is obvious that the deflection is inversely proportional to the moment of inertia of the castellated beam about x-x axis. But after certain limit there is a increase in deflection though there is a increase in moment of inertia due to increase in depth of the section by increasing the expansion ratio. It is because of web buckling due to increase in slenderness ratio, there is a possibility for web buckling of the castellated beam. So the main aim of the paper is to find the minimum deflection i.e. optimized section of the beam using change in expansion ratio.***

Key words: Castellated beam, Expansion ratio

I. INTRODUCTION

Economy in construction of steel structure cannot obtained by increasing utilization of high strength steel for the construction. Economical construction can be obtained up to certain extent by using modified steel structure design. So the next way is to modification of standard steel section i.e. castellated beam for flexural member.

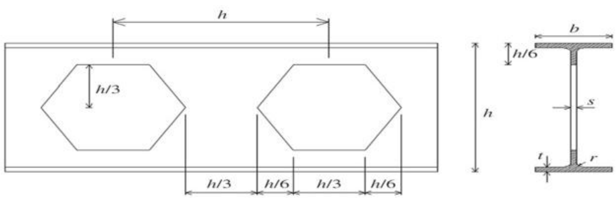

Fig. 1 Castellated beam and opening geometry.

II. FABRICATION

Profile cutting is done in web of I – section in zigzag manner as shown in fig.2. than these two halves are separated and slid by the length equal to half the width of hollow portion. In this position these two separate parts are joined as shown in fig.2. Remaining portion is considered as a wastage, shich is shown by hatch lines as shown in fig.2.

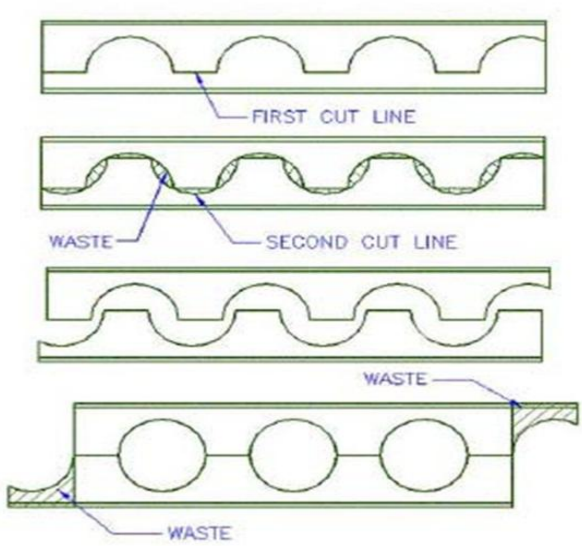

Fig. 2 Fabrication of castellated beam

III. VIERENDEEL ANALYSYS

A castellated beam having a span of L and overall depth D is as shown in fig.3. It is subjected to uniformly distributed load q Kg/m. For the design of castellated beam it is required to find the maximum stresses in the beam which may occur at any point in the length of the beam within the region of T-section. For convenience of calculation, the beam is analyzed as a vierendeel truss where the longitudinal fiber stress is governed by both the beam bending moment as well as vertical shear. The following assumptions are made in calculating stresses.

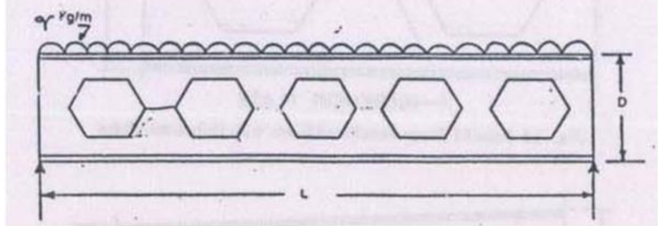

Fig. 3 Typical castellated beam under uniformly distributed superimposed loading.

In the open portion of the web, vertical shear divides equally between the upper and lower tees. For bending moment in the T-section due to shear, point of contraflecture is assumed to exist in the vertical centre line of the open section. Fiber stress varies linearly and the maximum stress in the open section is computed as an algebraic sum of both primary and secondary stresses which are due to shear in the T-section respectively A typical section of a castellated beam is shown in the fig. 4(a) The stress distribution diagram is shown in fig. 4(b).

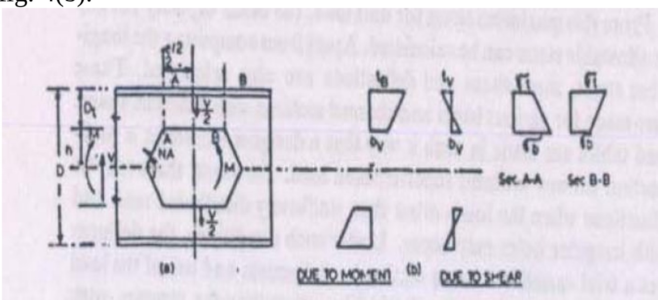

Fig.4 Typical section and distribution of stresses of castellated beam.

Maximum fiber stress at section A-A.

$$б_b = b_B + b_V = \frac{M_A}{I_g}\ X\, h + \frac{V\,.e}{4S_g} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Maximum fiber stresses at section B-B.

$$б_t = t_B + t_V = \frac{M_B D}{2I_g} + \frac{V\,e}{4\,S_f} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

The maximum longitudinal fiber stresses can occur at inner edge of the tee web i.e. bending stress at top fiber of the tee i.e. maximum bending stress would occur at section A-A and is computed by the equation 1. The maximum bending stress would occur at section B-B and is computed by equation 2. A castellated beam section is most efficiently used when bending stress at section B-B is governing stress. However, this is not always possible particularly on the short spans.

Shear Stress analysis

The shear capacity will be governed by the least area either in the vertical web or in the throat length. Maximum shear stress may generally occur in the throat length except in case where the expansion ratio is high when it may occur in the vertical section. The shear stress in the web elements are calculated as follows. The different forces acting on the element are shown in the fig.5. It is required to find horizontal shear at section X-X which is obtained by taking moment at point C.

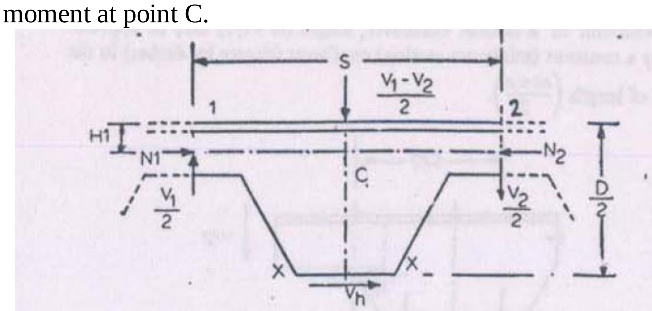

Fig.5 Free body diagram of top segment of the beam.

Free body diagram of top segment of the beam.

$$V_h = \frac{\frac{V_1}{2} X \frac{S}{2} + \frac{V_2}{2} X \frac{S}{2}}{\frac{D}{2} - H_1} = \frac{\frac{S}{4}\,(V_1 + V_2)}{\frac{D}{2} - H_1}$$

If,

$$V_1 = V_2 = V;$$

$$V_h = \frac{\frac{S}{2} X\, V}{\frac{D}{2} - H_1}\ ;$$

$$V = \frac{2\,V_h}{S}\left(\frac{D}{2} - H_1\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.3)$$

IV. RESULT AND DISCUSSIONS

Problem & Definition

Here there is a study of the castellated beam by analyzing the castellated beam with the help of ANSYS WORKBENCH 11. The problem is taken as a 10m span of castellated beam with both end fixed and both and hinged means fixed beam and simply supported beam and fixed beam respectively. The beam is analyzed with 1000pa load on the upper flange of the beam. There is a change in depth of castellated beam from 700 mm to 800 mm with change in expansion ratio from 1.4 to 1.6. The properties of the parent section of the I section is as follow.

ISMB 500 @ 86.9 Kg/m.
Sectional area a = 110.74 cm^2.
Depth of the beam D = 500 mm.
Width of the beam B_f = 180 mm.
Thickness of the web t_w = 10.2 mm.
Thickness of the flange t_f = 17.2 mm.
Slope of flange = 98˚.
Radius at root Y_1 = 17.0 mm.
Radius at toe Y_2 = 8.5 mm.
Moment of inertia I_{xx} = 45218.3 cm^4.
Moment of inertia I_{yy} = 1369.8 cm^4
Radius of gyration r_{xx} = 20.21 cm.
Radius of gyration r_{yy}= 3.52 cm.
Section modulus Z_{xx} = 1808.7 cm^3.
Section modulus Z_{yy} = 152.2 cm^3.

The results obtained are as follows.
Deflection of the castellated beam for the fixed beam as well as simply supported beam for each expansion ratio.
Maximum von mises stresses for each expansion ratio of the castellated beam for fixed as well as simply supported beam.
Maximum strain for each expansion ratio for the fixed beam as well as simply supported beam.
The above results are used to generates,
The relationship between the deflection v/s depth of the castellated beam means depth of the hole.
The relationship between the deflection v/s Expansion ratio of the castellated beam
The relationship between the maximum von mises stresses v/s depth of the castellated beam.
The relationship between the maximum von mises stresses v/s expansion ratio of the castellated beam.
The relationship between the maximum deflection v/s angle of inclination of the castellated beam.

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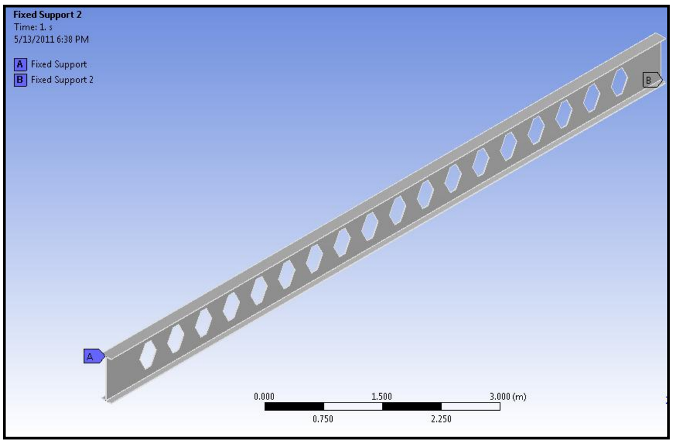

Fig.6 Figure showing the castellated beam analyzed in ANSYS

Results & Discussion

From the problem of castellated beam, the castellated beam is analyzed with same loading with uniformly distributed load of 1000 pa. And the expansion ratio is vary from 1.4 to 1.6 and the depth of castellated beam of parent section ISMB 500 is varying from 700 mm to 800 mm with 2 mm increment with 50 nos. of models.

For this castellated beam, the castellated beam is analyzed and the parameters obtained are as follows.

The maximum deflection of the beam.

The maximum von misses stresses in the beam.

The maximum strain in the beam.

From the above results, the following graphs are plotted

Deflection v/s depth of the castellated beam.

Deflection v/s angle of inclination.

Deflection v/s expansion ratio.

Max. stress v/s depth of castellated beam.

Max. stress v/s expansion ratio.

Table 1 Analysis Results For Fixed beam

Depth	Expansion ratio	DEFLECTION (mt.)	Angle of inclination Ǿ°	Max Stress (N/m2)	Max Strain
700	1.4	2.90E-02	89.84924432	2903000	0.0038215
702	1.404	2.89E-02	89.84924432	2888000	0.00391
704	1.408	2.88E-02	89.84924432	2875000	0.003895
706	1.412	2.85E-02	89.84924432	2849000	0.003938
708	1.416	2.85E-02	89.84924432	2853000	0.003922
710	1.42	2.85E-02	89.84924432	2850000	0.003915
712	1.424	2.85E-02	89.84924432	2848000	0.003904
714	1.428	2.82E-02	89.84924432	2820000	0.00378
716	1.432	2.85E-02	89.84924432	2845000	0.003978
718	1.436	2.83E-02	89.84924432	2834000	0.00404
720	1.44	2.83E-02	89.84924432	2825000	0.003477
722	1.444	2.79E-02	89.84924432	2792000	0.004017
724	1.448	2.78E-02	89.84924432	2776000	0.003352
726	1.452	2.81E-02	89.84924432	2812000	0.00361
728	1.456	2.77E-02	89.84924432	2774000	0.003996
730	1.46	2.83E-02	89.84924432	2830000	0.003579
732	1.464	2.76E-02	89.84924432	2757000	0.004443
734	1.468	2.77E-02	89.84924432	2774000	0.003682
736	1.472	2.76E-02	89.84924432	2758000	0.003738
738	1.476	2.70E-02	89.84924432	2696000	0.00372
740	1.48	2.76E-02	89.84924432	2761000	0.003933
742	1.484	2.74E-02	89.84924432	2740000	0.004307
744	1.488	2.73E-02	89.84924432	2731000	0.003681
746	1.492	2.68E-02	89.84924432	2677000	0.00381
748	1.496	2.67E-02	89.84924432	2668000	0.003742
750	1.5	2.64E-02	89.84924432	2637000	0.003922
752	1.504	2.73E-02	89.84924432	2733000	0.003968
754	1.508	2.71E-02	89.84924432	2706000	0.00377
756	1.512	2.69E-02	89.84924432	2693000	0.00441
758	1.516	2.65E-02	89.84924432	2649000	0.004451
760	1.52	2.64E-02	89.84924432	2642500	0.0043744
762	1.524	2.65E-02	89.84924432	2652000	0.0044183
764	1.528	2.63E-02	89.84924432	2631000	0.003663
766	1.532	2.61E-02	89.84924432	2609000	0.004271
768	1.536	2.66E-02	89.84924432	2658000	0.004251
770	1.54	2.66E-02	89.84924432	2663000	0.0041313

772	1.544	2.68E-02	89.84924432	2683000	0.0047596
774	1.548	2.73E-02	89.84924432	2727000	0.004205
776	1.552	2.69E-02	89.84924432	2692000	0.0046999
778	1.556	2.66E-02	89.84924432	2663000	0.0041142
780	1.56	2.67E-02	89.84924432	2665700	0.004329
782	1.564	2.61E-02	89.84924432	2606000	0.0044138
784	1.568	2.61E-02	89.84924432	2607000	0.004389
786	1.572	2.60E-02	89.84924432	2600000	0.004999
Depth	Expansion ratio	DEFLECTION (mt.)	Angle of inclination Ø°	Max Stress (N/m2)	Max Strain
788	1.576	2.60E-02	89.84924432	2597000	0.004153
790	1.58	2.60E-02	89.84924432	2598000	0.004537
792	1.584	2.61E-02	89.84924432	2605000	0.0045416
794	1.588	2.59E-02	89.84924432	2587000	0.004729
796	1.592	2.59E-02	89.84924432	2591000	0.004518
798	1.596	2.67E-02	89.84924432	2673000	0.005929
800	1.6	2.67E-02	89.84924432	2668200	0.006145

Table 2 Analysis Results For Simply supported beam

DEPTH	Expansion ratio	DEFLECTION (mt.)	Angle of inclination Ǿ°	Max stress (N/mm2)	Max. strain
700	1.400	0.0289	8.0686	8.25570E+06	0.00410
702	1.404	0.0282	8.2979	8.22040E+06	0.00411
704	1.408	0.0299	8.1397	8.56710E+06	0.00428
706	1.412	0.0299	7.4271	7.79510E+06	0.00390
708	1.416	0.0303	7.2068	7.66690E+06	0.00383
710	1.420	0.0282	8.2782	8.21730E+06	0.00411
712	1.424	0.0296	8.1699	8.50770E+06	0.00425
714	1.428	0.0298	8.7681	9.18380E+06	0.00459
716	1.432	0.0297	7.9240	8.26010E+06	0.00413
718	1.436	0.0292	8.8980	9.14980E+06	0.00458
720	1.440	0.0292	9.3287	9.59350E+06	0.00480
722	1.444	0.0293	7.9126	8.13360E+06	0.00407
724	1.448	0.0290	8.3842	8.54040E+06	0.00427
726	1.452	0.0290	8.9157	9.08930E+06	0.00455
728	1.456	0.0289	8.9403	9.08440E+06	0.00454
730	1.460	0.0288	7.8764	7.98010E+06	0.00399
732	1.464	0.0238	10.4910	8.81750E+06	0.00441
734	1.468	0.0272	8.1985	7.83770E+06	0.00392
736	1.472	0.0271	9.0672	8.65080E+06	0.00433
738	1.476	0.0269	8.3480	7.89210E+06	0.00395
740	1.480	0.0269	8.5481	8.12700E+06	0.00405
742	1.484	0.0268	8.5597	8.07970E+06	0.00404
744	1.488	0.0268	8.9154	8.39560E+06	0.00420
746	1.492	0.0266	8.5358	7.98180E+06	0.00399
748	1.496	0.0266	7.5764	7.07110E+06	0.00354

750	1.500	0.0263	9.2911	8.61150 E+06	0.00431
752	1.504	0.0266	8.0277	7.49160 E+06	0.00375
754	1.508	0.0264	7.6996	7.13570 E+06	0.00357
DEPTH	Expansion ratio	DEFLECTION (mt.)	Angle of inclination Ø°	Max Stress (N/m2)	Max. strain
756	1.512	0.0263	8.3364	7.76220 E+06	0.00385
758	1.516	0.0261	7.9280	7.26330 E+06	0.00363
760	1.520	0.0260	9.0920	8.32500 E+06	0.00416
762	1.524	0.0260	9.3691	8.56890 E+06	0.00429
764	1.528	0.0259	9.3866	8.55030 E+06	0.00428
766	1.532	0.0258	9.2224	8.38880 E+06	0.00419
768	1.536	0.0278	7.7793	7.58720 E+06	0.00379
770	1.540	0.0277	7.7678	7.55210 E+06	0.00378
772	1.544	0.0275	7.3665	6.91640 E+06	0.00356
774	1.548	0.0275	8.0522	7.78350 E+06	0.00389
776	1.552	0.0270	7.7719	7.38460 E+06	0.00369
778	1.556	0.0256	9.2882	8.21020 E+06	0.00420
780	1.560	0.0256	8.5492	7.71160 E+06	0.00386
782	1.564	0.0255	8.2324	7.36100 E+06	0.00369
784	1.568	0.0255	8.6428	7.74010 E+06	0.00387
786	1.572	0.0253	8.6334	7.69720 E+06	0.00385
788	1.576	0.0253	9.2956	8.28200 E+06	0.00414
790	1.580	0.0252	8.2142	7.29060 E+06	0.00365
792	1.584	0.0366	6.0063	7.14800 E+06	0.00386
794	1.588	0.0251	8.3646	7.39560 E+06	0.00370
796	1.592	0.0251	9.1568	8.10110 E+06	0.00405
798	1.596	0.0255	7.0070	6.26360 E+06	0.00313
800	1.600	0.0255	7.6264	6.82080 E+06	0.00341

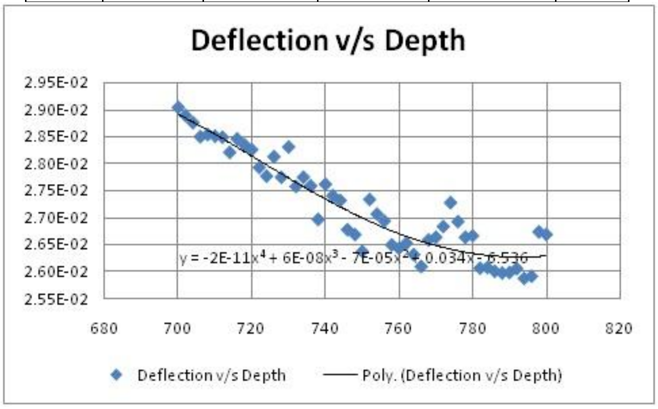

Fig. 7 Deflection v/s Depth of the castellated beam for fixed beam

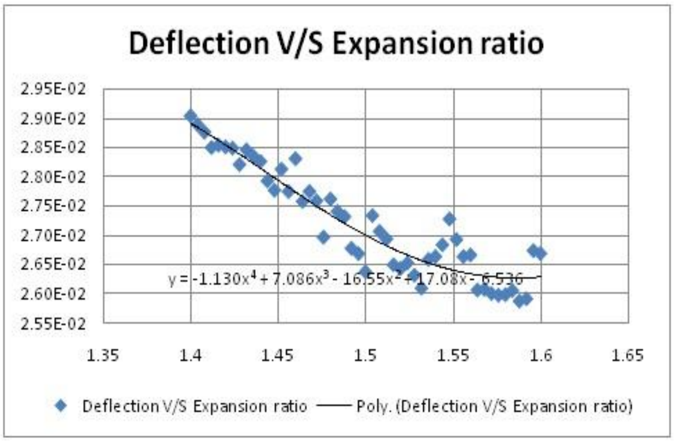

Fig.8 Deflection V/S Expansion ratio of castellated beam for fixed beam

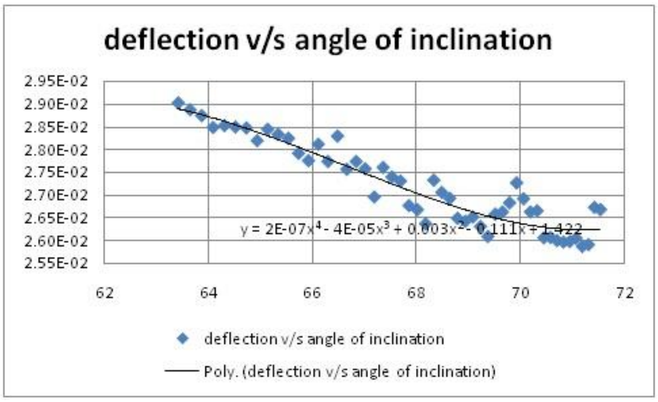

Fig.9 Deflection V/S Angle of inclination of castellated beam for fixed beam

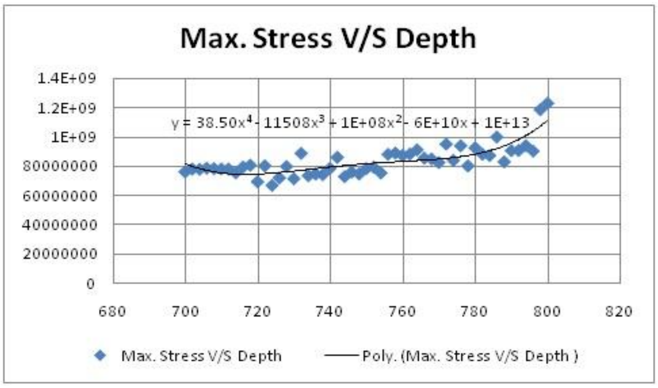

Fig.10 Maximum stress V/S Depth of castellated beam for fixed beam

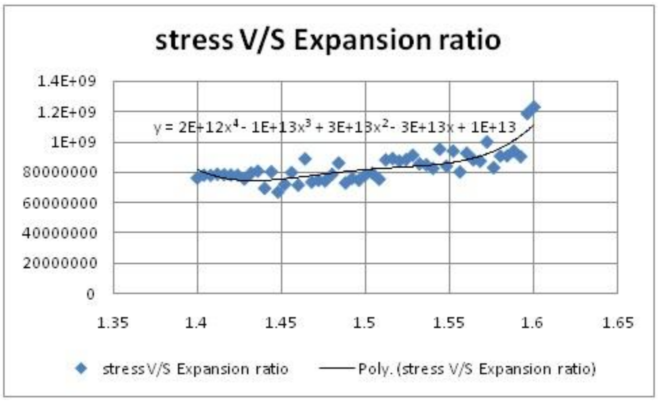

Fig.11 Maximum stress V/S Expansion ratio of castellated beam for fixed beam

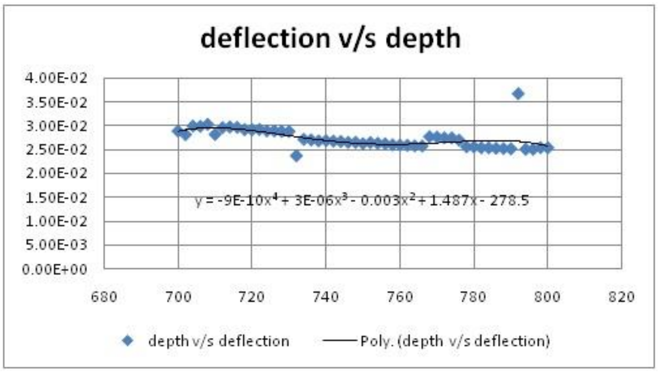

Fig.12 Deflection V/S Depth of the castellated beam for the simply supported beam

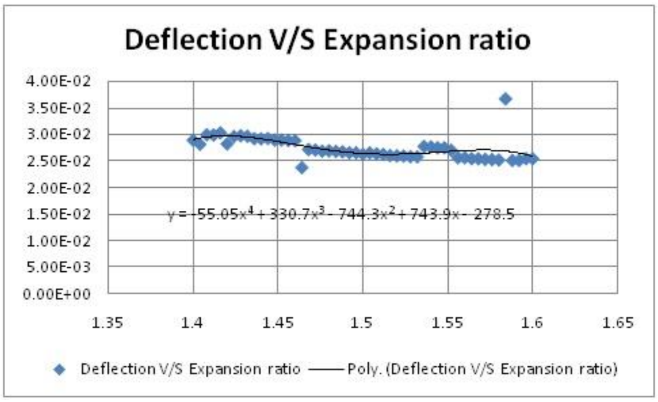

Fig.13 Deflection V/S Expansion ratio of the castellated beam for the simply supported beam

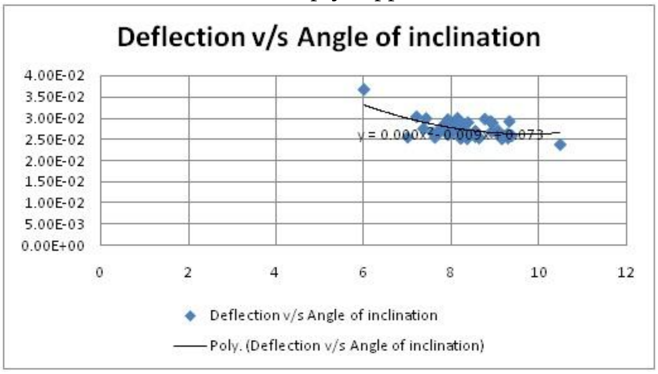

Fig.14 Deflection V/S Angle of inclination of the castellated beam for the simply supported beam

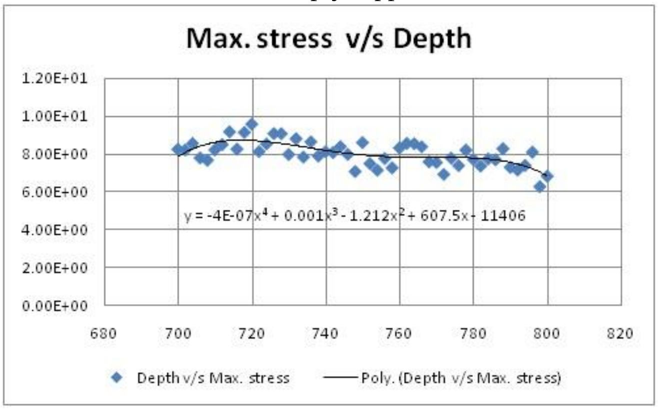

Fig.15 Max. stress V/S Depth of the castellated beam for the simply supported beam

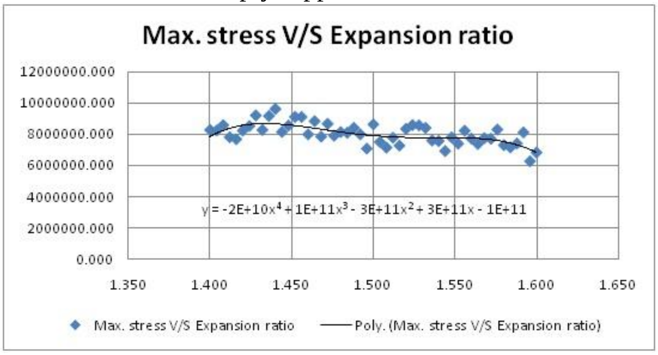

Fig.16 Max. stress V/S Expansion ratio of the castellated beam for the simply supported beam

V. CONCLUSION

The main objective of this thesis is to know the behavior of the castellated beam under static gravity loading, as well as to calculate the minimum deflection of the castellated beam corresponding to expansion ratio, depth as well as the angle of inclination. The following results have been obtained for the castellated beam under static gravity loading for the different and condition. First is the ends have restrained against vertical as well as horizontal displacements only. Second is restrained against the vertical, horizontal as well as rotational.

Table 3 Analysis result summary for Fixed beam

	Deflection (m)	Max. stress (N/m2)	Max. strain
Minimum	2.5870E-02	2587000.0000	0.0034
Depth	7.8800E+02	788.0000	724.0000
Expansion ratio	1.5760E+00	1.5760	1.4480
Angle of inclination	7.0823E+01	70.8234	65.9161

Table 4 Analysis result summary for Simply supported beam

	Deflection(m)	Max. stress(N/m2)	Max. strain
Minimum	2.38000E-02	6263600.00000	0.00313
Depth	732	798.00000	724
Expansion ratio	1.464	1.59600	1.448
Angle of inclination	66.6555	70.82336	71.4210

From the results, it is observed that, for the fixed end beam and simply supported beam, the minimum deflection, Max. von misses stresses and the Max. strain values of the parameters like angle of inclination, depth and expansion ratios are different. So to reduce the stress, strain or deflection, it is obvious to adopt the particular parameters like angle of inclination, depth and expansion ratio.

- As it is observed from the deflection vs depth curve that the deflection is gradually decreasing with increase in depth but after some value of depth it remains constant for a particular intensity of load.
- The similar trends can be observed from the curves of deflection vs expansion ratio, and deflection vs angle of inclination.
- It is observed that stress value attains higher magnitude with higher values of depth of the beam.
- The similar trend can be observed from the curve of stress vs expansion ratio, and stress vs angle of inclination.
- Defferent boundary conditions affect the deformation parameters of the beam.

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