International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2015): 6.391

Cable Stayed Portals

Pramod V. Deshmukh

Principal, Dr. Panjabrao Deshmukh Polytechnic, Amravati-444603
(Government of Maharashtra Aided Institute)

Abstract: ***Cable stayed structure in general is a structure in which high strength cables are used to provide intermediate support to the structure. Portal frames are the two dimensional rigid frames that have the basic characteristics of a rigid joint between column and beam. The main objective of this form of design is to reduce bending moment in beam which allows the frame to act as one structural unit. An attempt to use the principle of cable staying in building construction is the essence of the present work. The beam in the portal frame are supported at intermediate points by cables, which resulted in strengthening the beam. The load carrying capacity of the beam is increased for the same cross-section or the depth of the beam can be reduce for carrying the same load which resulted in overall economy of the structure. In present study the bent up bars of tensile reinforcement are taken out from beam and anchored in column which serves the purpose of cable stay on both side of beam. The analysis for single storey two bay portal, with and without cable stay, are carried out and deflection, bending moment formulae for cable stayed portal are presented. It is observed that there is a considerable reduction in deflection bending moment in cable stayed portal as compared to simple portal. Thus, the load carrying capacity of cable stayed portal increases considerably as compared to simple portal and hence for the same span and loading the cable stayed portal is ecomical than the simple portal.***

Keywords: Simple portal, cable stayed portal, hanger, suspension, space roof structures, bridges.

1. Introduction

High strength steel cables have been used extensively over the past so many years for space roof structures, bridges in which steel cables were used only for suspension of the main roof structure, which can be either conventional, e.g. beams, cantilever, etc., or a space frame. In this case, the main roof structure, instead of being supported, is actually suspended from steel cables above the roof, which transmit the tensile forces to appropriate anchorages (1) They are cable stayed structures. This type of construction are in used as industrial buildings where the roof structure, either as a single or a double cantilever, is suspended from cables, which in turn are anchored on robust pylons above the roof level. In this type of construction, the cables behave as simple suspension elements, while the roof structure itself behaves like a normal load resisting unit subjected to moments shear and other kinds of action. It is expected that suspending elements remain in tension due to the acting loads. The study of cable stayed bridges started from 1784, but the first modern cable stayed bridge was constructed in 1955 in Sweedon named as 'Stromsund Bridge'. This tremendous gap between 1784 to 1955 for the development of the above technique is because of non-availability of high tensile steel.(2)

A cable stayed portals in general is a structure in which high strength cables provide intermediate support to beam and hence depth can be reduced for the same load or providing the same depth, span can be increased.

In present study, the principle of cable staying is incorporated in building structure. The beams supported at intermediate points by hangers with different inclinations were made during 1975-76(8), cabel inclined inward, cable inclined outward and cable vertical, and it was found that the load carrying the beam having any type of cable support is more that of the ordinary beam without hangers. Among these three cable inclined outward have more capacity than that of other two configurations and their load carrying capacity is about 20% more than ordinary beam. Hence, they found to be more economical than the ordinary beam.

In this paper the analysis of single storey two bay cable stayed portals is presented. The deflection, moment formulae thus arrived at through the analysis are compared with the deflection, moments of single storey two bay simple portal of same size and span. Deflection are calculated analytically for a sample case by assuming the size of column, beam and span in a such way that there will be ease in casting, handling and testing in future study to compare the results arrived at with the actual laboratory test results. In analytical analysis it is found that the deflection of the cable stayed portals are less as compared to simple portals. Thus the cable stayed portals are quite strong and stiff than sample portals.

2. Analysis of Cable Stayed Portals

Portals are the structure consisting of beams and columns rigidly connected at joints. The analysis of single storey two bay symmetrical portals have been carried out by moment distribution and the principal of superposition is used to arrive at the final moment and deflection for cable stayed portals. For cable staying the bent up bars of tensile reinforcement are taken out of the beam at $1/5^{th}$ of span from support inclined at 45^0 to the axis of beam on either side of beam and firmly anchored in the column overhang specially provided for this purpose. Analysis for both end conditions, i.e., column ends hinged and column ends fixed are carried out. For moment distribution usual sign convention, i.e., clockwise moments are taken as positive and anticlockwise moments are negative is used. For bending moment the sagging moments are positive and hogging moments are negative is used. Upward deflections are considered to be positive and downward deflection as negative.

3. Moments for Cable Stayed Portals

1. Portal with column ends hinged -

Final moments for u.d.L. of w unit per unit length and span = Lm are -

$$MAB = 0$$

$$MBA = +\frac{3wL^2}{68} + \frac{9L(9F_1^{'} - 4F_2^{'})}{2125}$$

$$MBC = -\frac{3wL^2}{68} + \frac{8L(43F_1^{'} + 4.5F_2^{'})}{2125}$$

$$MCB = +\frac{7wL^2}{68} - \frac{32L(F_1^{'} + 9F_2^{'})}{2125}$$

For the remaining half portion of the portal, the moments are same with reverse sign.

2. Portal with column ends fixed -

Final moments for u.d.L. of w unit per unit length and span = Lm are -

$$MAB = +\frac{wL^2}{40} + \frac{3L(4.5F_1^{'} - 2F_2^{'})}{625}$$

$$MBA = +\frac{wL^2}{20} + \frac{3L(9F_1^{'} - 4F_2^{'})}{625}$$

$$MBC = -\frac{wL^2}{20} + \frac{2L(49F_1^{'} + 6F_2^{'})}{625}$$

$$MCB = +\frac{wL^2}{10} - \frac{L(11F_1^{'} + 84F_2^{'})}{625}$$

Where, $F_1^{'}$ = Component of cable tension F_1 at L.H.S. column.

$F_2^{'}$ = Component of cable tension F_2 at column central.

For the remaining half portion of the portal, the moments are same with reverse sign.

4. Moments for Simple Portals

1. Portal with column ends hinged -

Final moments for u.d.L. of w unit per unit length and span = Lm are -

$$MAB = 0$$

$$MBA = +\frac{3wL^2}{68}$$

$$MBC = -\frac{3wL^2}{68}$$

$$MCE = -\frac{7wL^2}{68}$$

For the remaining half portion of the portal, the moments are same with reverse sign.

2. Portal with column ends fixed -

Final moments for u.d.L. of w unit per unit length and span = Lm are -

$$MAB = +\frac{wL^2}{40}$$

$$MBA = +\frac{wL^2}{20}$$

$$MBC = -\frac{wL^2}{20}$$

$$MCB = +\frac{wL^2}{10}$$

$$MCB = -\frac{wL^2}{10}$$

For the remaining half portion of the portal, the moments are same with reverse sign.

5. Numerical Example

In future study, it is proposed to verify the analytical observations and results by actual laboratory test of the cable stayed portals. Hence, for simplicity and owing to the limitations in handling and testing of model in laboratory, the size of portal members considered for the analysis are-

Size of column and beam = 60 mm x 80 mm, C/c span of beam = 1.00 m

Total height of column = 1.00 m, out of which 2/3 metre is taken as the effective height upto beam axis and 1/3 metre is projecting above, which is used for anchoring the bars acting as hangers.

Grade of concrete used M200
Reinforcement provided as -

Column - 4 Nos 3 mm Φ with 3 mm two legged lateral ties 200 mm c/c

Beam - 5 Nos. 3 mm Φ as tensile reinforcement out of which 2 bars are bent up bars, bent at L/5 from the column centre at an angle of 45^0 to the axis of beam, 2 Nos. 3mm θ are provided at top with stirrups of 3mm Φ at 200mm C/c.

The bent up bars are taken out of the beam for anchoring in the column in cable stayed portals, where as they are provided at top in simple frame at support.

6. Deflections

Deflections are calculated at three points along span, i.e., Y_1 at x= 200 mm, Y_c at x= 500 mm and Y_2 at x=800mm.
Final deflection are calculated as -

1) deflections due to u.d.L. of w KN/m over beam
2) deflections due to cable tension $F_1^{'}$ and $F_2^{'}$ upward component of cable tension F_1 and F_2
3) deflection due to moments

The net deflection at any section is the algebraic sum of all these deflections, at that section.

These deflection equations are in terms of F_1', F_2' and w. Hence, the values of F_1' and F_2' are calculated in terms of w. For these purpose, elongation of cables and rotation of hanger points and their deflection are considered.

1) For column ends hinged, the values of F_1' and F_2' in terms of w are found out to be -

$$F_1' = 0.0000236w \quad and \quad F_2' = 0.00311w$$

2) For column ends fixed, the values of F_1' and F_2' in terms of w are found out to be-

$$F_1' = 0.00052w \quad and \quad F_2' = 0.0301w$$

General Formulae for Deflections -

After substituting the values of F_1' and F_2' in deflection equations and their algebraic sum at respective points gives the general formulae for computing deflections at that point -

1) Considering column support hinged -

(i) Cable stayed portal

$Y_1 = 0.069w$ mm

$Y_2 = 0.0314w$ mm

$Y_c = 0.097w$mm

(ii) Simple portals

$Y_1 = 0.0789w$ mm

$Y_2 = 0.0464w$ mm

$Y_c = 0.1307w$ mm

2) Considering column ends fixed -

(i) Cable stayed portals

$Y_1 = 0.0628w$ mm

$Y_2 = 0.0287w$ mm

$Y_c = 0.1w$mm

(ii) Simple portals

$Y_1 = 0.073w$ mm

$Y_2 = 0.0456w$ mm

$Y_c = 0.1245w$ mm

Where, Y_1 deflection at 200 mm from L.H.S.

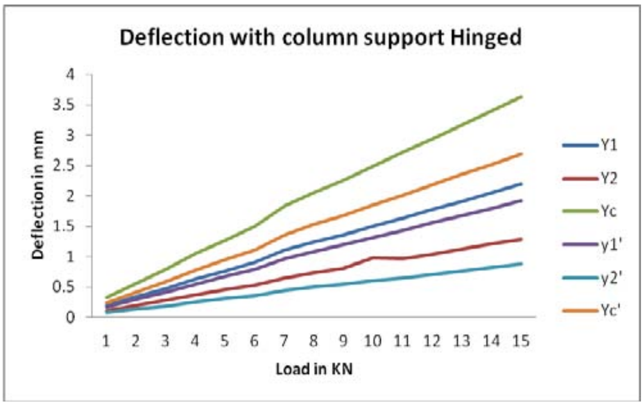
Y_2 deflection at 800 mm from L.H.S.

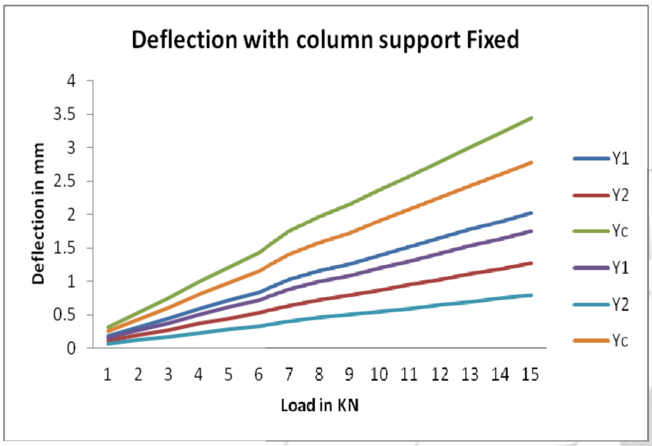
Y_c deflection at centre of beam

Note : All deflections Y_1, Y_2 and Y_c are in the downward direction, hence -ve as per sign convention.

Table showing the deflection at various points aong the span of beam for a sample numerical example

S. N.	Load in KN	Deflection for simple portal in mm						Deflection for cable stayed portals in mm					
		Column Eng Hinged			Column Eng Fixed			Column Eng Hinged			Column Eng Fixed		
		Y_1	Y_2	Y_c	Y_1	Y_2	Y_c	Y_1'	Y_2'	Y_c'	Y_1'	Y_2'	Y_c'
1	2.5	0.1972	0.116	0.3267	0.1825	0.114	0.3112	0.1725	0.0785	0.2425	0.157	0.0717	0.25
2	4.25	0.3353	0.1972	0.5554	3102	0.1938	0.5291	0.2932	0.1334	0.4122	0.2669	0.1219	0.425
3	6	0.4734	0.2784	0.7842	0.438	0.2736	0.747	0.414	0.1884	0.582	0.3768	0.1722	0.6
4	8	0.6312	0.3712	1.0456	0.584	0.3648	0.996	0.552	0.2512	0.776	0.5024	0.2229	0.8
5	9.75	0.7692	0.4524	1.2743	0.7117	0.4446	1.2138	0.6725	0.3061	0.9457	0.6123	0.2798	0.975
6	11.5	0.9073	0.5336	1.503	0.8395	0.5244	1.4317	0.7935	0.3611	1.1155	0.7222	0.33	1.15
7	14	1.1046	0.6496	1.8298	1.022	0.6384	1.743	0.966	0.4396	1.358	0.8792	0.4018	1.4
8	15.75	1.2426	0.7308	2.0585	1.1497	0.7182	1.9608	1.0867	0.4945	1.5277	0.9891	0.452	1.575
9	17.25	1.361	0.8004	2.2545	1.2592	0.7866	2.1476	1.1902	0.5416	1.6732	1.0833	0.495	1.725
10	19	1.4991	0.9816	2.4833	1.387	0.8664	2.3655	1.311	0.5966	1.843	1.1932	0.5453	1.9
11	20.75	1.6371	0.9628	2.712	1.5147	0.9462	2.573	1.4317	0.6515	2.0127	1.3031	0.5955	2.075
12	22.5	1.7752	1.044	2.9407	1.6425	1.026	2.79	1.5525	0.7065	2.1825	1.413	0.6457	2.25
13	24.25	1.9133	1.1252	3.1694	1.7702	1.1058	3.007	1.6732	0.7614	2.3522	1.5229	0.6959	2.425
14	26	2.0514	1.2064	3.3982	1.898	1.1856	3.224	1.794	0.8164	2.522	1.6328	0.7462	2.6
15	27.75	2.1894	1.2876	3.6269	2.0257	1.2654	3.441	1.9147	0.8713	2.6917	1.7427	0.7964	2.775





7. Result

The analysis for portal with cable stay at L/5 from the column support on both side of beam for single storey two bay portals is carried out by assuming the uniformly distributed load of w unit per unit of length and span=L m. The formulae for calculation of moments for cable stay portals and simple portals are presented. The formulae are useful for calculation of moments at various section of similar cable stay portals for various loads, sections and span and respective bending moments diagram can be drawn and compared with the bending moments of simple portals.

Numerical example for a sample case is analysed for deflection and the deflection at various sections are presented for cable stayed portal and simple portal for column support as hinged and fixed in tabular form.

From the graph and table it is observed that there is a considerable reduction in the deflections for cable stayed portals than the simple portal. Thus the cable stayed portal are strong and stiff than the simple portal. Due to intermediate support to beam by stay, the moments for cable stay portals are also less than the simple portals for the same section, load and span. Hence, the load carrying can be increased by cable staying or the section can be reduced for the given load which results in the overall economy of structure.

8. Conclusion

Principle of cable staying is applied in building construction and the analysis of portal frame with cable stay is presented in this paper. The bent up bars in tension reinforcement are utilised for providing the stay and upper columns as hangers for anchoring. From the analysis and results it is concluded that the cable stayed portals can be effectively use in the building. There is a considerable reduction in deflections which shows that the cable stayed portals are stiff than the simple portals. Also because of the intermediate support there is reduction in moments and load carrying capacity increase due to cable staying. The cable stayed portals are economical because for the same load the section can be reduced.

References

[1] Design considerations in cable-stayed Roof structures by Lawerence A. Kloiber, P.E., Davit E. Eckmann, A1A. SE., P.E. Thomas R. Meyar, S.E. and stephanie J Hautzinger, AIA, S.E., North American steel conference, March 2004, Modern steel construction.
[2] Design of Bridge Superstructure - Prof. Colin O' Connor
[3] Journal of Structural Division - Vol.98, Jul-Dec. 1972
[4] Journal of Structural Division - Vol.98, Jan-Jun-March 1972
[5] Journal of Structural Division - ASCE, Vol.97, No.ST,- Jan 1971
[6] Journal of the institution of Engineers (India) Civil Engg. Division - Vol.56, Part CI_3 and CI_4 Nov.1975, Jan. 1976
[7] Transactions of ASCE - Vol. 139, 1974
[8] Dissertation "Cable stayed Girder Bridges" Guided by Prof. P. S. Godbole, Nagpur University, 1975-76.