Approach to Analyze and Design V Shaped Beams

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Abstract

This instructional paper emphasizes on a very common structural situation faced by designers, how to approach the analysis of a V shaped or corner beams. In this paper, an example is solved first using SAP2000 and then manually implementing appropriate theory for such a problem. This paper not only covers analysis of V shaped beams but also explains the approach taken by FEM software for the same.

Keywords : **Beam curved at right angle, corner beam, V shaped beam**

I. INTRODUCTION

Beams curved in plan are used to support curved floors in buildings, balconies, curved ramps, and halls [1]. In a curved beam, the centre of gravity of the loads acting normal to the plane of curvature lies outside the line joining its supports. This situation develops torsional moments in the beam in addition to bending moments and shearing forces. To maintain stability of beam against overturning, the supports must be fixed or continuous[1].

In designingof frame structures whether residential or commercial, therewill always be V shaped beam or beams meeting at right angle, especially in the corners. Now as a designer it is a dilemma on how to approach this kind of configuration.

There are mainly two scenarios emerging in such a condition.

(1) Dividing a V shaped beam into two cantilever beams intersecting at a joint.

(2) Dividing a V shaped beam into a cantilever and a beam simply supported on first cantilever.

This is not a correct approach to this problem.

II. PROBLEM FORMULIZATION

In this instructional paper a V shape beam uniformly distributed loading using SAP2000 is anaalyzed and the results are tabulated here. The same problem is analyzed with manual calculations using strain energy principle. Comparison between two results affirms our approach to analysis of a V shaped beam.

Analysis using SAP2000

Two beams 5 feet long intersect at right angles at the corner of the building. Member properties and Loads are shown in Table I and II respectively. Fig. 1 shows the plan and Fig. 2 shows bending moment.

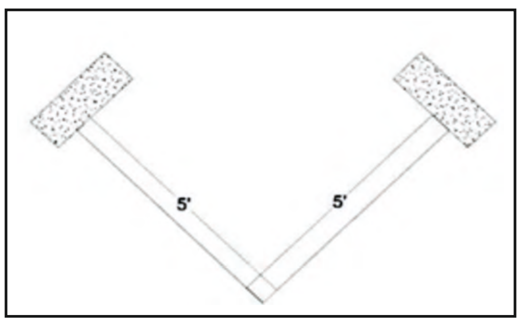

Fig. 1. Plan

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Analyzed the structure (Fig. 1) for a load combination of 1.5 Dead + 1.5SDead using SAP2000.

Moments from the analysis are tabulated in Table III along with the BM diagram (Fig. 2).

III. MANUAL ANALYSIS

A. Theory

As per Hassoun and Manaseer [2], in order to analyze such beams, strain energy principles should be applied to correctly assess actual distribution of internal forces and internal stresses as torsion.

For this, consider a very common case of a V-shape beam fixed at its both ends carrying a uniform load w (kN/m). The following be the expressions for Bending and Torsional moments for such case:

Moment at the centre line of the beam, section C

TABLE I.
MEMBER PROPERTIES

Cross-Section	12 inches x 24 inches
Cover	40 mm top and bottom
Grade of Concrete	M25
Grade of Steel	Fe500

TABLE II.
LOADS

Loads	
Self Weight	To be calculate by software
Member Load from 9 inches thick 8.5 feet high wall	0.228 x 2.5908 x 20 (unit load of masonry) = 11.81kN/m

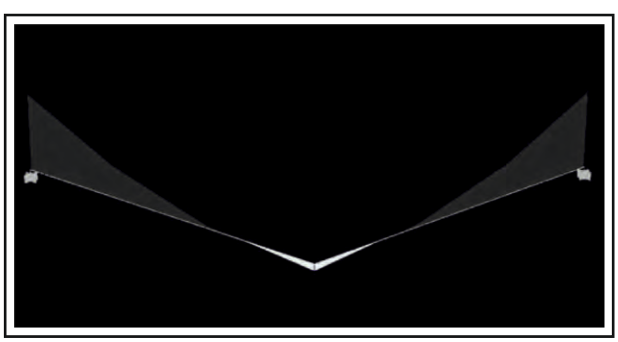
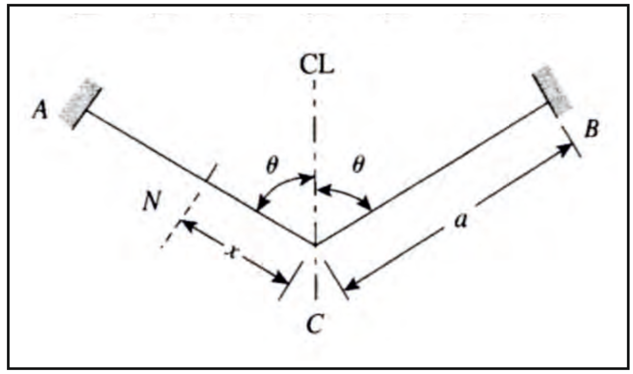
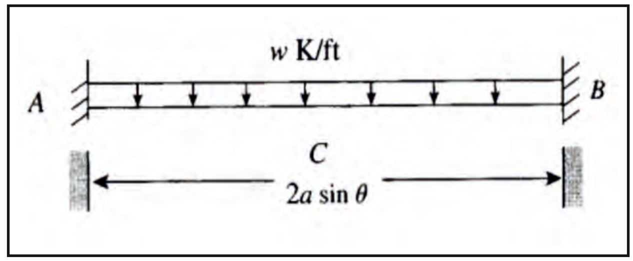


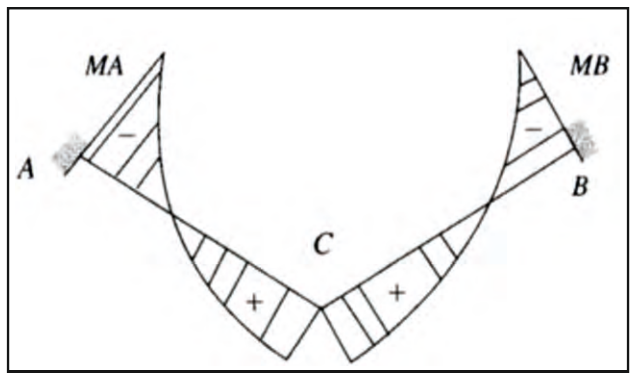
Fig. 2. Bending Moment Diagram



(a) Plan



(b) Uniformly Distributed Load Over the Beam



(c) Bending Moment Diagram

Fig. 3. V shape Beam Under Uniformly Distributed Load

(M_c), is calculated as follows [1]:

$$M_c = wa^2\,[\sin^2 Y/\{6\sin^2 Y + \lambda\cos^2 Y\}] \qquad (1)$$

Where,

$\lambda = EI/GJ$;

a = half the total length of the beam ;

Y = half the angle between arms of the V.

Fig. 3 shows V shape beam under uniformly distributed load

The torsional moment (T_c) at the centre line section is

$$T_c = (M_c/\sin Y)\ x\ \cos Y = M_c \cot Y \qquad (2)$$

Now the bending moment M_N and torsional moment T_N

TABLE III.

MOMENT VALUES

S.No.	Location	Moments
1	Fixed End A	26.53 kNm
2	Joint B	2.12 kNm
3	Fixed End C	26.53 kNm

at any section N along half the beam AC or BC at a distance x from section C are calculated as follows:

$M_N = M_C - w(x^2/2)$ (3)

$T_N = T_C = (M_C/\sin Y) \times \cos = M_C \cot Y$ (4)

At supports, $M_A = M_C - w(a^2/2)$ (5)

$T_A = T_C = M_C \cot Y^1$ (6)

B. Calculations

Modulus of Elasticity, $E = 5000\sqrt{f_{ck}} = 5000\sqrt{25} = 25{,}000$ MPa (7)

Where f_{ck} is the characteristic compressive striength of concrete

Shear Modulus, $G = E/2(1+\eta) = 25000/2(1+0.2)$
$= 12{,}254.90$ MPa (8)

Where η is Poisson's Ratio

Moment of Inertia, $I = bd^3/12 = (305 \times 610^3)/12$
$= 5{,}769{,}100{,}417 mm^4$ (9)

Where,

b width;

d depth.

Polar Moment of Inertia, $J = (1/12)(bd^3 + db^3)$
$= (1/12)(305 \times 610^3 + 610 \times 305^3) = 7{,}211{,}375{,}521 mm^4$

(10)

$\lambda = EI/GJ = 1.63$ (11)

w = 1.5(self weight + imposed load) = 24.69 (12)

self weight = 4.65kN/m (13)

imposed load = 11.81kN/m (14)

$M_c = wa^2[\sin^2 Y/\{6\sin^2 Y + \lambda\cos^2 Y\}]$

$= 24.69 \times 1.524^2 [\sin^2 45°/\{6(\sin^2 45° + \lambda\cos^2 45°)\}]$

TABLE IV.

COMPARISON OF MOMENTS

S.No.	Location	Moments (SAP2000)	Moments (Manual)
1	Fixed End A	26.53 kNm	25.04 kNm
2	Joint B	2.12 kNm	3.63 kNm
3	Fixed End C	26.53 kNm	25.04 kNm

=3.63 kNm

$M_A = M_B = M_C - wa^2/2 = -25.04$ kNm (15)

Where, M_A Moment at end A;

M_B Moment at end B.

Torsional Moment = $T_A = M_C \cot Y = 3.63$ kNm (16)

Shear at support A and B is V_A and V_B respectively $= V_A = V_B = 24.69 \times 1.524 = 37.62$ kN (17)

IV. RESULT

Table IV shows the comparision of Moments calculated by the software along with manual calculations.

It is evident from the comparison that the moments obtained manually are almost similar to the moments obtained using SAP2000. This proves that the right approach to analyzing a V shaped beam is the one covered in detail in this paper.

V. CONCLUSION

The topic included in this instructional paper is extremely common for Structural Designers but the general approach to it is lacking. Though FEM software has the right tools to analyze such beams, it depends on how the designer is conceptualizing the structure.

In this paper, the writer tries to explain the theory behind the analysis and design of a V shaped beam and its verification using Sap2000.

AUTHOR'S CONTRIBUTION

Aqeel A S Wagla Wala worked alone on this research and preparation of manuscript.

CONFLICT OF INTEREST

The author certifies that he has no affiliation with or involvement in any organization or entity with any financial interest, or non-financial interest in the subject matter, or materials discussed in this manuscript.

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About the Author

Er. Aqeel A S Wagla Wala is a Structural Engineer with about 13 years of experience in industry as well as in academics. He is always keen on research and looks forward for opportunities where he can put his education and experience to use for the development of Civil Engineering.