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Numerical Studies on Non-Prismatic Members

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***Abstract*—This study compares the design and analysis of Non-Prismatic member and Prismatic Member of same Load capacity. It has been observed from the results that deformation in Non-Prismatic members is relatively more when compared to Prismatic ones, but the Maximum Normal stresses due to bending is 531MPa , which is lower when compared with 839MPa of Prismatic Beam. A comparatively lower maximum shear stress is observed in Non-Prismatic section. Volume is reduced by 40% so is the self weight by 42%.**

***Index Terms*—Non-Prismatic members, Normal Stress, Shear stress, Stiffness.**

I. INTRODUCTION

Prismatic beams are designed for the maximum bending moment at a section. Bending moment is maximum at the centre of the beam, so the depth required to resist the bending moment at the centre of the beam is taken for the whole span, for the ease in fabrication. But every section on the beam has different bending moment, so the depth required to resist that Bending Moment is different, this is where Non-prismatic members comes into picture.

Non-prismatic members are the beams in which the depth of the beam varies depending upon the moment it has to resist at a particular section.It is obvious that bending moment due to Dead and live Loads at the centre of the beam is maximum, so more depth has to be provided in order to resist this Moment. In other words, any section on the beam should be of the optimum depth to resist the stresses due to the externally applied loads, Garbett et.al.[1]. These beams are aesthetically more appealing than the Prismatic beams due to their varying depth, which take the shape of the curve. The curve is the optimized shape of the beam and the further optimization based on the shear force is done by Bailliss [2]. Due to complexity in the shape these beams are difficult to fabricate. Skilled labors are required for the fabrication as well as casting of such beams, So these beams cant be used for general construction. But all of the above mentioned disadvantages can be improved if these beams are pre-cast as stated by Orr et.al[3] as the conditions in precast are controllable and the workers are skillfull.

In this research, designing of the members will be based on bending moment at each section of the beam and other effects will be neglected. By equating bending moment to moment of resistance, the depth at any section can be calculated and this equation is given by Orr et.al.[4],and is used for the calculation of depth at particular section and hence the beams are designed using specification given in British standardscode of practice for Designing and Construction[5] and Euro code 2[6], modeled and analyzed on the Ansys, as the similar setup has been tested by real life simulation and the deflection values were calculated by digital image correlation by Orr et al.

II. METHODOLOGY

Two simply supported beams were modelled in Catia v5 Sofware package, one being the Prismatic beam, as the reference beam and the other was the Non-prismatic beam. Then these models were exported to Ansys 14 workbench for the Analysis. After the analysis, results of both the beams were compared and the inference was projected in the conclusion

III. PROCEDURE

The span and the width of the two beams was kept constant as 5*m*and 250*mm* and the only varying dimension was the depth of the beam which was constant 500*mm* for the prismatic beam and varied for the Non-prismatic member and the equation for the varying depth is given in Section IV. Same breadth and the span of the beam was taken for the convenience of the comparison of results. The dimensions of the Prismatic beam are given as 500*mm x* 100*mm x* 100*mm*.

Next step was to calculate the dimensions of the Nonprismatic beam, which was done by dividing the span in N equal sections, for this research N was taken as 10, which means five from each side of the centre. Then the bending moment was calculated on each section. Specifications given is British code for Design and construction were used to calculate depth of the beam at each section which provided the Longitudinal profile of the the beam.

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After the dimensions were determined for both the beams, Both of the beams were modeled in Catia V5 and then exported to Ansys. Both the beams had support conditions as Frictional roller, the supports itself were fixed as shown in Fig. 1 and Fig. 2 and were loaded with pressure of 29.6 MPa acting downwards. The beams were checked for normal stress, Total shear stress and total deformation deformation and the results were compared in Section V.

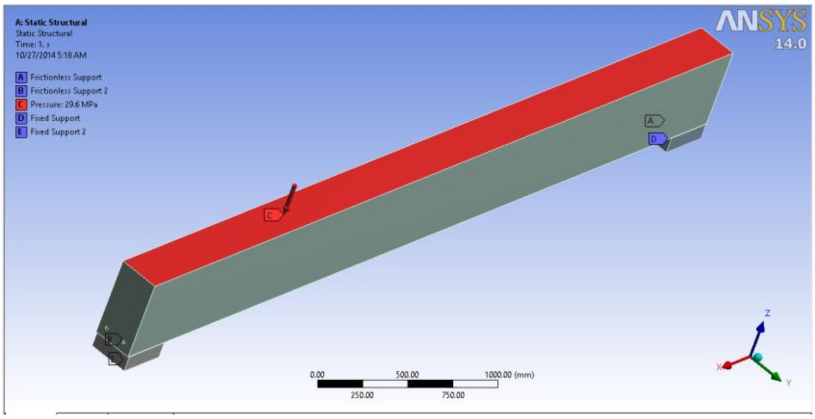

Fig 1. Support and Loading conditions of Prismatic section.

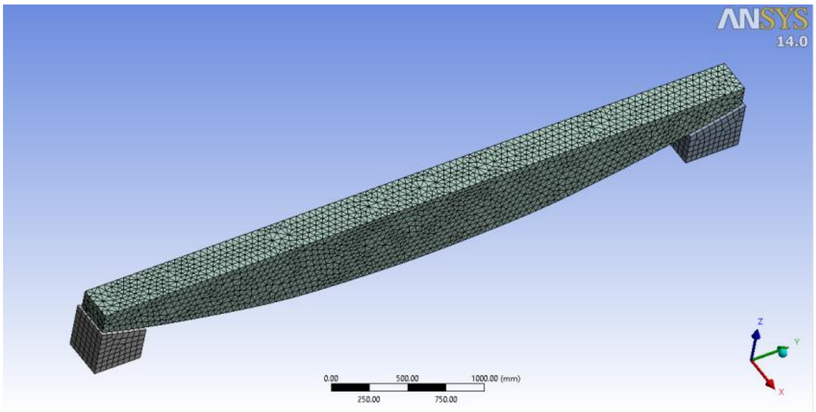

Fig 2. Support and loading conditions of Non-Prismatic Sections

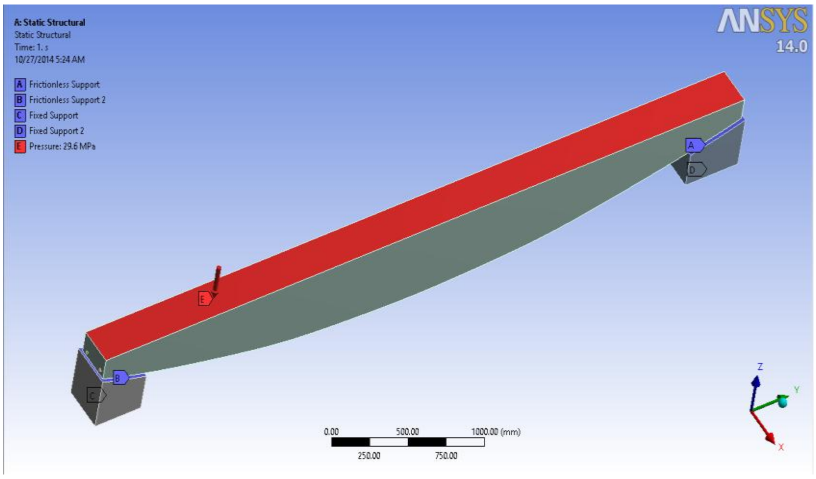

Fig 3. Meshed Model Non Prismatic Section.

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IV. DESIGN

A. Design of Prismatic Beams

The prismatic beam to be designed was taken as the reference beam with which the results of the actual non-prismatic member were compared. To design the reference beam an arbitrary beam with D as 500mm and B as 250 mm was taken. Length of the beam was assumed 5 meters and the span was same for both the samples. The loads that were considered while designing this beam were live and dead loads. The total load per meter acting on the beam was calculated as follows from British code.

$TotalLoad = 1.5g_k + 1.6q_k = 29.6kN/m$

Where $g_k$is the Self weight Factor of safety and $q_k$is the Live load Factor of safety.

Moment at the centre is maximum for the UDL and is given by$WL^2/8 = 92.5kN - m$

Area of steel is for the section is calculated by the following equation

$Ast = M/0.87f_y xz = 674mm^2$

Where $z = 0.5 + (0.25 - k/0.9)^{0.5}$ $and k = M/f_{cu}bd^2$.

B. Design of Non-Prismatic Beams

The same span of this beam was taken same as the Prismatic one, but the depth profile was calculated based on the equation 1. In other words depth was varying with the cross section.Beam was divided into 10 equal parts and bending moment at each section was calculated. As the bending moment of the UDL simply supported beam varies parabolically so does the depth. The equation by which depth at any section of the beam was calculated is given below.

$Depth = 0.45\,x + Z + \varphi/2 + C,\ z = M/F_s$

$M = Wx^2/2, F_s = 0.87f_y Ast.$

Where φ is the diameter of the bars, Z is the section modulus; X is the depth of the neutral axis from the top. The equation for the depth profile of the Non-Prismatic member is as follows.

$$116.1((74-14.4x^2)/243347)+10+25 \quad (1)$$

As seen in the above equation the only variable is x, which is the variation in the span of the beam. So Depth at any point on the span can be calculated. For simplicity, Span was divided into ten equal sections and at each section the depth was calculated and is tabulated in Table 1.

Table 1. Depths for chosen sections for Non Prismatic members.

S.No.	Section	Depth
1	S1	151.10mm
2	S2	287.90mm
3	S3	394.37mm
4	S4	478.39mm
5	S5	516.00mm
6	S6	530.00mm
7	S7	516.00mm
8	S8	478.39mm
9	S9	394.37mm

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10	S10	297.90mm
11	S11	151.10mm

V. RESULTS AND DISCUSSION

Samples were exported to Ansys workbench and were meshed to 30mm element size. The support conditions given were simply supported and the supports itself were kept fixed and a constant pressure of 29.6 MPa was applied to both the beams as shown in Figure 1 and Figure 2.

The analysis was run and the beams were tested for Deformation, Normal stress and Maximum shear stress. The results so obtained were compared in the following section.

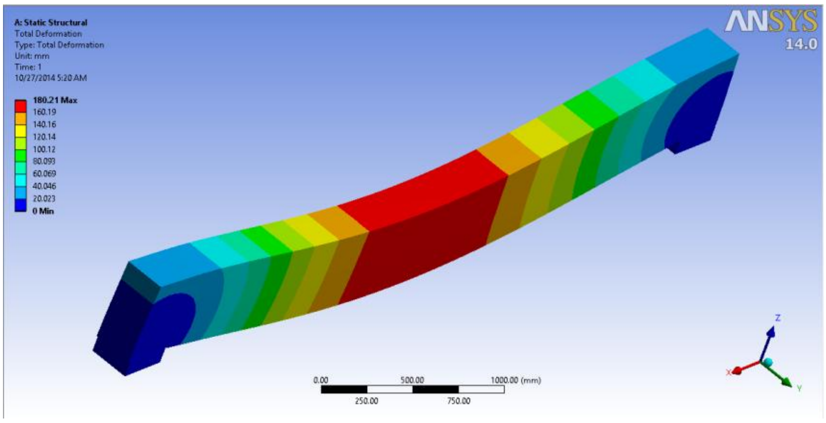

Fig 4. Total Deformation of Prismatic Member.

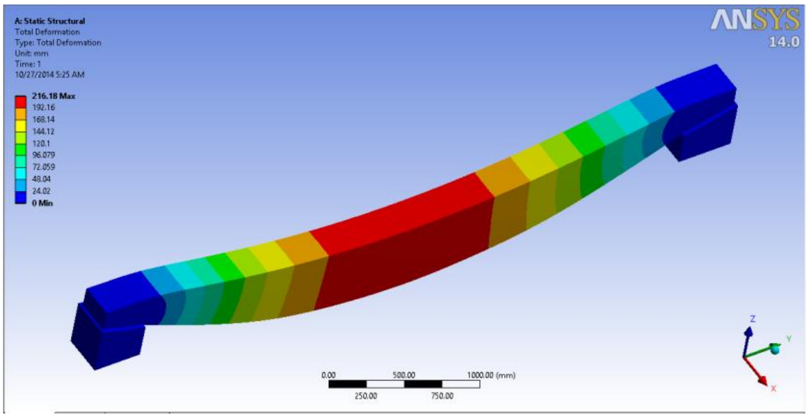

Fig 5. Total Deformation of Non. Prismatic Member

From Figure 4 and Figure 5 , the maximum deformation inthe Non-Prismatic member is 216.68*mm* and that of prismatic member is 180.21*mm*. The deflection in the Non-Prismatic member was relatively more than that of Prismatic beam and the reason for that is the beam stiffness is more for the prismatic member, as we know that deflection is inversely proportional to the depth of the member and as the depth in the Non-Prismatic member varies and decreases from centre to the supports of the beam, so the deformation in the Non-prismatic member is more as there is less confinement to the sections in the beam as the depth is decreasing from the centre of the beam. The beams were also checked for shear and normal stress and the results are depicted in the following figures

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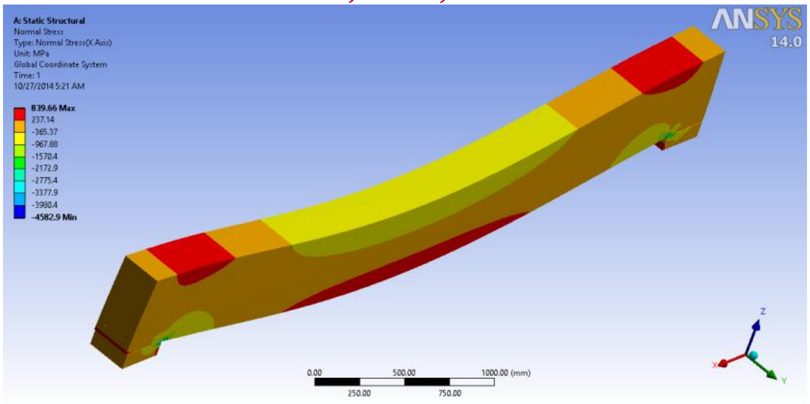

Fig 6. Normal Stress contours of Prismatic Member.

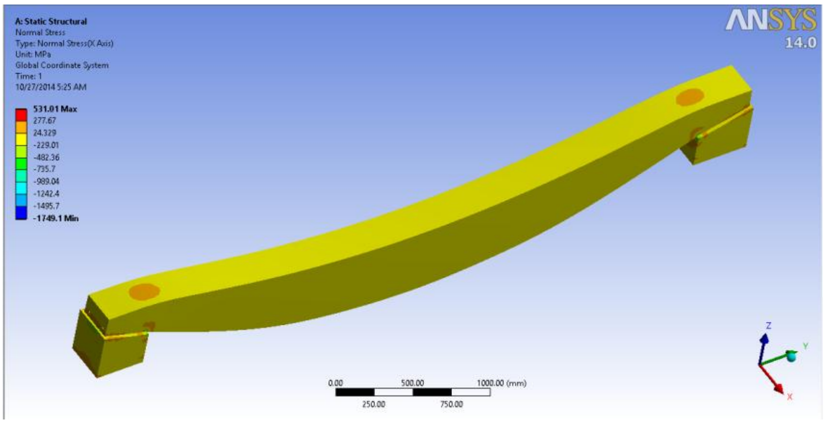

Fig 7. Normal Stress contours for Non- Prismatic Member

As evident from Figure 6 and Figure 7 , it is seen that the normal stress due to bending in Non-prismatic member is much lower than that of Prismatic one. Comparing both the figures it is seen that the maximum stresses for a beam are found near their supports and the midspan, The . The maximum stress value for Prismatic member observed was 839.66*MPa* and this stress was dominant near supports and in the bottom fibres of midspan. In case of Non-prismatic section although the maximum stress is observed as 531*MPa* but the dominant stress near supports was observed to be 277.67*MPa*, which is much lower than that of Prismatic member The below figures show the variation of Maximum shear stress in both the beams. Comparing Figure 8 and Figure 9, it is observed that Maximum shear stress in Non-Prismatic member is less than that of Prismatic beam, Max. Shear stress for Non-Prismatic being 2363.7*MPa* and that of prismatic being 3911.4*MPa*. On comparing the two, it was obvious that even shear stress was lower in Non-Prismatic members.

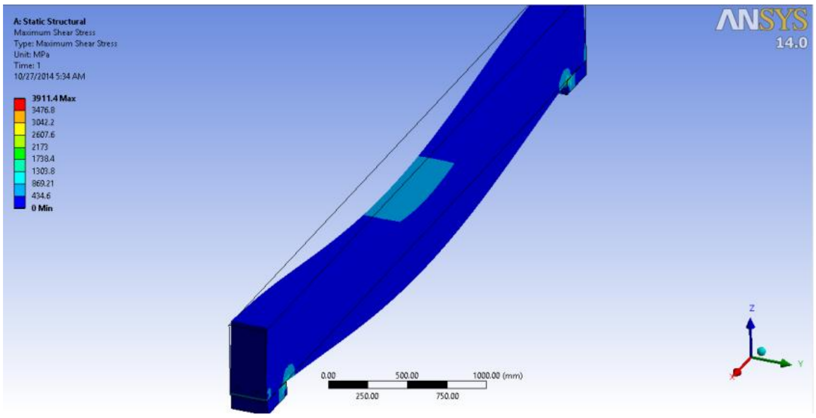

Fig 8. Shear Stress Contours of Prismatic Member

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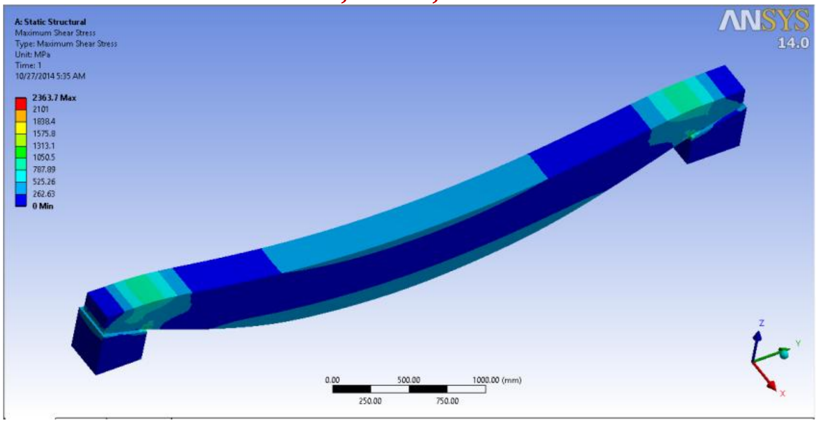

Fig 9. Shear stress contours of Non- Prismatic member.

The above figures compare the results between Prismatic and Non-Prismatic beams. It is evident from the above figures that even though the deflection in Non-Prismatic member is slightly more but Shear stress and mostly Normal stress values much lower than that of Prismatic. So the stresses are released as we transform a Prismatic member to Non-Prismatic one.

A. Volume and Weight comparisons

As depicted in table 2. The volume of concrete in Non-Prismatic members is reduced by 40% and the weight isreduced by 42%.

Table 2. Volume and Weight Comparisons.

Beam Type	Volume
Prismatic	$0.625m^3$
Non Prismatic	$0.276m^3$
	Weight
Prismatic	$15.6kg/m^3$
Non Prismatic	$6.90kg/m^3$

VI. CONCLUSIONS

- Non-Prismatic members deform a bit more than prismatic beams.
- Normal stresses in Non-Prismatic members are much lower hence making it a stress free beam, which is good for a structure.
- Maximum shear stress in the Non-Prismatic member is little lower than that of Prismatic beam.
- Due to complexity in formwork for Non-prismatic beams, they are preferred for Pre fabricated structures where the fabrication of formwork is comparatively flexible and easier.
- The volume of the beam is reduced by 40% and so is the self-weight. Non-prismatic members are almost 42% lighter, which makes them more economical than Prismatic beams.
- Transformation from Prismatic to Non-prismatic beam improves the flexure member in many ways, stresses are released, volume is reduced and self-weight is reduced.

Hence Non-Prismatic members are far more efficient than Prismatic members.

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