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Simulation Study on a Mixed Beams Structure

M.D.Yaqoob Mehdi[1] & A.Purushotham[2]

1. Mechanical Engineering Graduate student of Sree Nidhi Institute of Science and Technology, Hyderabad, India

2. Professor of Mechanical Engineering Department of Sree Nidhi Institute of Science and Technology, Hyderabad ,India

Abstract: *Applications of mixed and arc beams find in various civil structures, heavy weight lifting mechanisms and many machine parts. Many kinds of analysis are available on the arc beams to determine their behavior under static and dynamic load. Most of analysis includes theoretical modeling. The main problem with the theoretical model of arc beams is mathematical complexity in solving governing equations related to arc beams .In this paper, A new approach has been introduced to simplify the analysis of arc beams. In this method, the principles of FEA along with ANSYS software are deployed to determine the behavior of various curved beams. The study focuses on rectangular cross section curved beams with different end conditions. The exhaustive simulation study has been done on Quarter arc beam (90 degree) and semi arc beam (180 degree)due to wide applications in various civil structures and mechanical heavy machineries. Further the analysis has also been made on a typical mixed beams structure by choosing different type of materials (steel, aluminum, alloy steel). A comparative study has been made on the variation of stresses and deflections developed in quarter and semi arc beams.*

Keywords: *Arc beam, ANSYS, Bending stress, Von mises stresses, Mixed beams.*

I. Introduction

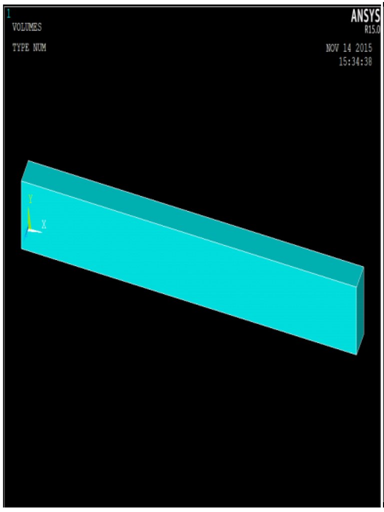
Arc beams are deployed in construction of buildings and structures. But they are also used in heavy weight lifting machines and mechanisms. Hence the determination of their behavior under load is must. To analyze their behavior many methods are deployed which include might be theoretical analysis, mathematical analysis and numerical analysis. W.C. Young & R.G Budynas, Rorks(1) and Dym,C.L & Williams,H.L(2) were exhaustively discussed to evaluate stresses and deflections in arc beams with different end conditions. It is observed that in theoretical analysis deflection formulae are determined by taking certain assumptions and the values obtained are near approximate. Another approximate procedure adopted by Tore Dahler(4) was of mathematical analysis where castigliano's second theorem is utilized. Both these methods have certain assumptions and mathematical complexity, hence near accurate values are not possible.

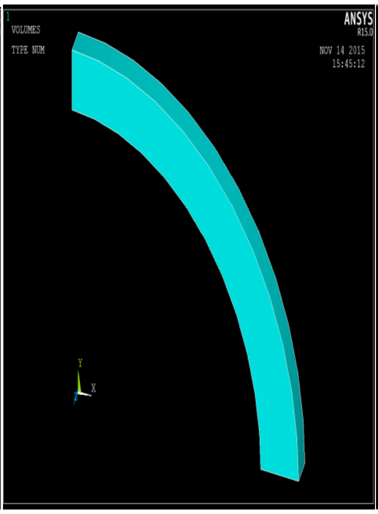
In this paper an attempt has been made to utilize principles of Finite Element Analysis (FEA) for analyzing the behavior of the arc beams. Victor Debnath and Bikramjit Debnath (3) attempted analysis of Arched beams with Ansys APDL. As APDL command based approach, the modification in geometry of structure is not fully controlled GUI. In order to simplify modeling and postprocessing study, ANSYS geometric based approach is used. By this method the analysis becomes easy and less time consuming. The results obtained are nearer to accurate that are obtained with analytical method. Unlike other methods, ANSYS doesn't deals with complex formulae, instead matrices are deployed for this purpose which are solved by the software, hence reducing the effort.

The paper is organized in the following manner: Section 2 describes the geometric and mesh models of all beams individually and structures consist of two straight beams and one semi arched beam. The simulation results are discussed in section 3 and finally section 4 draws conclusions.

II. Modeling And Meshing Of Mixed Beams Structure

Different beams include straight simple cantilever, cantilever Quarter arc (90 degree) and fixed semi arc (180 degree) have been taken for the simulation study. The included angle is taken as a variable to distinguish straight, semi arc and quarter arc beams. The cross section of the beam chosen is 1cmx1cm.The length of beam selected is 10cm.The developed models are shown in figure numbers Fig 2.1,2.2,2.3 Further the analysis has been made by choosing different type of materials such as steel, aluminum, alloy steel. The loading of the beam is varied from 1KN to 10KN.





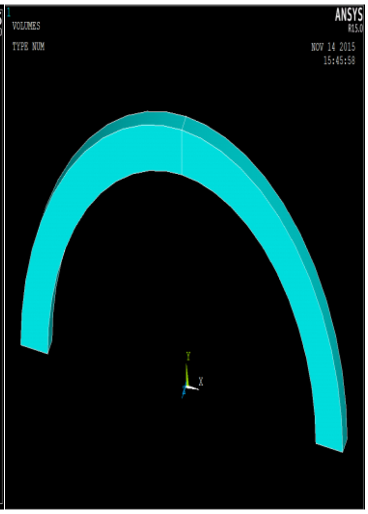
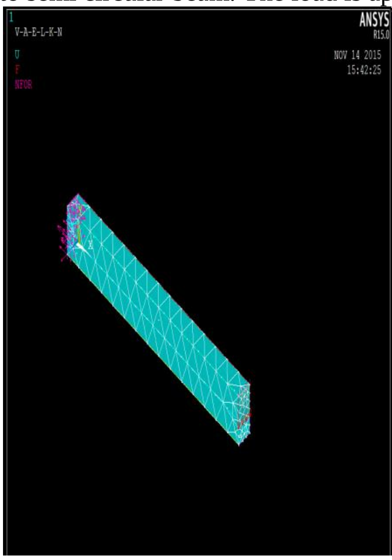
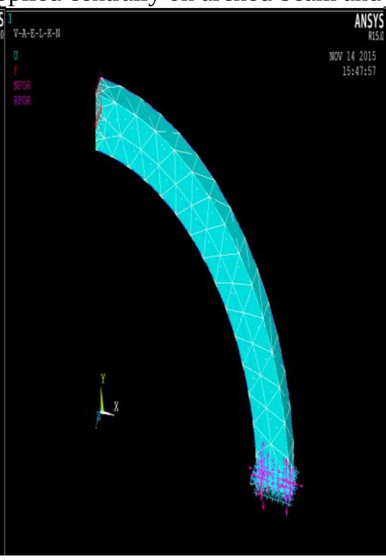


Fig 2.1: Model of straight beam   Fig 2.2: Model of quarter arc beam Fig 2.3: Model of semi arc beam

In FEA modeling of beams BRICK 4 NODE solid elements have been used due fast convergence and more accurate. One end of the cantilever beam is constrained with all degrees of freedom and a standard load is applied in vertical direction on the nodes of the other edge. In quarter arc the base area is fixed and standard load is applied on the nodes of other end edge. In semi arc the both base areas are fixed and a standard force is applied at the center of the curved beam. The elementised models along with the loads and end constraint are shown in figures 2.4, 2.5 and 2.6.

The paper also attempted the simulation study on a mixed beam where two straight beams and one semi arc beam are used. Each beam cross section is same (1cm x 1cm).The model and meshing of the mixed structure are shown in figures 2.7 and 2.8 respectively. Vertical beam and Horizontal beam have been attached to semi circular beam. The load is applied centrally on arched beam and the analysis is carried out.





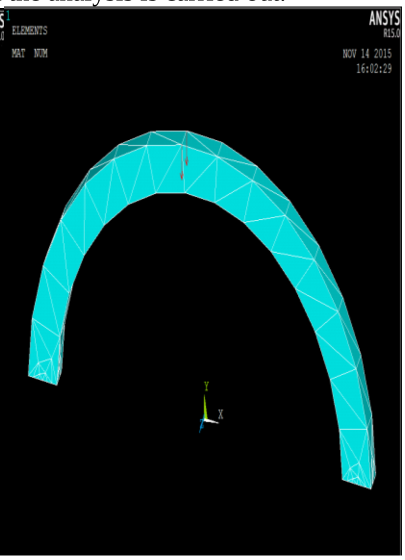


Fig 2.4: Mesh of straight beam   Fig 2.5: Mesh of quarter arc beam   Fig 2.6:Mesh of semi Arc beam

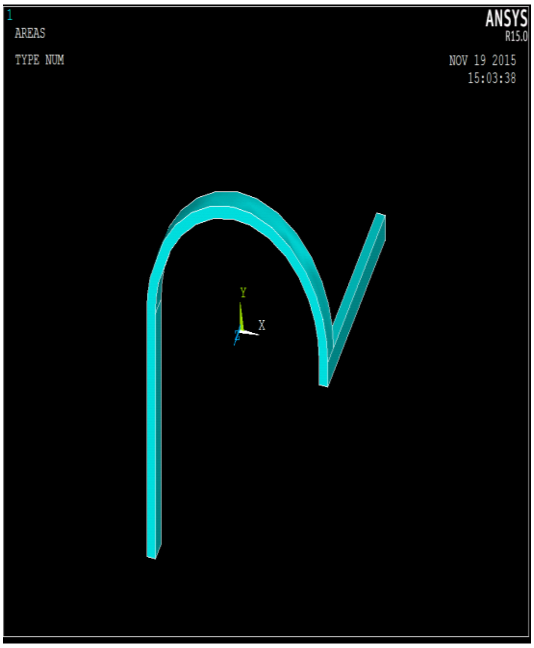
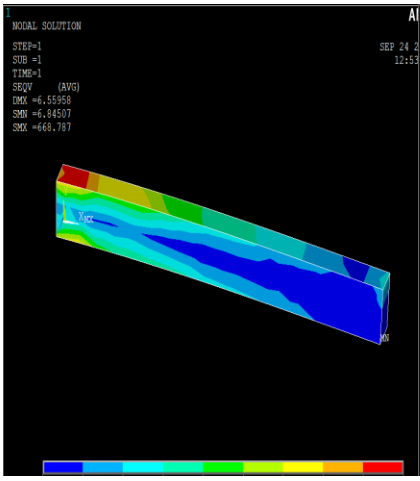


Fig 2.7: Model of Mixed beam

Fig 2.8: Meshing of Mixed beam

III. Simulation Results And Discussion

In this section three finite models developed in section 2 are considered with materials aluminum, steel and alloy steel. Initially simulation on beams made up of aluminum (density: 2689.8, young's modulus: 800000, poison's ratio : 0.34) was carried out. In ANSYS the material constants such as young's modulus and poisson's ratio are included in the preprocessor stage. After applying solution stage on various FE models,the values of stresses and deflection are extracted in postprocessor stage. Stress analysis of cantilever beam was carried out by selecting Von Mises theory and the result is shown in fig.3.1.Next analysis of an cantilever quarter arc was carried out and the obtained stress contour is shown in fig 3.2. Finally the analysis of fixed semi arc beam was carried out and the corresponding stress distribution is shown in fig 3.3.The stress was found to be minimal in arc cantilever when compared to straight cantilever. Further decrement in stress was noticed in fixed semi arc beam.



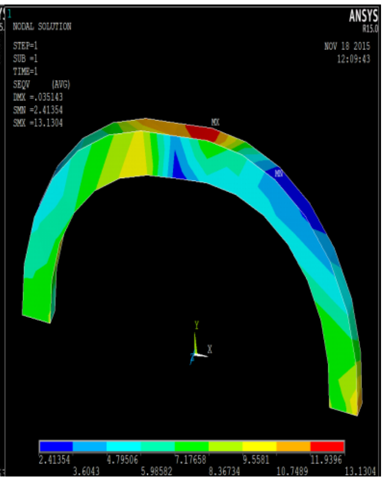
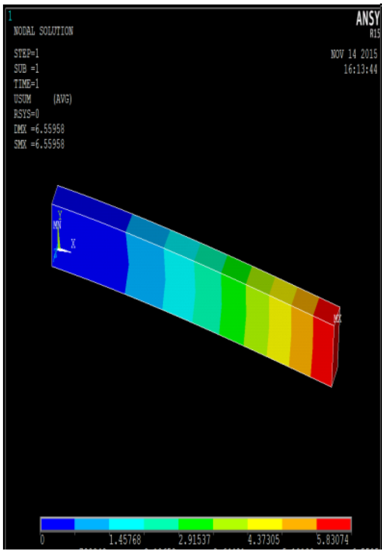


Fig 3.1:Stresses in Straight beam(Al) Fig 3.2:Stresses in quarter Arc beam(Al) Fig 3.3:Stresses in Semi Arc beam(Al)

The simulation study was also made to calculate the deflection of aluminum beams. The deflections contour of straight cantilever beam is shown in fig 3.4, cantilever arc beam is shown in fig 3.5 and fixed semi arc beam is shown in fig 3.6. The deflection was found almost similar in straight cantilever beam when compared with quarter arc cantilever beam, and minimum deflection was observed in fixed semi arc beam.



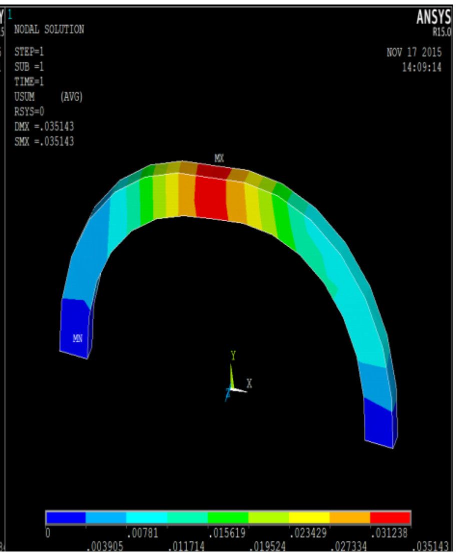
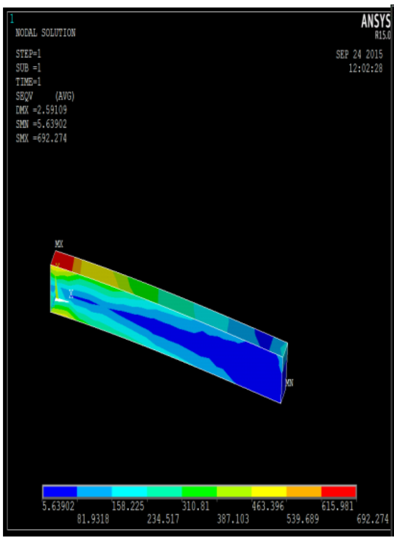


Fig 3.4: Deflections in straight beam(Al) Fig 3.5:Deflections in quarter Arc beam(Al) Fig 3.6:Deflections in semi circle beam(Al)

Secondly, simulations were run for steel beams(density:7860, young's modulus:210GPA, poison's ratio:0.28).Straight cantilever beam was simulated first by taking von mises stress theory, and the simulation results are shown in fig 3.10. Similar procedure was performed on quarter arc cantilever beam and fixed semi arc beams and the corresponding simulations are shown in fig 3.11 and 3.12 respectively. It was observed that stress in cantilever arc beam is less compared to straight arc beam, and stress further decreases for fixed semi arc beam.



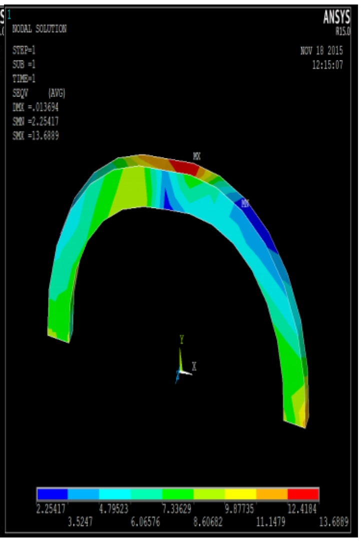


Fig 3.7: Stresses in straight beam(Steel) Fig 3.8:Stresses in quarter Arc beam(steel) Fig 3.9:Stresses in semi circle beam(Steal)

The deflection simulation was also performed on steel beams and simulation results are shown for straight cantilever beam in fig 3.10,quarter arc cantilever beam in fig 3.11 and fixed semi arc beam in fig 3.12.It was observed that same amount of deflection was observed in straight cantilever beam and quarter arc cantilever beam, and deflection was found to be decreased in fixed semi arc beam.

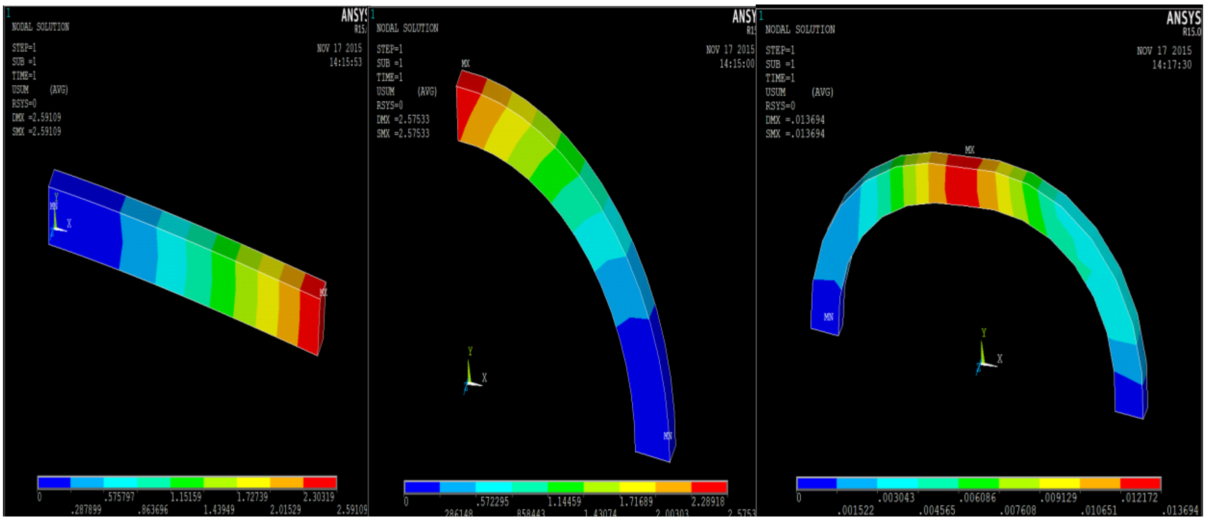


Fig 3.10: Deflections in straight beam(Steel) Fig 3.11:Deflections in quarter Arc beam(steel) Fig 3.12:Deflections in semi circle beam(Steal)

Thirdly and finally, similar stress simulations were performed on alloy steel(density:7830,young's modulus:105 GPa, poison's ratio:0.3) and results are shown for straight cantilever beam in fig 3.13,quarter arc cantilever beam in fig 3.14 and fixed semi arc beam in fig 3.15. It was observed that stress in quarter arc cantilever beam was less when compared with straight arc beam, and maximum depression in stress was observed in fixed semi arc beam. The following figures shows the stresses developed in alloy steel material for different elements:

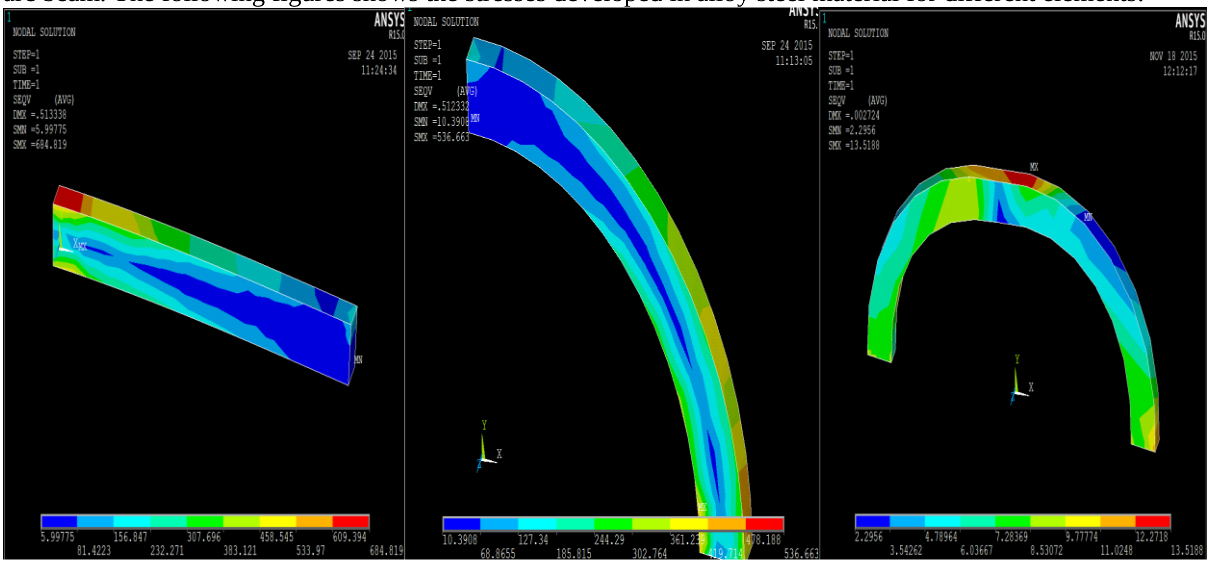
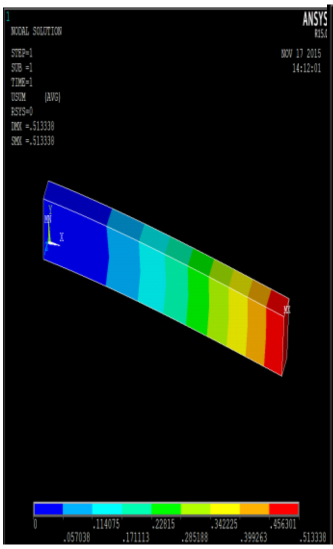


Fig 3.13: Stresses in straight beam(Alloy) Fig 3.14:Stresses in quarter Arc beam(Alloy) Fig 3.15:Stresses in semi circle beam(Alloy)

Similar deflection simulations were made on alloy steel as above materials and results are shown for straight cantilever beam in fig 3.16, quarter arc cantilever beam in fig 3.17 and fixed semi arc beam in fig 3.18. The deflection was almost same in straight arc cantilever beam and quarter arc cantilever beam, and minimal depression was observed in fixed semi arc beam.



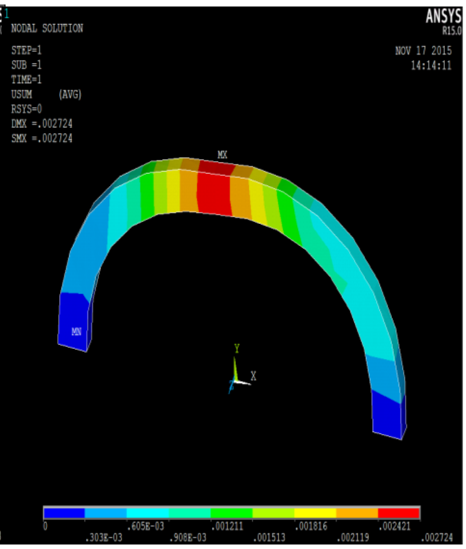


Fig 3.16: Deflections in straight beam(Alloy) Fig 3.17:Deflections in quarter Arc beam(Alloy) Fig 3.18:Deflections in semi circle beam(Alloy)

The simulation results on a mixed beam structure with similar load condition are shown in figures 3.19 and 3.20.It is ibsreved that the stresses are more horizontal stright beam and less semi arc beam despite its larger deflection in the structure. With this analysis one can conclude that the use of arc beams in structural applications does not create extra stress concentration for the structure.

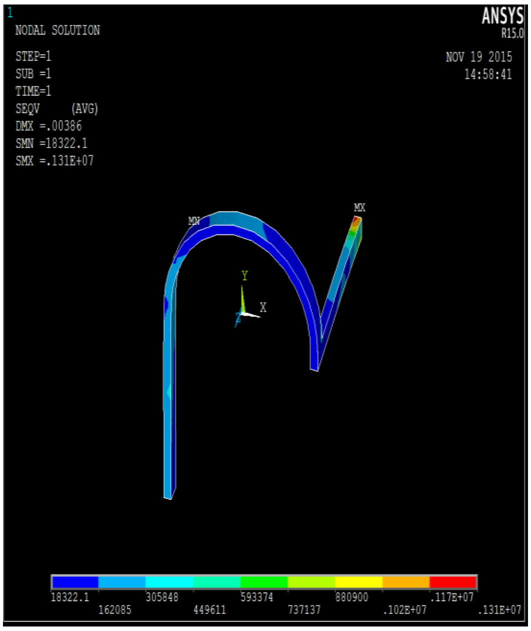


Fig 3.19: Stresses in mixed beam(Steel) Fig 3.20:Deflections in mixed beam(steel)

IV. Conclusions

Three shapes of beams: straight, quarter arc and semi arc have been taken for the simulation studies in this paper .A comparative study is worked out by keeping same cross section and a type of loading. ANSYS software simulation has been applied on these beams. With the work carried out in the present paper it is concluded that semi arc beam is less stressed than other two beams. The deflection also be small in semi circular arc beam. It is evident that stress in particular element remains same irrespective of different material properties. If stress alone is to be minimized keeping the deflection as constant quarter arc cantilever beam suggested over straight cantilever beam.If both stress and deflection are needed to be reduced fixed semi arc beam is appreciable. With this study one can conclude that arc beams are also be equally good as straight beams to incorporate in civil and mechanical engineering applications as stresses developed are less. In order to study the behavior of arc beam in connection with straight beams, A mixed beams structure is modeled and analyzed. In this study it is observed that less stresses are developed in curved portion of the beam. This paper also gives the idea of adopting ANSYS software for the analysis of beams instead of sorting the solution through analytic expressions which are generally complicated.

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