iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** V **Month of publication:** May 2018

DOI: http://doi.org/10.22214/ijraset.2018.5286

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue V, May 2018- Available at www.ijraset.com

Analysis and Design of Suspension Cable Bridge

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Abstract: The Suspension bridge is a type of bridge which the deck is hung below suspension cables on vertical suspenders. A suspension bridge covers longer distances as compare to other types of bridges. As it gets larger span it become flexible structure. The main elements of a cable suspended bridge are cable system. The forces in suspension bridge are tension in cable and compression in tower. The model analysis is performed by finite element software SAP2000. The suspension bridge is designed for dead load, live load and other occasional loads. All the loading and unloading conditions in analysis are considered as per the IRC codal specification. The output of the software presents result including moments, axial loads, shear force and displacements. This report examines issues analysis and design calculation in over a structure will safe under all condition.
Keywords: Suspension Cable, SAP2000, Model Analysis, Software Output, Design Calculations.

I. INTRODUCTION

A type of bridge where the deck is hung below the suspension cable in vertical suspenders is known as Suspension Cable Bridge. The design of modern suspension bridge allows them to cover longer distance than other types of bridge. The main element of a cable suspended bridge is the cable system. The main forces are tension in cable and compression in the towers. The cable is anchored at each end of the bridge to maintain tension in this cable. It has a span range from 70 to 2000 meters. The modal analysis is performed by analysis Software SAP2000.

II. ASSUMPTIONS FOR ANALYSIS

A. Materials

The materials of the structures and the structural components are linearly elastic. This assumption allows the superposition of actions and deflections and, hence, the use of linear methods of analysis. The development of linear methods and their solution by computer has made it possible to analyze the large complex statically indeterminate structures.

1) *Deck*: The decks are assumed to be Steel I Girder. This assumption causes the horizontal plan displacements of all vertical elements at a floor level to be definable in terms of the horizontal plane rigid body rotation and translation of the floor slab.
2) *Negligible Deformations:* Deformations that are relatively small and little influence are neglected. These include the shear and axial deformations of girder, in plane bending and shear deformation of floor slabs, and the axial deformations of towers
3) *Tower Modelling:* The dimension of tower is 2.5 m x 2.5 m. The towers and the cross beam are modelled using the linear elastic frame section based on gross cross-section properties.

III. MATERIAL PROPERTIES TABLE I

Components	Modulus of elasticity (kN/m2)	Mass density (kN/m3)	Poisson’s ratios
Concrete Tower	2.5×10^7	25.00	0.15
Cross Beam of Tower	2.5×10^7	25.00	0.15
Steel Girders Deck	1.999×10^8	78.50	0.3
Steel Wire for Cables & Hangers	1.999×10^8	78.50	0.3

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IV. ANALYTICAL STUDIES

A. Bridge Details

TABLE II KEY STATIC OF SUSPENSION CABLE BRIDGE

Left span length	98 m
Middle span length	245 m
Right span length	98 m
Deck width	19 m
Column height (H1)	16 m
Column height (H2)	32 m
Minimum middle sag	7.5 m
Left number of Division	33 Nos
Middle number of Division	82 Nos
Right number of Division	33 Nos

Main cable		Hanger	
Diameter	0.35 m	Diameter	0.05 m
Area	0.1 m^2	Area	0.002 m^2

V. CABLE MODELLING

A. Suspension Cable

The suspension cable is undoubtedly going to be one of the most highly stressed elements within the structure (along with the towers). It will be assumed that the cable experience only tensile force and that any transverse movement from wind will be ignored. It will also be assumed that deck is stiff and therefore evenly distributes the loads across the cable. The forces within the cable can be easily assessed using:

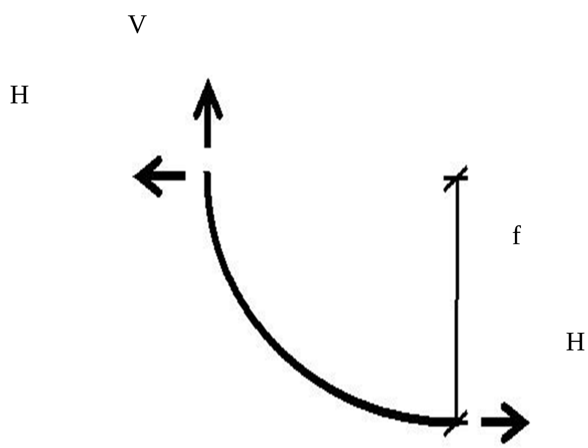

Fig. 01 - Horizontal and vertical forces in suspension cable

Where, $H = \frac{WL^2}{8f} = \frac{(184.13)x\,(245^2)}{8\ x\ 24.50} = 56389.21$ kN

$V = \frac{WL}{2} = \frac{184.13\ x\ 245}{2} = 22555.925$ kN

The Maximum tension in main Cable,

$T = \sqrt{H^2 + V^2} = \sqrt{56389.21^2 + 22555.925^2} = 607.33$ kN

Stress in cable, 6 $= \frac{T}{A} = \frac{60733.127}{2x\frac{\pi}{4}x\,0.35^2} = 315.62$ mpa

VI. SPACIMAN MODELING AND RESULT

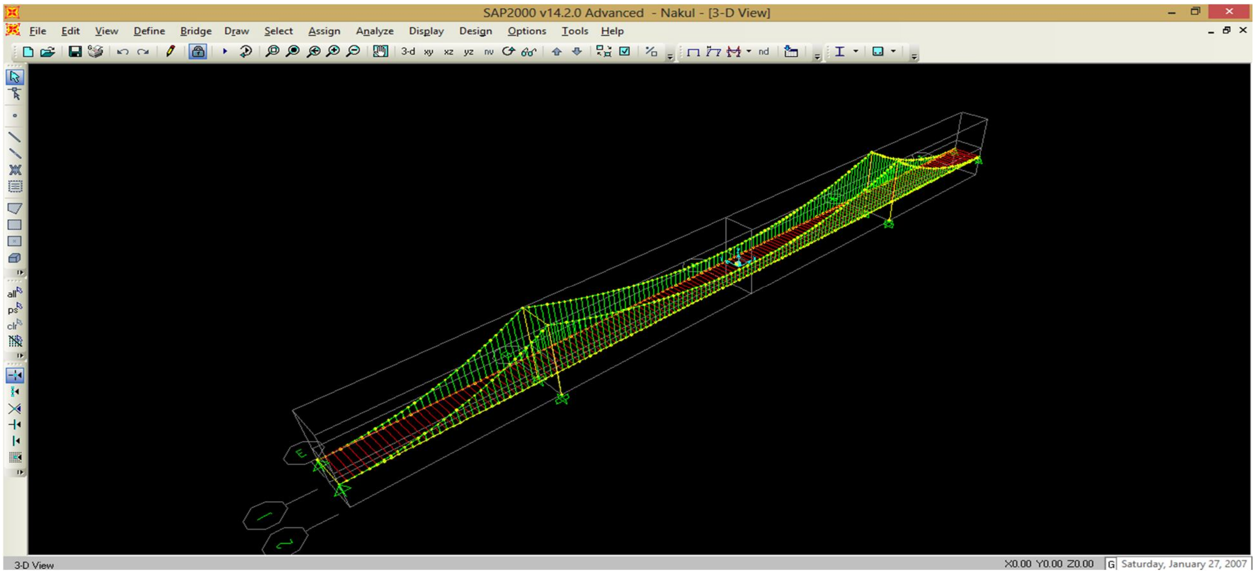

Fig. 2: 3 D View of Suspension Cable Bridge (Sap 2000)

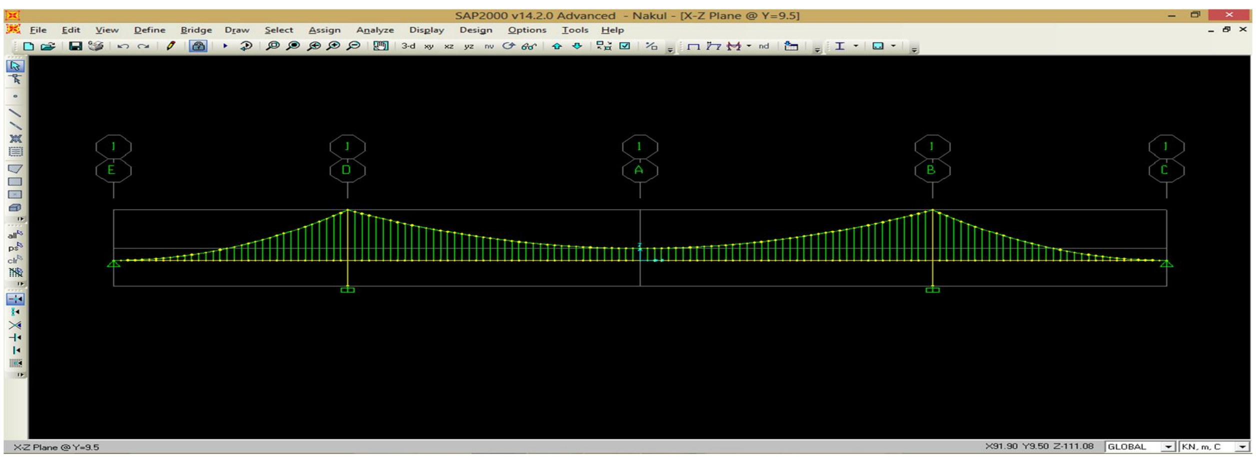

Fig. 3: 2 D View of Suspension Cable Bridge (Sap 2000)

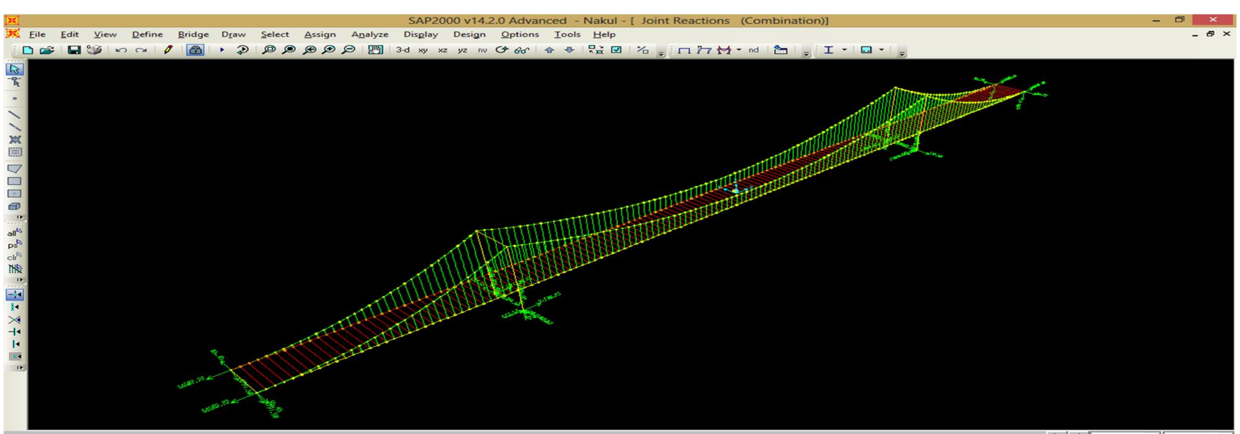

Fig. 4: Joint reaction of Suspension cable Bridge (Sap 2000-3D View)

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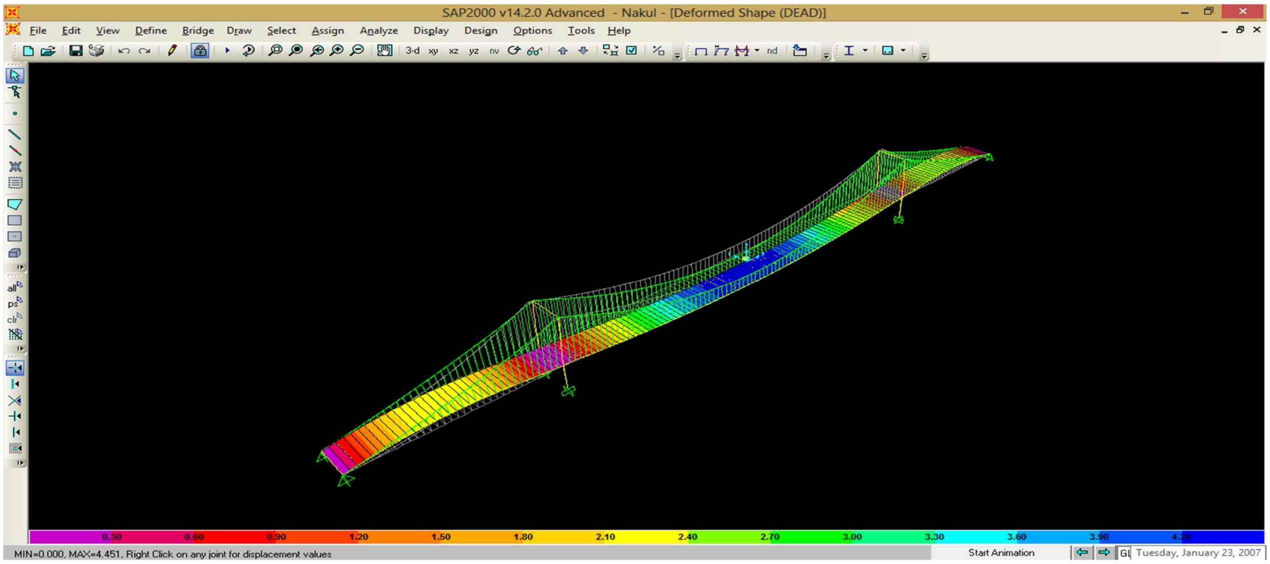

Fig. 5: Deflection Shape of Suspension cable Bridge (Sap 2000-3D View)

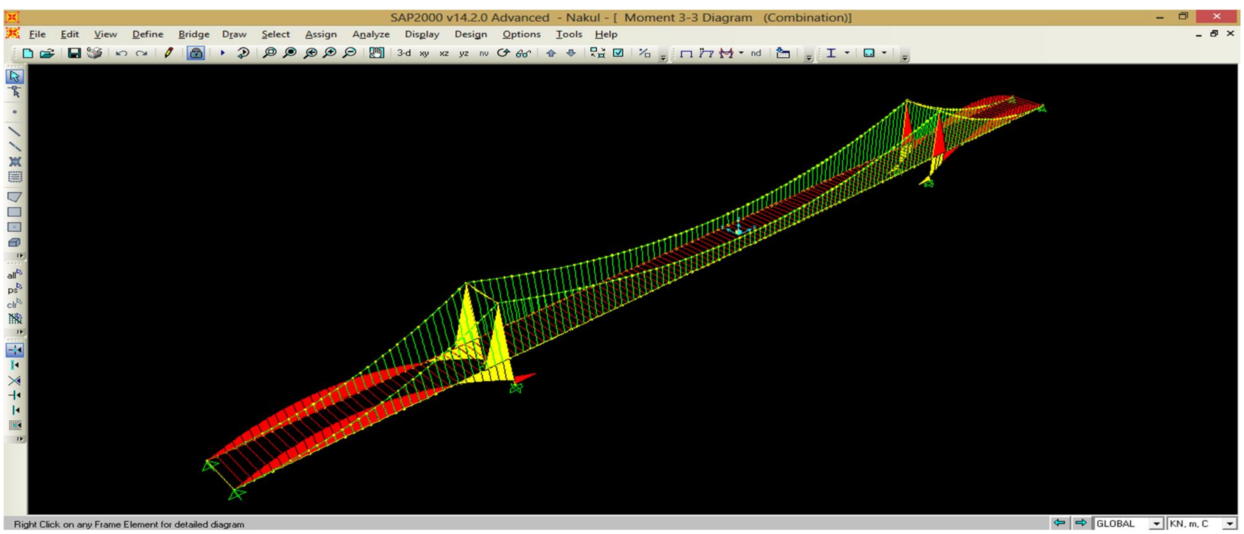

Fig. 6: Bending Moment Diagram of Suspension cable Bridge (Sap 2000-3D View)

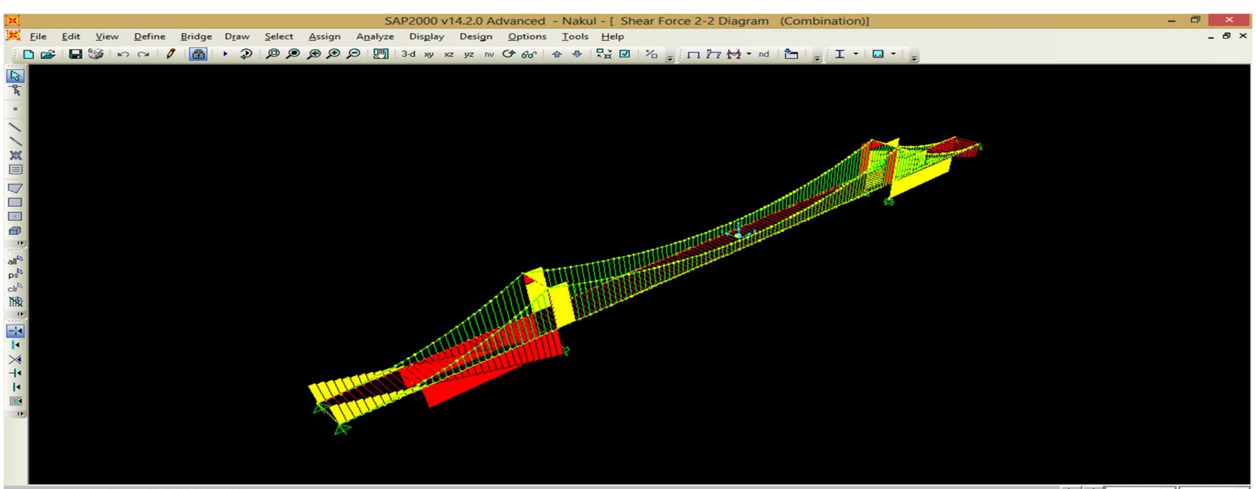

Fig. 7: Shear Force Diagram of Suspension cable Bridge (Sap 2000-3D View)

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VII. CONCLUSIONS

A. The analysis of Suspension Cable Bridge is carried out by using SAP2000. These result including joint reaction, deformation, bending moments, shear force at each node at every point within the element can be easily obtained from this software.

B. The reaction, deformation, bending moments, shear force values are analysed by software and compared with manual design of Suspension Cable Bridge.

C. To achieve the good suspension cable bridge, a full understanding of the cable is important but also the measures taken to protect it. This is necessary since a failure in any of the cables is could result in endangering whole structure.

D. The stresses distribution becomes more uniformly distributed between the cables when the vertical load increase, i.e. the cables will deform uniformly.

E. The cable is economical as it in tension and it reduce the diameter of cable. The cross section area of suspenders is small.

VIII. RESULT AND GRAPHICAL REPRESENTATION

A. Difference between Manual Calculation and Software Analysis Result

TABLE III

Sr. No.	Components		Analysis Result	Manual Calculation Result	Difference (%)
1	Sag in cable (m)		21.48	20.27	5.63
2	Deflection in cable (m)		0.13	0.12	7.69
3	Forces (kN)	Horizontal	56941.48	56389.21	0.96
		Vertical	21866.52	22555.925	3.05
4	Tension in cable (kN)		746.306	607.33	18.62
5	Bending Moment kN/m		236.61	213.34	9.83

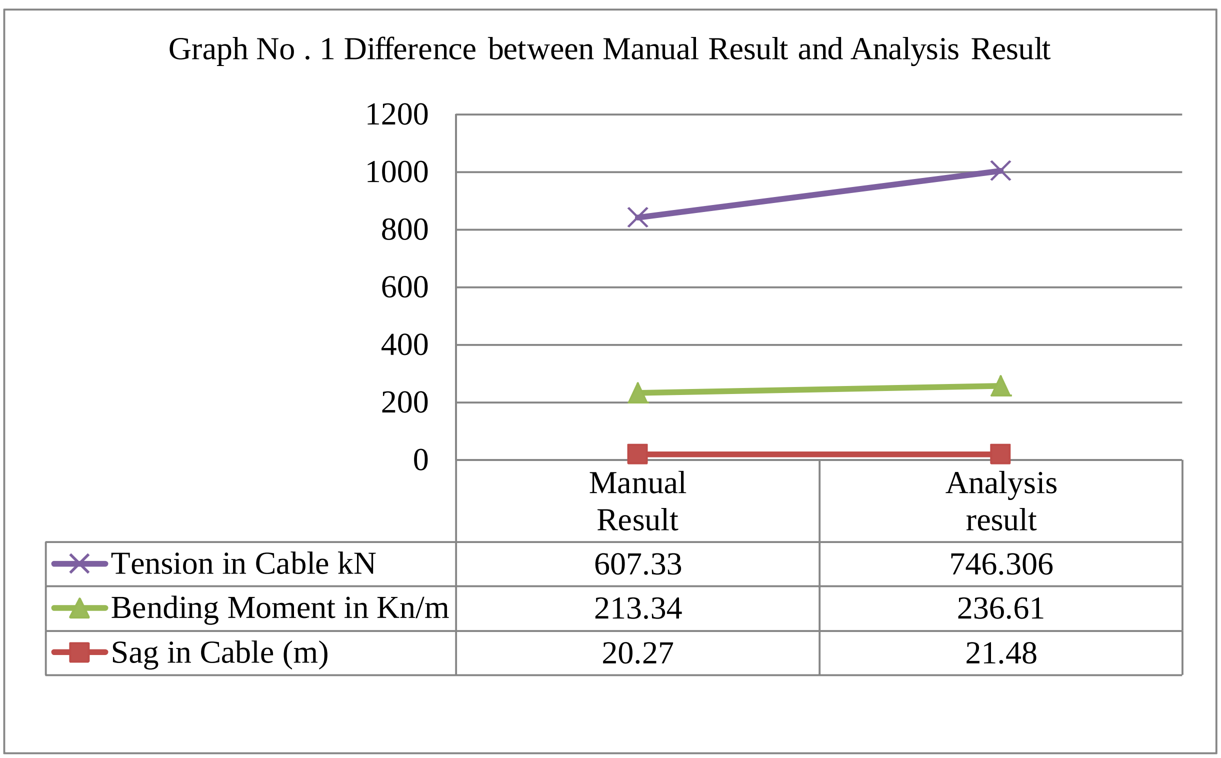

Fig. 8: Difference between Manual Result and Analysis Result

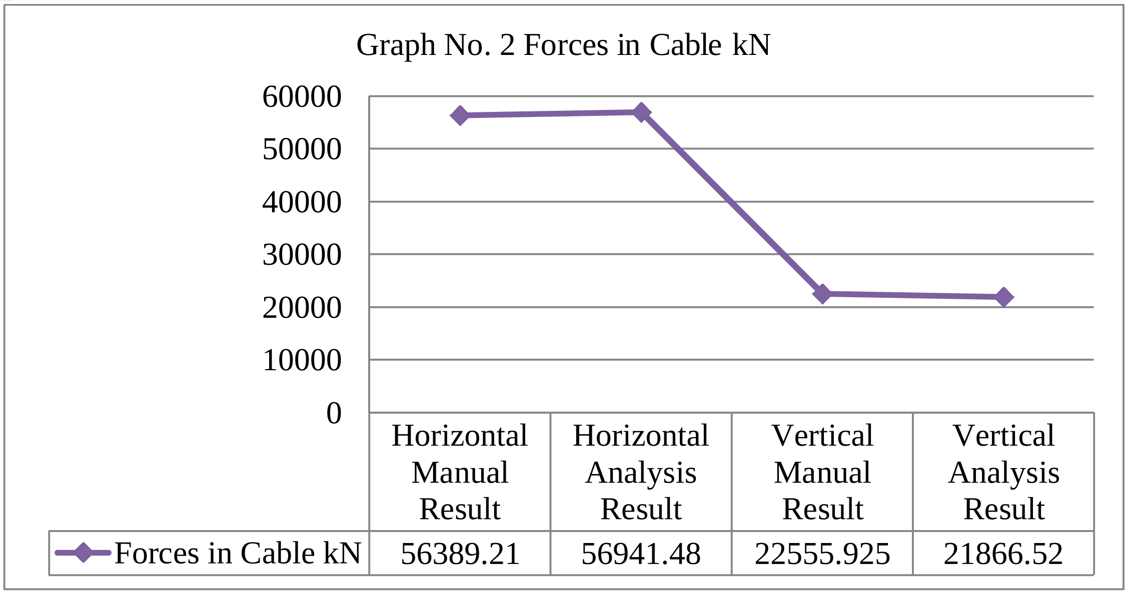

Fig. 9: Forces in Cable (kN)

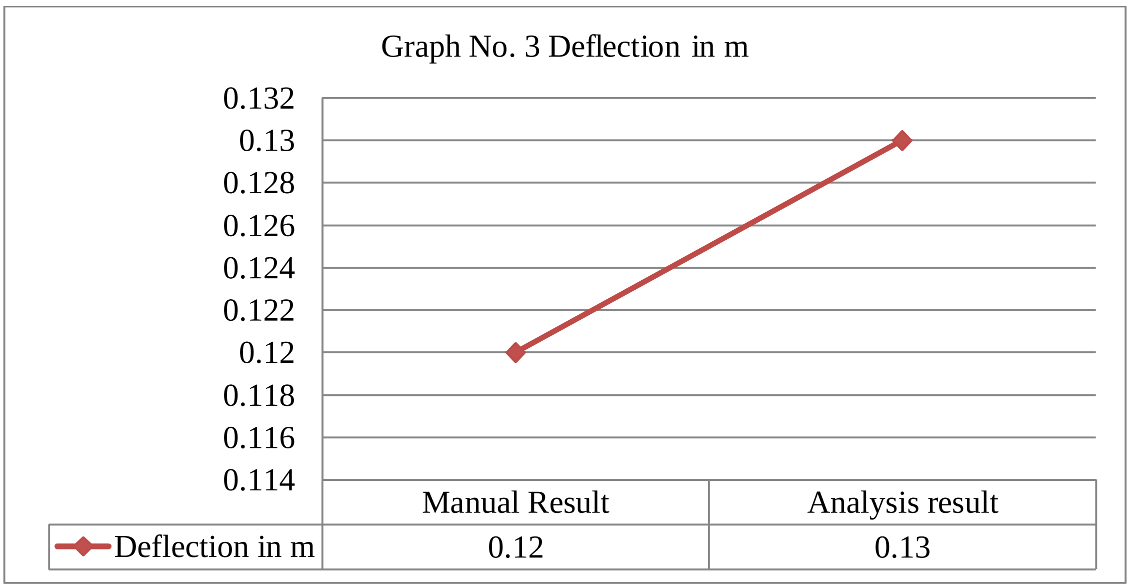

Fig. 10: Deflection in m

IX. ACKNOWLEDGMENT

We would like to thank Dr. Ramesh Meghrajani, Structural Consultant, New Infrastructure Consultants, Nagpur, for all the technical insight and help and also for his invaluable support and guidance for completing the work.

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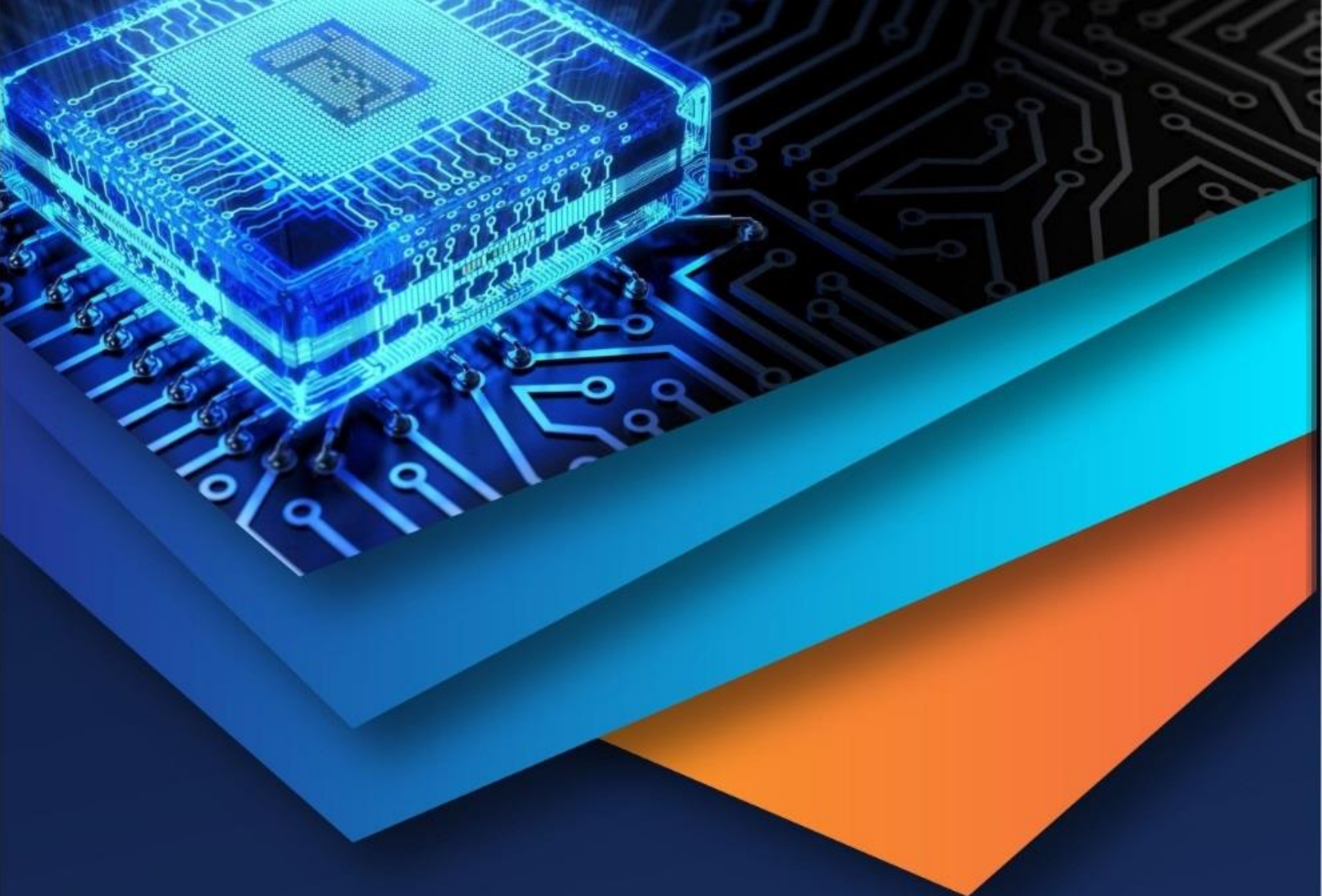

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