SPECTRUM ANALYSIS OF DIFFERENT COLUMN CONFIGURATION SUBJECTED TO BASE EXCITATION USING MODAL SUPERPOSITION METHOD

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Abstract - *The performance of a structural component is a important criteria in analyzing a life of a structure. The scope of the present work is to investigate and understand the effect of different parameters including cross section shape wrapping on modal parameters like modal frequency, mode shape which subjected to ground motion. This paper presents the modal super position method obtained from the computations of slender columns. The analysis was performed for Solid RC, Steel and composite wrapped columns.*

Key Words: **Vibration, Composite columns, Modal super position method, Modal frequency, Mode shape, Ground motion.**

1. INTRODUCTION

The subject of vibration became interested to people after the first failure of the Tacoma Bridge in 1940's. The main cause of failure of the bridge was concluded due to the vibration caused due to negative damping. Negative damping is the opposite of normal damping where oscillation decreases in other words in negative damping bigger oscillations takes place.

The project is performed for a individual structural component so as to determine the stability under the base excitation. In order to counteract these forces base isolation is adopted according to Eurocode 8. The analysis is performed using modal super position method in the ANSYS software.

1.1 Base Isolation

The most executed methods for ensuring a structure against quake forces is known as seismic base seclusion or base isolation. Base disconnection framework comprises of separation units with or without isolation segments, Isolation units are the essential components of a base disengagement framework which are expected to give the decoupling impact to a building or non-building structure. Isolation segments are the associations between segregation units and their parts having no decoupling impact of their own.

Base segregation is a standout amongst the most intense instruments of quake building to control the basic vibration caused because of seismic forces.

1.2 Base Excitation

Base excitation is mainly caused due to the seismic forces acting on the structure, preventing these excitations from passing from a vibrating base through structure. The excitation is always defined as a linear acceleration. The result defined relative to ground, the displacement, velocity and accelerations of any point on the structure will include the base motion. The excitation is at the base not the mass and the excitation is given in terms of displacement not force.

2. SOFTWARE USED FOR THE ANALYSIS

For the present study ANSYS software was used, under the dynamic analysis spectrum analysis was done for the column using modal superposition method.

A range is one in which the after effects of a modular investigation are utilized with a known range to compute displacement and stresses in the model. It is for the most part utilized as a part of place of a time-history examination to decide the reaction of structures to arbitrary or time-subordinate stacking conditions, for example, tremors, wind loads, sea wave loads, stream motor push, rocket engine vibrations, etc. A reaction range input speaks to the greatest reaction of single level of frameworks to a period history stacking capacity.

3. GEOMETRIC MODELLING

In this paper, square sections are demonstrated with various thicknesses of steel tube and CFRP wrapping. The size of column is taken as 100x100x3000mm. These thicknesses are provided in outer and central portion of the column. Provided thickness of steel fibers are 0.2, 0.4, 0.8, 1.2, 1.6, 2mm for square column.

3.1 MODAL SUPER POSITION METHOD

Many solution disciplines of structural dynamics uses the modal superposition technique to perform efficiently the transient or harmonic analysis. Essentially, the range examination dependably utilizes the modular superposition as a fundamental idea. The fundamental thought of the modular superposition strategy is to depict the dynamic reaction of a structure by a direct blend of the principal 'n' undamped mode shapes. The condition is given by

$$u(t) = \sum_{i=1}^{n} \varphi_i \cdot y_i(t) = \phi . y(t)$$

Where φ_i denotes the undamped mode shape of mode i, and $y_i(t)$ is its modal coefficient. In the columns of the modal matrix ϕ, we find the n undamped mode shapes φ_i and the vector y(t) consists of the n modal coefficients $y_i(t)$. By substituting the above equation in $m\ddot{x} + c\dot{x} + kx = F(t)$

And further pre-multiplying with the transposed modal matrix Φ^T we get,

$$\Phi^T M\phi.\ddot{y}(t) + \Phi^T C.\phi.\dot{y}(t) + \Phi^T K\phi.y(t) = \Phi^T. f(t)$$

Since the undamped mode shapes are orthogonal regarding the mass and firmness network, the above condition is decoupled and speaks to 'n' conditions each portraying a summed up single level of flexibility display in the modular subspace. Just, an arrangement of decoupled conditions is just accomplished if the damping framework is corresponding to the aggregate mass and the aggregate firmness lattice.

3.2 BOUNDARY CONDITIONS

The displacement boundary condition is needed to constrain the model to get the solution. Boundary condition is given for the column as one end fixed and other end free. To ensure the one end fixed for the column, all degree of freedom is selected.

3.3 MATERIAL PROPERTIES

Table -1: Material properties of Steel used in analysis

Property name	Symbols	Values	Units
Young's modulus	E	200	Gpa
Poisson Ratio	ν	0.3	----
Density	ρ	7900	Kg/m³

Table -2: Material properties of CFRP used in analysis

Property Name	Symbol	Values	Units
Young's Modulus in x-direction	E_x	180	GPa
Young's Modulus in y-direction	E_y	10.3	GPa
Young's Modulus in z-direction	E_z	10.3	GPa
Poisson ration in xy plane	ν_{xy}	0.28	---
Poisson ration in yz plane	ν_{yz}	0.015	---
Poisson ration in xz plane	ν_{xz}	0.015	---
Shear Modulus in xy plane	G_{xy}	71.7	GPa
Shear Modulus in yz plane	G_{yz}	10.3	GPa
Shear Modulus in xz plane	G_{xz}	10.3	GPa
Shear Modulus in xy plane	ρ	1800	kg/m³

4. RESULTS AND DISCUSSION

In this project columns were subjected to model and spectrum analysis by modal super position method and the analysis were extracted up to 10 modes. The first case was considered was for fully solid column, and from case 2 to case 7 and case 8 to case 12 analysis was done with varying thickness of the steel and composite wraps respectively.

4.1 MODAL ANALYSIS

The table below shows the modal analysis results for different column configuration. The frequency values for solid model steadily increases up to mode 6 and after the 7th mode the value rapidly increases from the 6th mode the results obtained will be in three dimensional and the mode shape are variables.

Table -3: Results for Modal analysis of Solid and steel wrapped columns

	case1	case2	case3	case4	case5	case6	case7
	solid	Steel wrap					
Thickness, mm		0.4	0.8	1.2	1.6	2	4
Mode	Frequency, Hz	Frequency, Hz	Frequency, Hz	Frequency, Hz	Frequency, Hz	Frequency, Hz	Frequency, Hz
1	0.17	0.19	0.21	0.22	0.23	0.24	0.28
2	0.17	0.19	0.21	0.22	0.23	0.24	0.28
3	1.08	1.19	1.29	1.37	1.44	1.5	1.74
4	1.08	1.19	1.29	1.37	1.44	1.5	1.74
5	2.99	3.31	3.58	3.8	3.99	4.17	4.8

6	2.99	3.31	3.58	3.8	3.99	4.17	4.8
7	4.87	5.18	5.42	5.62	5.8	5.95	6.52
8	5.8	6.41	6.92	7.35	7.72	8.04	9.24
9	5.8	6.41	6.92	7.35	7.72	8.04	9.24
10	7.91	8.26	8.58	8.85	9.09	9.3	10.09

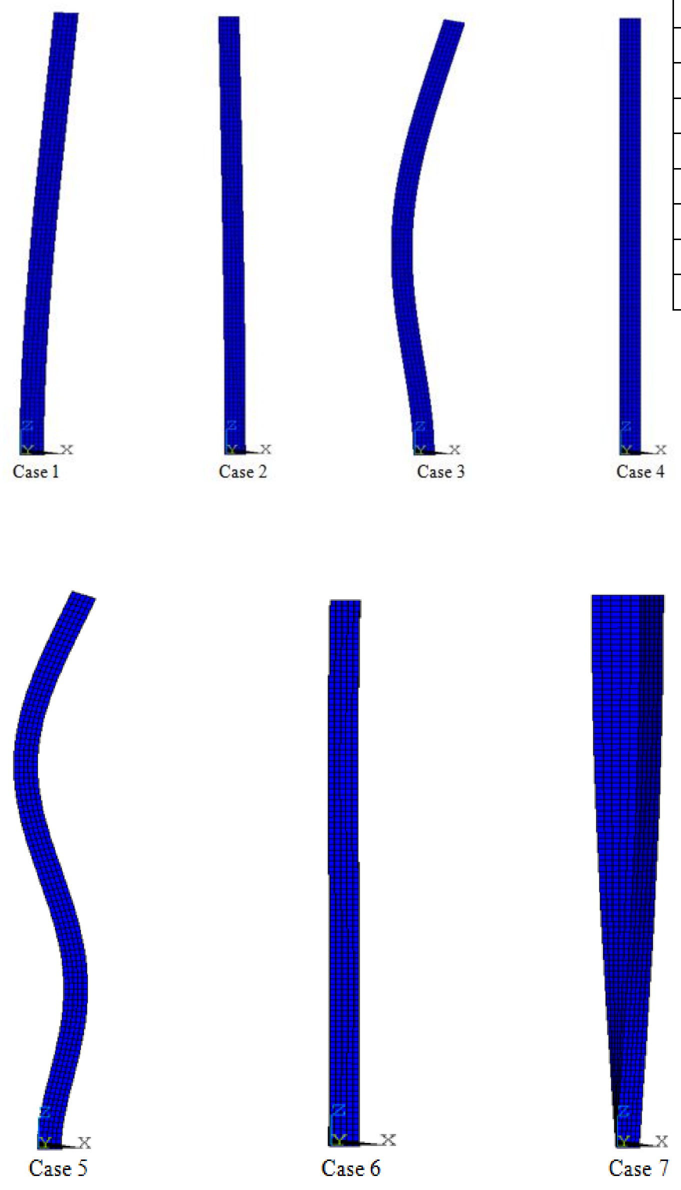

Fig -1: Mode Shape for case 1-7 with one end fixed boundary condition

As seen from the mode shapes for case one the displacement in x direction is more at the free end. For columns with increasing thickness of the steel wrap the frequency at the 10th mode higher this concludes that as the thickness increases the frequency value decreases.

Table -4: Results for Modal Analysis of Composite Wrapped Columns

	case8	case9	case10	case11	case12
			Composite wrap		
Thickness, mm	0.4	0.8	1.2	1.6	2
Mode	Frequency, Hz	Frequency, Hz	Frequency, Hz	Frequency, Hz	Frequency, Hz
1	0.173	0.173	0.174	0.175	0.174
2	0.173	0.173	0.174	0.175	0.174
3	1.079	1.081	1.086	1.093	1.086
4	1.079	1.081	1.086	1.093	1.086
5	2.998	3.000	3.02	3.038	3.020
6	2.998	3.000	3.02	3.038	3.012
7	4.869	4.867	4.86	4.849	4.860
8	5.817	5.830	5.857	5.89	5.857
9	5.817	5.830	5.857	5.89	5.857
10	7.890	7.888	7.852	7.789	7.852

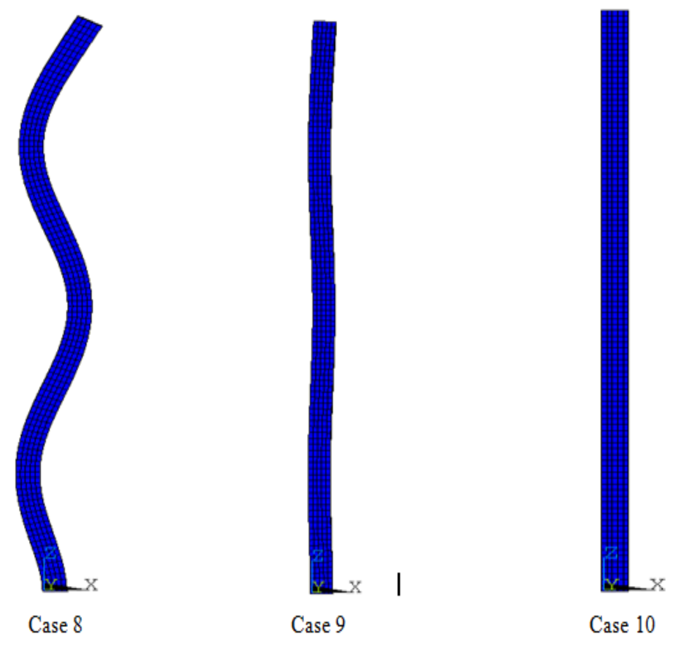

Fig -2: Mode Shape for case 8-10 with one end fixed boundary condition

The mode shape for the composite wraps with thickness is 0.4, 0.8, 1.2 is shown in the above figures. After the wrapping of column with 1.2mm it is observed that there are no much changes in the dynamic response of the structure.

The above table shows the results of modal analysis done for composite wrapped columns. The frequency thus obtained shows that the composite columns are much fatigue resistant as the frequency value is less compared to the steel wrap with varying thickness up to 2mm.

4.2 SPECTRUM ANALYSIS

Table -5: Results Of Spectrum Analysis For Solid Column

Mode No.	Frequency	SV	Participation factor	Mode Coefficient	M. C. ratio	Effective Mass	Cumulative Mass Fraction
1	0.1912	77.200	6.11	326.9	1.0000	37.3332	0.54706
2	0.1912	77.200	-3.021	-161.6	0.49444	9.12708	0.68080
3	1.192	77.200	-3.755	-5.168	0.01581	14.1007	0.88742
4	1.192	77.200	0.4581	0.6304	0.00193	0.209823	0.89049
5	3.311	77.200	2.175	0.3878	0.00118	4.72923	0.95979
6	3.311	77.200	-0.4541	-8.10E-02	0.00025	0.20619	0.96282
7	5.177	77.200	-1.64E-11	-1.20E-12	0.000	2.70E-22	0.96282
8	6.416	77.200	-1.576	-7.49E-02	0.00023	2.48301	0.99920
9	6.416	77.200	-0.2331	-1.11E-02	0.00003	5.43E-02	1.0000
10	8.270	77.200	-3.60E-09	-1.03E-10	0.000	1.30E-17	1.0000

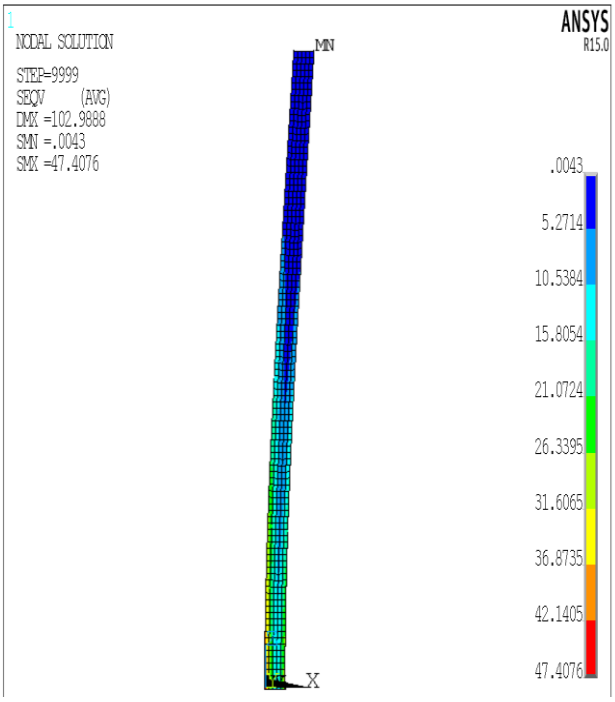

Fig -3: Maximum Stress Distribution in solid column subjected to base excitation in x-direction

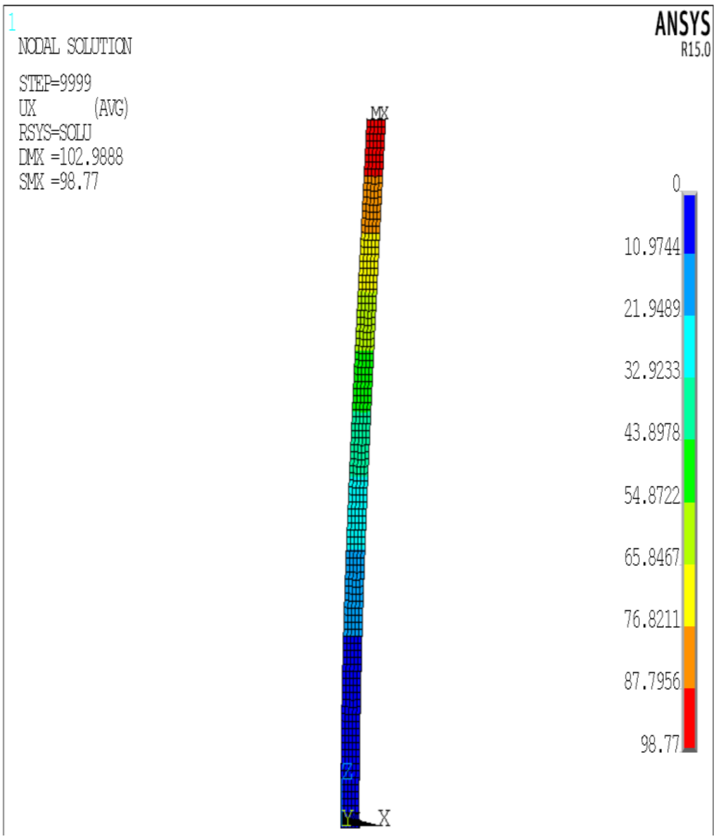

Fig-4: Displacement of solid column subjected to base excitation in x-direction

Table -6: Results Of Spectrum Analysis For Solid column wrapped with 0.8mm steel

Mode No.	Frequency	SV	Participation factor	Mode Coefficient	M. C. ratio	Effective Mass	Cumulative Mass Fraction
1	0.2067	77.200	5.808	265.8	1.00	33.7373	0.470635
2	0.2067	77.200	-3.88	-117.5	0.667995	15.0542	0.68064
3	1.288	77.200	-3.725	-4.39	0.016515	13.8762	0.874213
4	1.288	77.200	1.076	1.268	0.004772	1.15863	0.890376
5	3.575	77.200	2.11	0.3227	0.001214	4.4504	0.952459
6	3.575	77.200	-0.8591	-0.1314	0.000494	0.738027	0.962755
7	5.421	77.200	-1.68E-11	-1.12E-12	0.00	2.83E-22	0.962755
8	6.919	77.200	-1.597	-6.52E-02	0.000245	0.55064	0.998336
9	6.919	77.200	0.3454	1.41E-02	0.000053	0.119286	1.00
10	8.581	77.200	-1.59E-09	-4.22E-11	0.00	2.52E-18	1.00

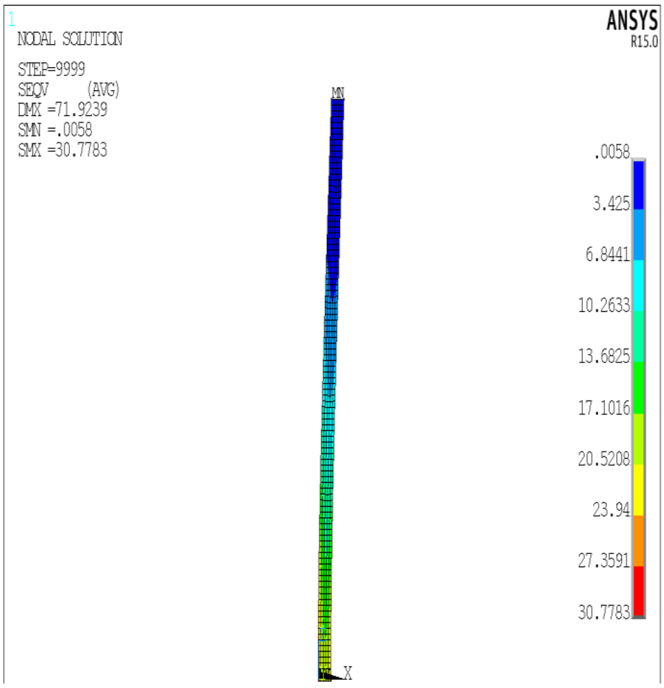

Fig-5: Maximum Stress Distribution in solid column wrapped with 0.8mm steel subjected to base excitation in x-direction

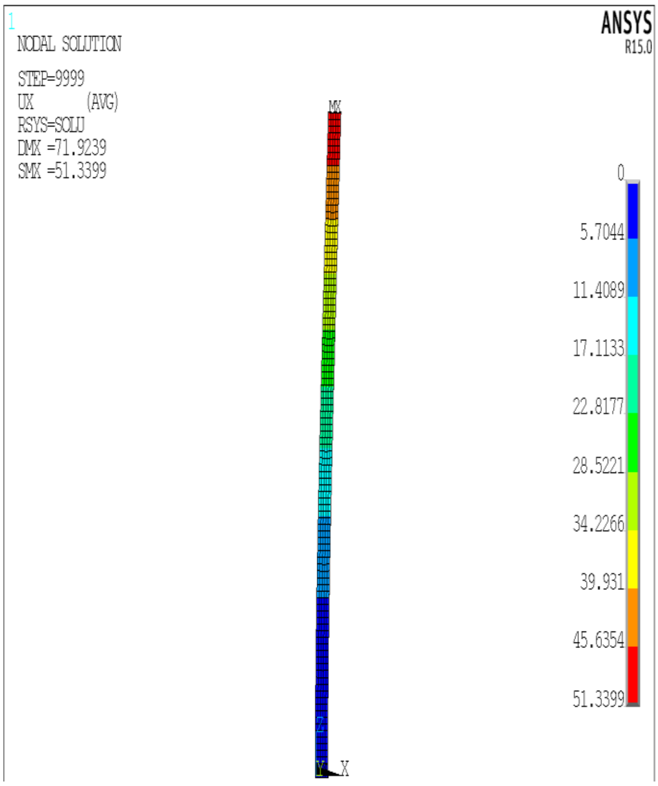

Fig-6: Displacement of solid column wrapped with 0.8mm steel under base excitation in x-direction

Table -6: Results Of Spectrum Analysis For Solid column wrapped with 1.6mm CFRP

Mode No.	Frequency	SV	Participation factor	Mode Coefficient	M. C. ratio	Effective Mass	Cumulative Mass Fraction
1	0.1742	77.200	5.42	349.4	1.000	29.3728	0.42753
2	0.1742	77.200	-4.173	-269.00	0.769912	17.4112	0.680955
3	1.086	77.200	-3.271	-5.432	0.015547	10.7488	0.837407
4	1.086	77.200	1.912	3.168	0.009067	3.65596	0.890621
5	3.02	77.200	1.937	0.4153	0.001189	3.75193	0.945231
6	3.02	77.200	-1.101	-0.2361	0.000676	1.21283	0.962885
7	4.86	77.200	-1.05E-11	-8.67E-13	0.000	1.10E-22	0.962885
8	5.857	77.200	-1.456	-8.30E-02	0.000238	2.11947	0.993734
9	5.857	77.200	0.6561	3.74E-02	0.000107	0.430491	1.000
10	7.852	77.200	-5.33E-11	-1.69E-12	0.000	2.84E-21	1.000

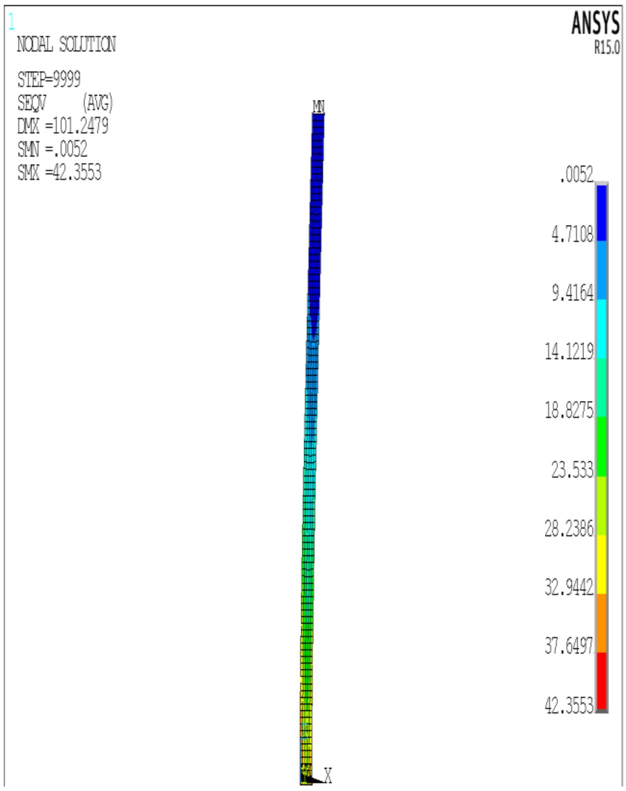

Fig-7: Maximum Stress Distribution in solid column wrapped with 1.6mm CFRP subjected to base excitation in x-direction

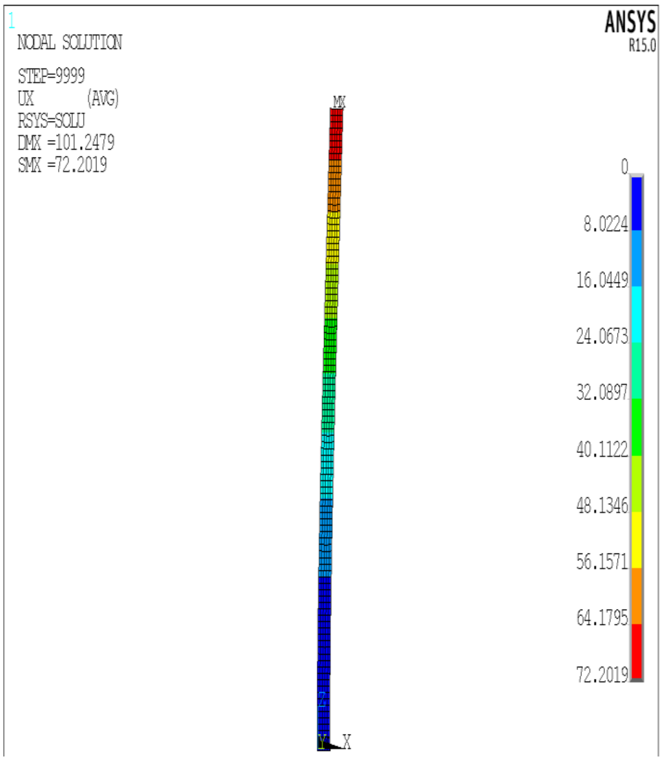

Fig-8: Displacement of solid column wrapped with 1.6mm CFRP under base excitation in x-direction

Table -7: Results of stress and displacement corresponding to different cases

	Stress max. MPa	Mode combined displacement, mm
case1	47	98.78
case2	40.93	69.29
case3	33.47	54.23
case4	30.6	48.3
case5	28.21	40.4
case6	27.5	37.14
case7	24.11	27.79
case8	48	90.36
case9	46	72.7
case10	40.54	71
case11	42	72.16
case12	44	71

5. CONCLUSIONS

1. The maximum stress value and the maximum displacement value for the solid column is greater when compared to the steel and CFRP wrapping.
2. The dynamic response from the mode shapes concludes that the modal analysis is effective only until the 6th mode shape. Further determination of mode shapes does not give satisfactory results.
3. After the 6th mode the stress and deformations are angular and rotational. Analysing the mode shapes in this condition, as there are 'n' number of modes the solution obtained are rational to conclude.
4. The solid column is likely to undergo more deformation. Hence the use of CFRP and steel warp with thickness up to 1.6 to 2 mm can be suitably adopted depending on the height of the column.

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