Analysis of RC Frame Strengthened by FRP Laminates using ANSYS Software

Mr. Rajendra P. Deshpande[1]

P.G. Student, Department of civil Engineering

Pravara Rural Engineering College, Loni.

Taluka-Rahata, District-Ahmednagar,

Maharashtra, INDIA

Prof. Dr. Kiran B. Ladhane[2]

Associate Professor, P.G.Co-ordinator

Department of civil Engineering

Pravara Rural Engineering College, Loni.

Taluka-Rahata, District- Ahmednagar,

Maharashtra, INDIA.

Abstract⸻**After occurrence of recent earthquakes in the most of world parts, scientific committees for reducing natural disasters and research centers declared based performance design, investigation faults, retrofitting, rehabilitation, new researches are related to strengthening of structures, notice performance, importance of structure, surface of earthquake levels, considering economic and feasibility. One of streningthening method of RC frame is using FRP laminates.**

Nowadays is running a lot of researches in case of using FRP bars and laminates for strengthening structural members but research about frame strengthened by FRP in Finite element is limited. In this present study the numerical study to simulate the behavior of retrofitted reinforced concrete (RC) frames.

In this analysis the ANSYS analysis software was used for the study of deflections developed in the given RC frame building as shown in plan.

The results of deflections of RC frame given by software for different cases of attaching laminates are compared for dead load and horizontal forces as given below.

Keywords⸻*Analysis; software; Creation; Model; Laminates; Contact; Connection; Solution.*

I. INTRODUCTION:

The maintenance, rehabilitation and upgrading of structural members, are perhaps one of the most crucial problems in civil engineering applications. Moreover, a large number of structures constructed in the past using the older design codes in different parts of the world are structurally unsafe according to the new design codes. Since replacement of such deficient elements of structures incurs a huge amount of public money and time, strengthening has become the acceptable way of improving their load carrying capacity and extending their service lives. Infrastructure decay caused by premature deterioration of buildings and structures has lead to the investigation of several processes for repairing or strengthening purposes. One of the challenges in strengthening of concrete structures is selection of a strengthening method that will enhance the strength and serviceability of the structure while addressing limitations such as constructability, building operations, and budget. Structural strengthening may be required due to many different situations.

Investigation of the behaviour of FRP retrofitted reinforced concrete structures has in the last decade become a very important research field. In terms of experimental application several studies were performed to study the behaviour of retrofitted beams and how various parameters influence the behaviour. The effect of number of layers of CFRP on the behaviour of a strengthened RC beam was investigated [1]. They tested simply supported beams with different numbers of CFRP layers. The specimens were subjected to dead load and horizontal forces. The results showed that the load carrying capacity increases with an increased number of layers of carbon fibre sheets.The model of RC building shown in plan was developed in ANSYS software.

In this method the cross section is subdivided in to small sub-elements, the deflections are considered constant within each sub-element. The deflections at each sub-element can be traced clearly and hence the gradual spread of yielding can be predicted. The plastic zone method eliminates the need for separate member capacity check, hence this method accepted to provide exact solution.

II. CASE STUDY DETAILS:

A RC frame building of an area of 7.55mX14.10m is to be covered in plan and having G+3 stories. The columns are at 4.57mc/c. If floor consist of 127 mm thick RCC slab and height of floor to floor is 3.05m of theframe.The horizontal forces of 250 kN each are applied at four top level beam column joints from front side. The self weight of the concrete is taken as 25kN/m^3. for vertical load.
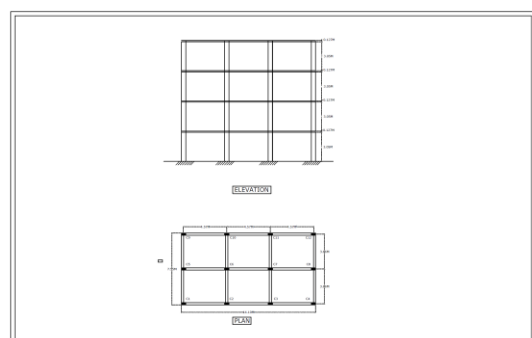

Fig 1: Plan of G+3 RC frame building.

Table No. I : MATERIAL PROPERTIES

SR. NO.	DESCRIPTION	MODULUS OF ELASTICITY (N/mm²)	POISSON'S RATIO
1	MATERIAL NO. 1 - CONCRETE	2.24E+04	0.3
2	MATERIAL NO. 2 - CFRP LAMINATES	2.40E+05	0.27

A. Dimensions of sections of members of RC frame building for Analysis.

- MATERIAL NO.-1- CONCRETE –M20
- COLUMN AND BEAM – 0.20 M X 0.30 M
- MATERIAL NO.-2-CFRP –
- COLUMN AND BEAM – THICKNESS – 0.015 M
- EXTERNAL DIMENSIONS – 0.23 M X 0.33 M
- INTERNAL DIMENSIONS – 0.20 M X 0.30 M

B. Creation Of Model In Ansys Software In Workbench.

C. Creation of column and beam of G+3 RC frame building without laminates.

Following are the steps in Creation of column and beam of G+3 RC frameBuilding without laminates.

1) For Creating column and beam, first of all we have to create Rectangle of 0.20 m x 0.30 m in plane right angle to the longitudinal axis of column and beam.

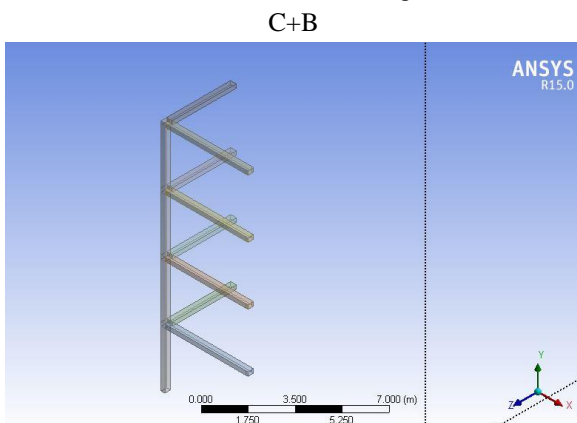2) Give extrude commamd to the rectangle for creating 3D column and beamas shown in figure.

C+B

Fig 2. : Creation of column and beam of G+3 RC frame buildingwithout laminates.

D. Creation of pattern of G+3 RC frame building without laminates.

Following are the steps in Creation of pattern of G+3 RC frame Buildingwithout laminates.

1) After Creating column and beam, give pattern command to create grid of column and beam for creating building model in ANSYS as shown in figure.
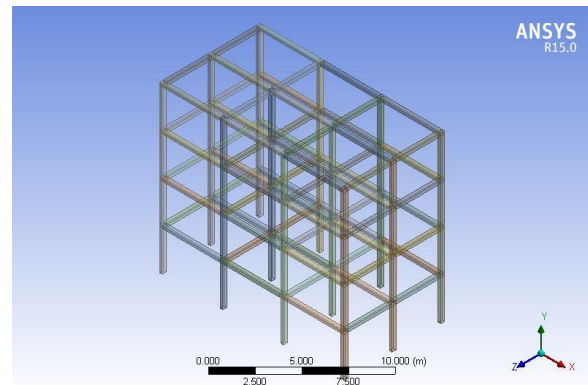
Pattern

Fig3. : Creation of column and beam of G+3 RC frame buildingwithout laminates.

E. Creation of slab of G+3 RC frame building without laminates.

Following are the steps in Creation of slab of G+3 RC frame Building without laminates.

1) After Creating column and beam, give 2D element area command to create area of slab in place of slab building model in ANSYS as shown in figure.

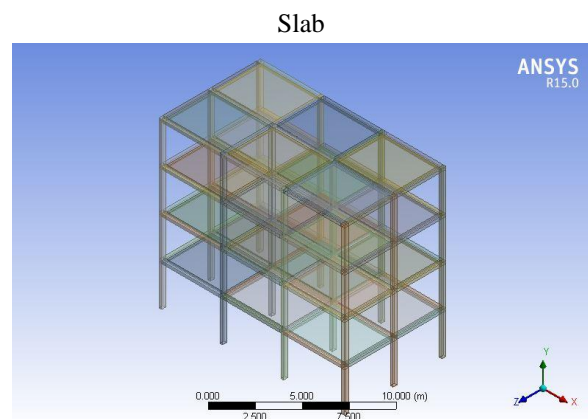2) Give the required thickness to the slab for creation of 3D solid element for Creation of slab as shown in figure.

Slab

Fig 4. : Creation of Slab of G+3 RC frame building without laminates.

F. Creation of 1 bottom side attached laminates to the beam and four side attached laminates to the column of G+3 RC frame building.

It is the stage for Creation of laminates for column and beam for building of G+3 RC frame Buildingas shown in figure.

1) After Creating column and beam, give 2D element area command to create area of laminates in place of laminates for building model in ANSYS as shown in figure.

2) Give the required thickness to the laminates for creation of 3D solid element for

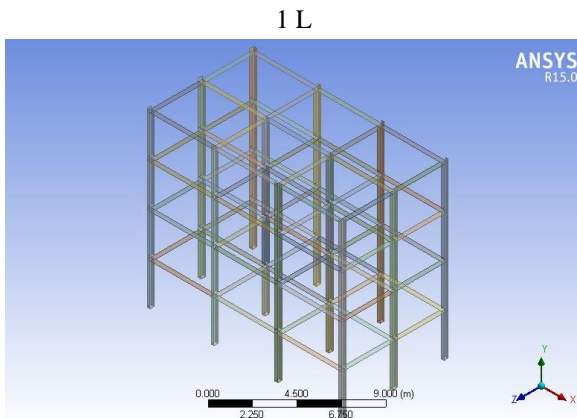Creation of laminates as shown in figure.

1 L

Fig 5. : Creation of four side of column and 1 bottom side of beam of G+3 RC frame building

J. Creation of 2 vertical side attached laminates to the beam and four side attached laminates to the column of G+3 RC frame building.

It is the stage for Creation of laminates for column and beam for building of G+3 RC frame Building as shown in figure.

1) After Creating column and beam, give 2D element area command to create area of laminates in place of laminates for building model in ANSYS as shown in figure.

2) Give the required thickness to the laminates for creation of 3D solid element for

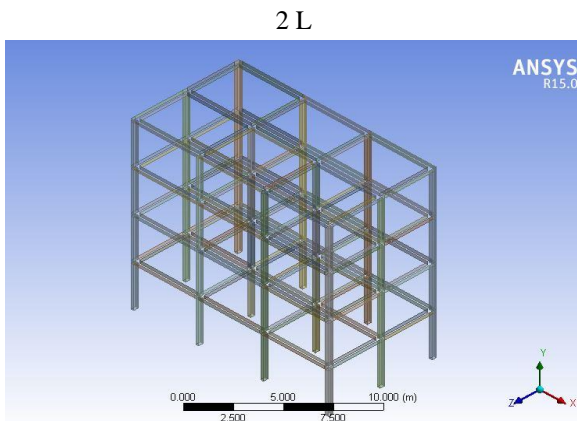Creation of laminates as shown in figure.

2 L

Fig 6. : Creation of four side of column and 2 vertical side of beam of G+3 RC frame building

K. Creation of 2 vertical side and 1 bottom side attached laminates to the beam and four side attached laminates to the column of G+3 RC frame building.

It is the stage for Creation of laminates for column and beam for building of G+3 RC frame Building as shown in figure.

1) After Creating column and beam, give 2D element area command to create area of laminates in place of laminates for building model in ANSYS as shown in figure.

2) Give the required thickness to the laminates for creation of 3D solid element for Creation of laminates as shown in figure.
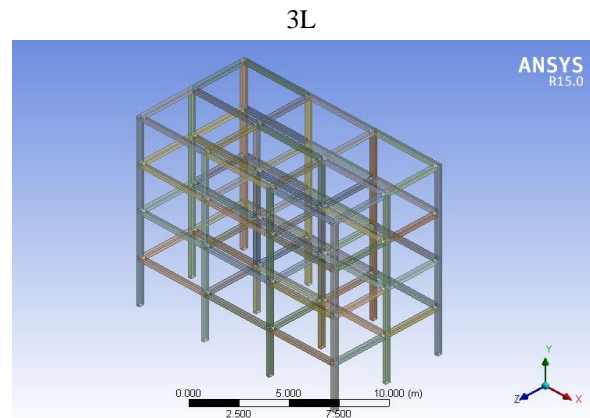
3L

Fig 7. : Creation of four side of column and 1 bottom side and 2 vertical side of beam of G+3 RC frame building

L. Creation of 2 vertical side and 1 bottom and 1 top side attached laminates to the beam and four side attached laminates to the column of G+3 RC frame building.

It is the stage for Creation of laminates for column and beam for building of G+3 RC frame Building as shown in figure.

1) After Creating column and beam, give 2D element area command to create area of laminates in place of laminates for building model in ANSYS as shown in figure.

2) Give the required thickness to the laminates for creation of 3D solid element for
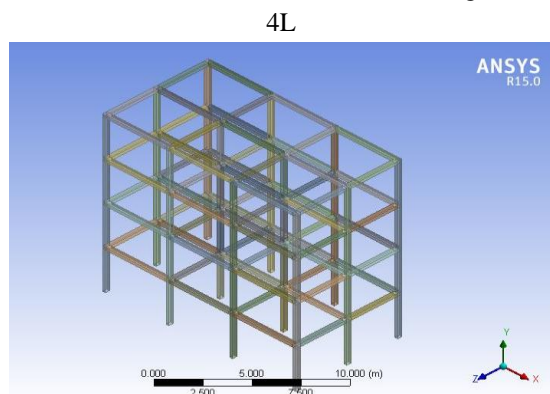
Creation of laminates as shown in figure.

4L

Fig 8. : Creation of four side of column and four side of beam of G+3 RC frame building

M. Creation of all layer of column and beam G+3 RC frame building with slab.

It is the stage for Creation of all layer of column and beam of G+3 RC frame Building with slab as shown in figure.
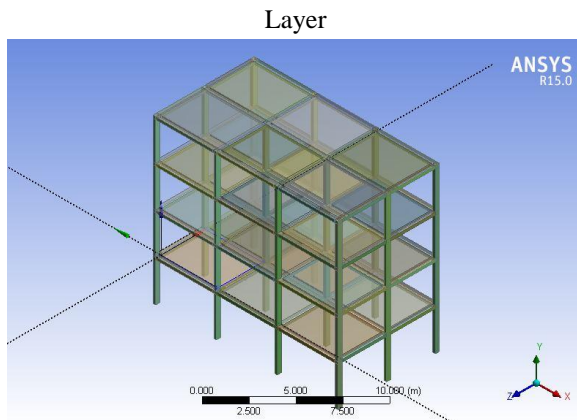
Layer

Fig 9. : Creation of layers column and beam of G+3 RC frame building

N. Creation of contact of G+3 RC frame building with laminates.

Following are the steps in Creation of contact of G+3 RC frame Building with laminates.

1) After Creating laminates to column and beam, give contact command to create connection of column and beam to the laminates for creating building model in ANSYS as shown in figure.
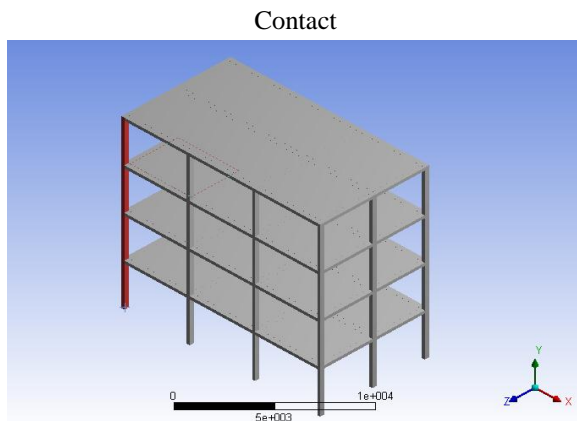
Contact

Fig 10. : Creation of Contact of G+3 RC frame building with laminates.

O. Creation of connection of G+3 RC frame building with laminates.

Following are the steps in Creation of connection of G+3 RC frame Building with laminates.

1) After Creating laminates to column and beam, give contact command to create connection of column and beam to the laminates for creating building model in ANSYS as shown in figure.
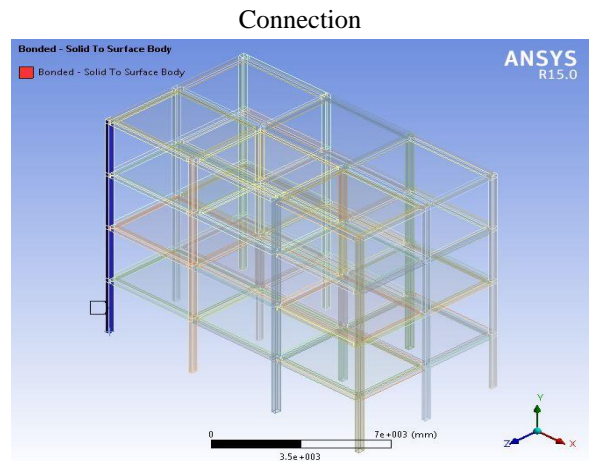
Connection

Fig 11. : Creation of Contact of G+3 RC frame building with laminates.

P. Creation of all connection of column and beam of G+3 RC framebuilding with laminates.

Following are the steps in Creation of connection of G+3 RC frame Building with laminates.

1) After Creating laminates to column and beam, give contact command to create all connection of column and beam to the laminates for creating building model in ANSYS as shown in figure.
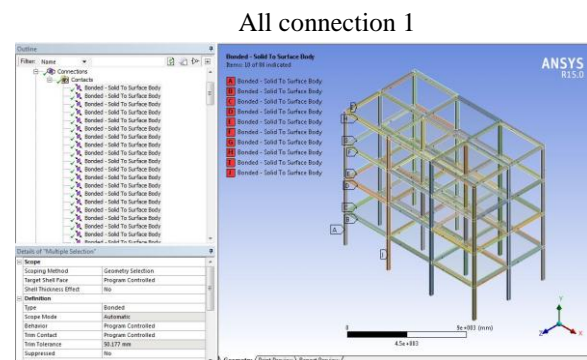
All connection 1

Fig 12. : Creation of connection of G+3 RC frame building with laminates.

Q. Creation of numbers to node points and names of column of one face of G+3 RC frame buildingwith laminates.

Following are the steps in Creation of numbers and names of column of G+3 RC frame Building with laminates.

1) After Creating laminates to column and beam, give numbers to the node points and names of columns of one face of the building model in ANSYS as shown in figure.
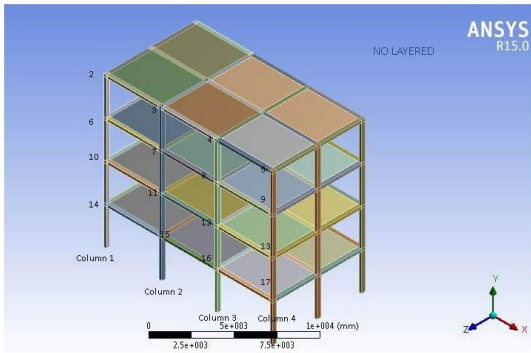
Numbers and Names

Fig 13. : Creation of numbers given to the nodes and columns of G+3 RC frame building with laminates

The modulus of elasticity of concrete M20 is taken for zero percentage of steel reinforcement for material no. 1.

III. ANALYSIS OF RC FRAME STRENGTHENED BY FRP LAMINATES USING ANSYS SOFTWARE

1. Loads applied for RC frame building for Analysis.

- The horizontal forces of 250 kN each are applied at four top level beam column joints
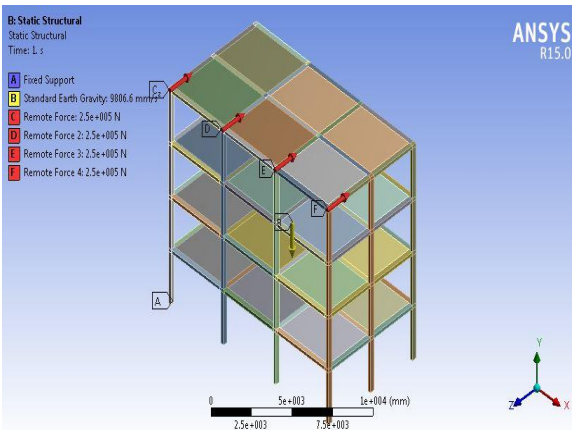- The self weight of the concrete is taken as 25 kN/m^3. for vertical load.

Fig 14. : Static Structural loading of G+3 RC frame building Withoutlaminates.

2. Following are the results of deflections of RC frame due to dead load and horizontal force applied as shown in figure.
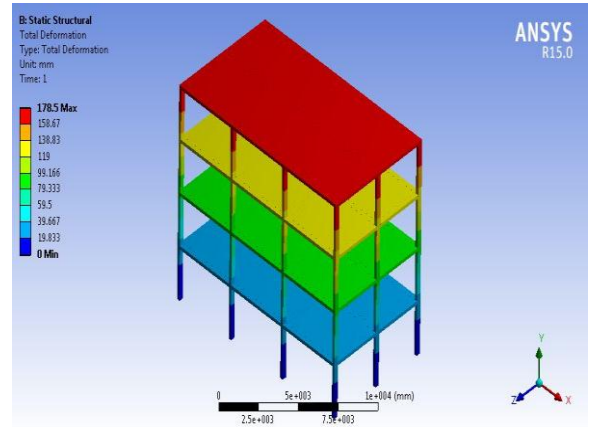

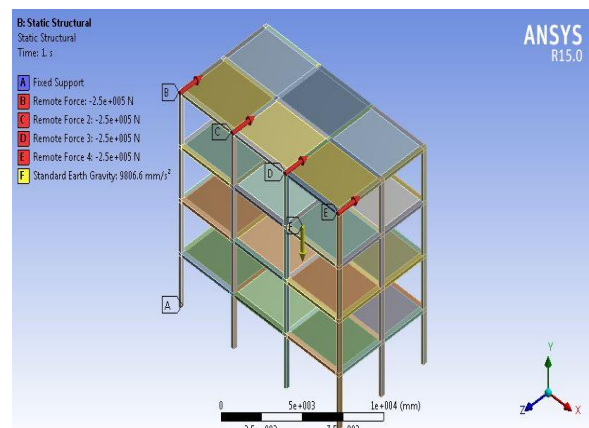Fig 15. : Total Deformation of G+3 RC frame buildingWithout laminates.

Fig 16 :Static Structural loading of G+3 RC frame building with 1Side attached laminates.

Fig 17. : Total Deformation of G+3 RC frame building with 1 Side attached laminates.

Fig 18. : Static Structural loading of G+3 RC frame building with 2Side attached laminates.
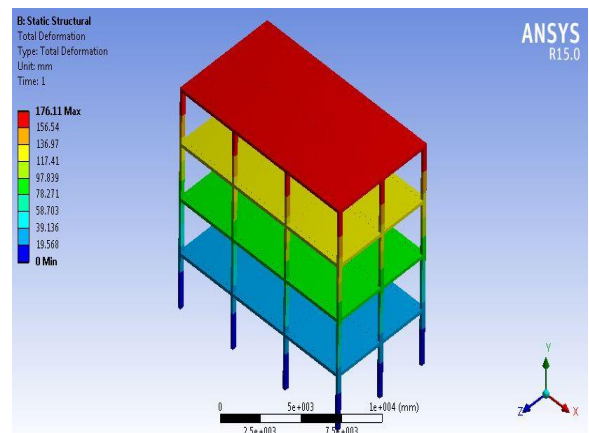

Fig 19. :Total Deformation of G+3 RC frame building with 2 Side attached laminates.
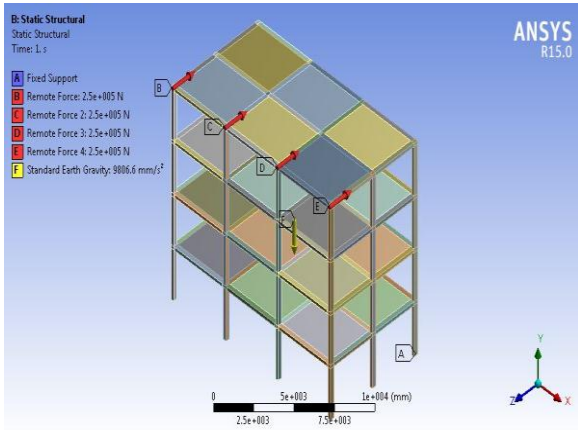

Fig 20. : Static Structural loading of G+3 RC frame building with 3Side attached laminates.
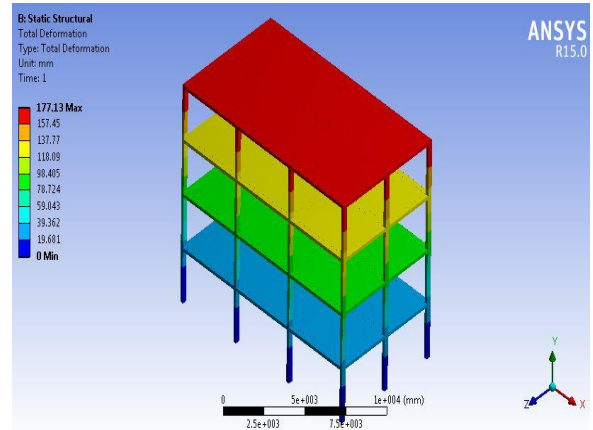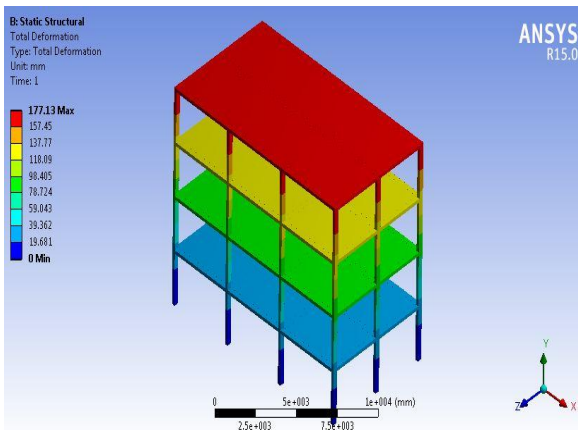

Fig 21. :Total Deformation of G+3 RC frame building with 3 Side attached laminates.

Fig 22. :Structural loading of G+3 RC frame building with 4Side attached laminates.

Fig 23.:Total Deformation of G+3 RC frame building with 4 Side attached laminates.

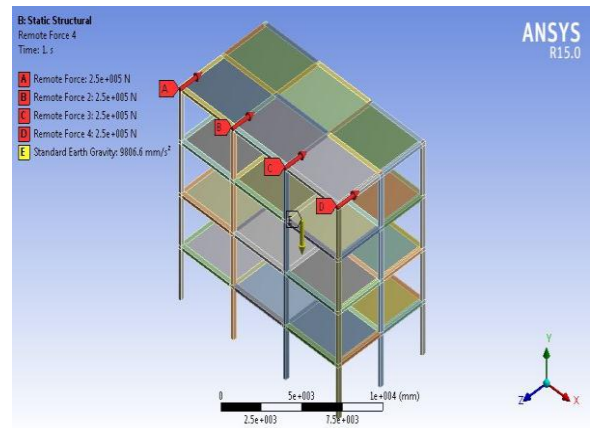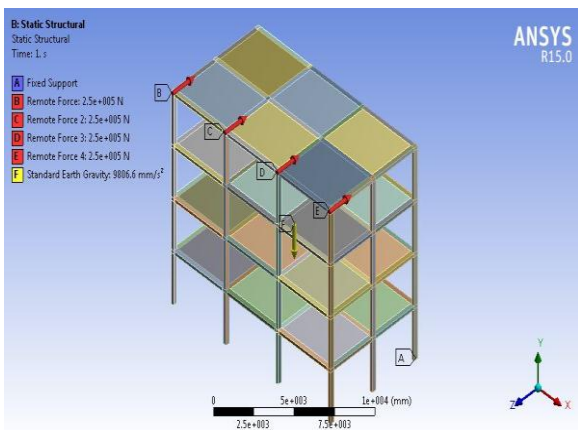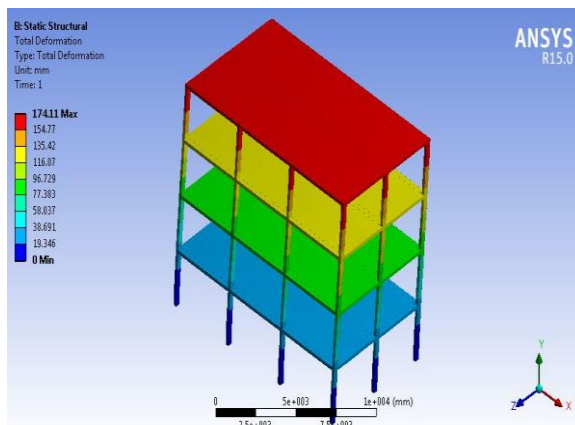Table No. II : Total Deformation of G+3 RC frame building with all types of laminates.

NODE N0.	CAMPARISION OF DEFLECTIONS AT NODES									
	TOTAL DEFORMATION (mm)					TOTAL CHANGE IN DEFORMATION (%)				
	Without laminates	1side attached laminates	2side attached laminates	3side attached laminates	4side attached laminates	Without laminates	1side attached laminates	2side attached laminates	3side attached laminates	4side attached laminates
2	177.54	175.15	176.17	174.140	173.160	0.00	-1.35	-0.77	-1.92	-2.47
6	133.11	131.33	132.06	130.580	129.860	-25.03	-1.34	-0.79	-1.90	-2.44
10	82.905	81.801	82.24	81.361	80.951	-53.30	-1.33	-0.80	-1.86	-2.36
14	33.886	33.439	33.599	33.292	33.183	-80.91	-1.32	-0.85	-1.76	-2.07
3	177.08	174.69	175.66	173.700	172.730	0.00	-1.35	-0.80	-1.91	-2.46
7	132.84	131.05	131.76	130.320	129.620	-24.98	-1.35	-0.81	-1.90	-2.42
11	82.686	81.575	82.002	81.147	80.748	-53.31	-1.34	-0.83	-1.86	-2.34
15	33.766	33.316	33.471	33.172	33.067	-80.93	-1.33	-0.87	-1.76	-2.07
4	176.93	174.53	175.47	173.570	172.610	0.00	-1.36	-0.83	-1.90	-2.44
8	132.73	130.94	131.62	130.220	129.530	-24.98	-1.35	-0.84	-1.89	-2.41
12	82.621	81.504	81.915	81.084	80.694	-53.30	-1.35	-0.85	-1.86	-2.33
16	33.744	33.29	33.440	33.149	33.048	-80.93	-1.35	-0.90	-1.76	-2.06
5	177.11	174.71	175.60	173.750	172.810	0.00	-1.36	-0.85	-1.90	-2.43
9	132.78	130.98	131.63	130.280	129.590	-25.03	-1.36	-0.87	-1.88	-2.40
13	82.708	81.587	81.981	81.172	80.790	-53.30	-1.36	-0.88	-1.86	-2.32
17	33.82	33.359	33.507	33.223	33.123	-80.90	-1.36	-0.93	-1.77	-2.06

The values for change in deformation (%) for nodes other than 3rd floor slab level in case of without laminates are considered in the table as zero (0), because of maximum basic value for comparision of other cases of attachment of laminates.

IV CONCLUSION

1. It is observed at the slab level of third floor, the observed deflection is 177.17 mm and that is maximum i. e. 100% for the building withoutlaminates. This is the basic value is considered for the comparision of decrease in deflection at other slab level of the building without laminates

2. It is observed at the slab level of second floor, the observed deflection is 132.87 mm and that is maximum for the building without laminates.The decrease in deflections at the slab level of second floor are about 25% when compared with deflection at the slab level of third floor of the building without laminates.

3. It is observed at the slab level of first floor, the observed deflection is 82.73 mm and that is maximum for the building without laminates.The decrease in deflections at the slab level of first floor are about 53.30% when compared with deflection at the slab level of third floor of the building without laminates.

4. 4It is observed at the slab level of ground floor, the observed deflection is 33.80 mm and that is maximum for the buildingwithoutlaminates.The decrease in deflections at the slab level of ground floor are about 80.92% when compared with deflection at the slab level of third floor of the building withoutlaminates.

5. 5 In case of RC building floorwise deflections are decreasing in columns similer to cantilever beam from free end with concentrated load applied at the end means at the top floor level.

6. It is observed at the slab level of third floor, the observed deflection is 177.17mm for the building without laminates. The decrease in deflections in 1 side attached laminates case is 1.35% and in 2 side attached laminates case 0.81% and in 3 side attached laminates 1.90% and in 4 side attached laminates case is 2.45%

7. It is observed at the slab level of second floor, the observed deflection is 132.87mm for the building without laminates. The decrease in deflections in 1 side attached laminates case is 1.35% and in 2 side attached laminates case 0.83% and in 3 side attached laminates case 1.89% and in 4 side attached laminates case is 2.42%

8. It is observed at the slab level of first floor, the observed deflection is 82.73mm for the building without laminates. The decrease in deflections in 1 side attached laminates case is 1.35% and in 2 side attached laminates case 0.84% and in 3 side attachedlaminatescase1.86% and in 4 side attached laminates case is 2.34%

9. It is observed at the slab level of ground floor, the observed deflection is 33.80mm for the building without laminates. The decrease in deflections in 1 side attached laminates case is 1.34% and in 2 side attached laminates case 0.89% and in 3 side attached laminates case 2.60% and in 4 side attached laminates case is 2.07%

10. In case of RC building by comparision with and without laminates, decrease in deflections are increasing as we attached more no. of sides with laminates except in case of 2 side attached laminates case it is 52.4% less decrease because of not attaching laminates to the bottom side and therefore decreasing in flexural strength.

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