Comparative Study of Progressive Collapse Analysis of RCC Multistoried Structure By Alternate Path Method of Non-Linear Static Analysis And Linear Static Analysis

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Abstract- *According to current innovations in the building industry, architects are needed to design high-rise structures using RCC. Unfortunately, owing to factors such as gas, this is not possible. explosion, terrorist assault, fire, etc., high-rise buildings experiences some severe component failure. As a result of the Failure of a significant component, and sometimes a portion of the building otherwise the whole building collapses. Furthermore, this Progressive collapse describes the structural behavior It is planned in this proposal to conduct out innovative Analysis of the collapse of a 12-story RC frame structure by deleting each column individually in accordance with the GSA guidelines. The Indian building code specifies a 6 x 5 bay, 3 m in X and Y directions. Structural model of The structure has been designed in ETABS and loads have been applied. according to GSA criteria for assessment of progressive collapse Utilization of a nonlinear static approach of analysis. As per Given in GSA, the first floor contains three column removal scenarios. similar to corner column C1 and interior column C43 exterior column C47. In such instances, nonlinear static study has been performed and joint displacements for three column joints removal cases are assessed. Additionally, PMM ratio and axial bending moments for neighbouring columns and shear forces for adjacent beams are assessed. The results indicate that, for gradual collapse, the internal column is more important than the other two sites, i.e. Exterior corner and column.*

Keywords- Progressive Collapse, nonlinear static analysis, Linear Static Analysis

I. INTRODUCTION

Food, clothes, and shelter are necessities of a human being and the structural engineering serves one of the basic needs of man i.e. Shelter. From stone age to up till now a man trying to improve his shelter. From the last 5-6 decades' improvement of structures technology has extraordinarily boosted. Now in the 21st-century man want to rise and up to construct taller, stronger and serviceable structures. But though we want to strengthen it, it may get affected due to natural calamities such as the earthquake. So, to construct more and more earthquake resistant structure huge scale of research going on worldwide. Despite from earthquake, there are some manmade enemies of structures. From the last 3-4 decades, the whole world is facing terrorist attacks. Terrorist attacks may lead to severe damage to structures. Nowadays in India commonly rcc framed structures are preferred as its ease in construction and economy. But rccframed structure has a chain like failure behavior. Destruction in one link may tend to the failure of the whole chain. The same way any damage in a single component of rcc framed structure leads to failure of the whole frame. Single bomb blast may not influence the whole frame, but it may damage any component of rcc frame and due to its chain like failure behavior the whole structure may get damaged.

Rather still in India, there is not any special design consideration involved to construct blast sustainable buildings. Though bis 15916-2010 [1] has given some special case design to resist some man-made loads such as fire and blast it is only for prefabricated concrete.it is now necessary to provide some specification of blast loading design to construct special or army buildings. This can only be carried out by studying the catastrophic failure mechanism of a structure.

The failure of rcc framed structure or any structure due to failure or destruction of any single structural component is known as the progressive collapse of the structure [2]. The progressive collapse is also known as catastrophic failure. There are various guidelines given by gsa [3] for the analysis of progressive collapse. Alternate path method is one of the famous methods used to study the progressive collapse. There is a total of four methods involved in alternate path method such as:

- Linear static method
- Non-linear static method
- Linear dynamic method
- Non-linear dynamic

Nowadays huge research is going on the construction of the blast resisting structure. Many researchers studying to increase the blast resistance of rcc structure but it is observed that the blast causes the only destruction of a few members, but the remaining frame leads to a relative collapse mechanism. So here we are going to study the progressive collapse of a normal rcc framed structure by static non-linear method. In this investigation report, a normal rcc framed building is studied according to is 456 [4]. The developed building is then analyzed with the help of sap2000. The progressive collapse behavior of the developed structure is then studied with the help of alternate path method by linear static analysis [5]. In the alternate path method of linear static analysis, the building is studied with the removal of a column and its effect on consecutive columns are studied. For non-linear static analysis, the columns at the various location are removed and then the building is analyzed [6]. The readings of axial force, moment after and before the removal of the column is calculated with the help of sap2000 and the change in it is interpreted. It is generally observed that the column consecutive to the removed or blast affected columns are mostly affected [7]. These methods are also used to study the progressive collapse behavior of structure under the effect of fire [8]. Some researchers used the progressive collapse analysis method for the assessment of structure under seismic loads [9]. there is large study going to perform the progressive collapse analysis with nonlinear dynamic analysis procedure [10] [11]. The progressive collapse behavior can be studied experimentally with the help of a prototype of a certain structure under blast loading [12].

II. OBJECTIVES

- To analyse the structure with the removal of the column at different locations
- To study the post column removal effect on structure with the help of linear static and nonlinear static method.
- To compare the linear static and no linear static method of progressive collapse.
- To suggest most realistic progressive collapse

III. LITERATURE REVIEW

Y.A. Al-Salloum et.al [14] an attempt has been made in this paper to develop a practical and acceptable procedure for the progressive collapse analysis of reinforced concrete (rc) framed structures. The adequacy of the procedure has been demonstrated by studying the progressive collapse behavior of a typical rc framed high-rise building in Riyadh when exposed to blast generated waves.

Aldo Mckay, Kirk Marchand, And Manuel Diaz [17] - the study concluded that the factors in the existing guidelines tend to yield overly conservative results, which often translate into expensive designs and retrofits. This study identified new load increase factors and proposes a new approach to utilize these factors when performing alternative path analyses for progressive collapse.

General Service Administration [3]- it is a most useful guideline for our research work this article include the detailed guidelines of progressive collapse analysis of different types of the structure along with different methods of progressive collapse behavior. This article helps us to select the appropriate analysis method for the progressive collapse behavior study. The loading provisions provided with different cases of analysis. The articles help to select the exact column removal location for the analysis. Also, the detailed information about dcr and its calculation formulas are provided for the ease of researchers. The gsa has provided irregularities in a structure where one cannot perform alternate path method linear analysis.

Mahmoud Yara et.al [9] - one first-storey column is fully removed at arbitrary locations within the building using alternate path method recommended in the ufc guidelines in order to study consequences and check safety of adjacent members. 3-d nonlinear dynamic analyses are employed using sap2000 is employed in the performed parametric study.

M.D. Goel, Dhiraj Agrawal and A. Chobey[2]- the author performed the progressive collapse analysis of the rcc framed structure with the help of a commercial software stad.pro. They performed the analysis with the help of alternate path method of linear static analysis. The results are interpreted with the help of various quantities such as dcr i.e. demand-capacity ratio, deflection, change in axial force and the change in bending moment.

Shalva Marjanishvili and Elizabeth Agnew[13]- a normal rcc framed structure analyzed for progressive collapse by 4 different analysis method including linear and nonlinear analysis. The structure is analyzed with the help of commercially available software sap2000. The result of the analysis of different methods is compared to review most realistic analysis method of progressive collapse.

Shu-Chao Lin [7]- based on the substructure model, a new method for progressive collapse analysis of steel frames under blast load is proposed. First, the massive explosion scenario inside a building is introduced. Then the substructure model within effective areas of blast influence is established. After that, the calculation method of non-zero initial conditions and initial damage for structural members is given, and finally the specific steps of the proposed method are described.

IV. METHODOLOGY

Three structures structure a, structure b, structure c having similar geometry but different bay and beam lengths are to be studied for catastrophic failure analysis after bomb blast scenario. for this progressive collapse mechanism studied the non-linear static analysis of alternate path method is used. In this method, the structure member is removed assuming failure of that member and then the whole structure is analyzed on the basis of various parameters such as dcr, change in deflection, change in axial force, change in a moment in consecutive beams and column with before and after removal of that structural member.in this research work, the whole structure is modelled with the help of fem based software sap2000 and staad.pro, the structures are analyzed assuming the bomb blast scenario at two different places at an external column and at an internal column. The result is interpreted with the help of graphs and tables. The detailing of three different structures is shown below.

4.1 Structure A:

Consider A Normal Symmetrical RCC Framed Structure Having 7 Stories Having Height 3m Each. The Building Is Having 5 Columns in Both X and Y Direction with A Spacing of 4 M Each. The Cross-Section of All Member Column and Beam Is Taken as 0.3m-0.3m. 2 Different Blasting Scenarios Is Assumed for This Structure Such as:

- The exterior column, column no. 2 near corner column get damaged.
- The internal column, column no. 7

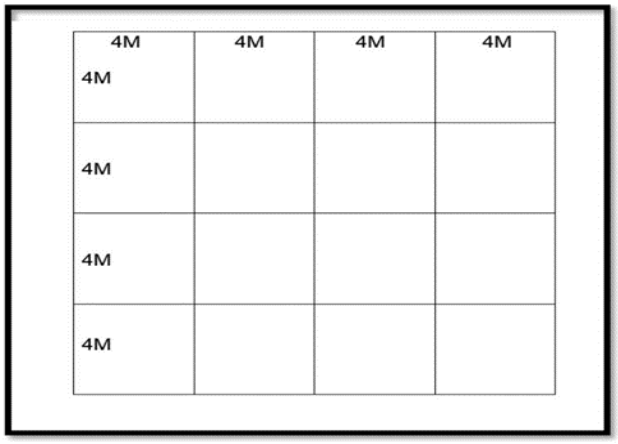

Fig1:Plan Structure A

4.2 Structure B:

Consider A Normal Symmetrical RCC Framed Structure Having 7 Stories Having Height 3m Each. The Building Is Having 5 Columns in Both X and Y Direction with A Spacing of 5m Each. Consider a typical symmetrical RCC-framed building with seven stories that are each three metres tall. The building has five columns spaced 5 metres apart in both the X and Y directions.

The Cross-Section of All Member Column and Beam Is Taken as 0.3m-0.3m. 2 Different Blasting Scenarios Is Assumed for This Structure Such as:

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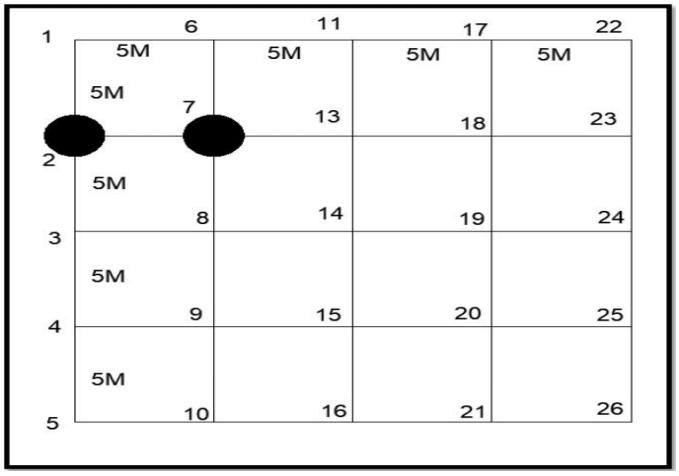

Fig 2: Plan Structure B

4.3 Structure C

Consider A Normal Symmetrical RCC Framed Structure Having 7 Stories Having Height 3m Each. The Building Is Having 5 Columns in Both X and Y Direction with

A Spacing of 6m Each. The Cross-Section of All Member Column And Beam Is Taken As 0.3m-0.3m. 2 Different Blasting Scenarios Is Assumed For This Structure Such As:

- The exterior column, column no. 2 near corner column get damaged.
- The internal column, column no. 7
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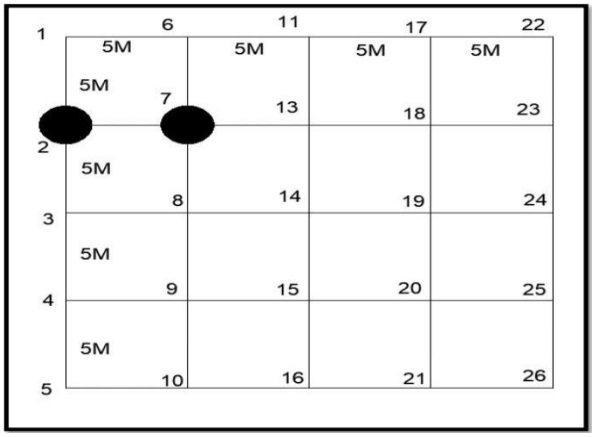

Fig 3: Plan Structure C

4.4 Modelling and development of structure:

4.4.1 Modelling with SAP200

All three structures are modelled with the help of FEM based software SAP2000. This software used to model the whole structure by assigning the cross-sections dimensions to the beams and columns. Also, materials are assigned with properties as per is 456 [4]. This software provides us the bending moments and the axial forces columns as well as shear forces based on fem analysis of given rcc framed structure.

For the analysis of the whole structure, the clear cover for all structural member is assumed to be 25 mm and the concrete of m20 grade along with the main reinforcement of fe415grade. In the first step, all the structures with all columns and beams are analyses to get a normal bending moment and axial and shear forces. This analysis gives us the before bomb blast scenario of the structures.

After getting all results of pre-blast bending and forces the frame is analyzed by assuming blasting scenario with the removal of columns at various locations as discussed earlier. The bending moment and the shear forces calculated as data provided by sap2000. Change in shear forces, axial forces and bending moment calculated with respect to previous analysis condition.

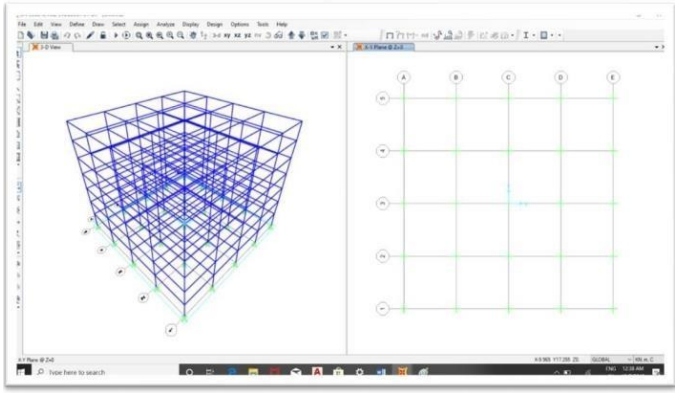

Fig 4: Modelling of structure in SAP2000

One of the important term used during the modelling for the progressive collapse behavior is allotment of hinges to the beam over the affected area. Hinges are used to study the plastic behavior of the member.

The hinges shows effects of loading on the structure. The extent of damage can be studied with the help of hinges. For analysis point of view two hinges to the beams are provided at the support.

The hinges reveal the loading effects on the structure. The level of damage may be determined using hinges. At the support, there are two hinges on the beams for analytical purposes.

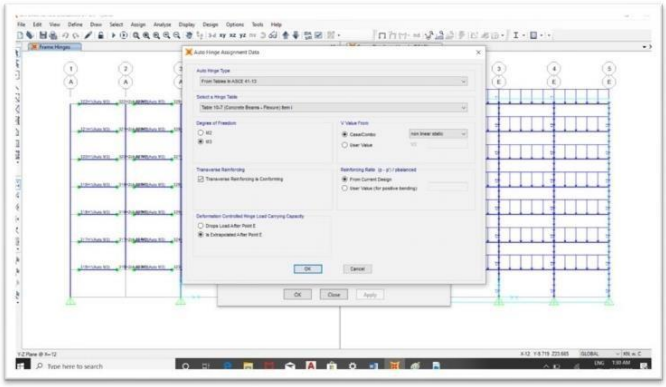

Fig: 5 Allocation of Hinges

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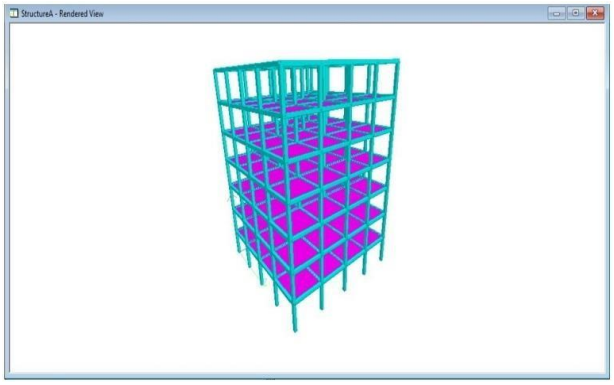

Fig 6: Modelling of structure in Staad.pro

4.5 Load

4.5.1 Nonlinear static method:

The progressive collapse behavior study with alternate path method of a non-linear static method is performed under static gravity loading. Non-linear static analysis is also know pseudo dynamic method. In this type of loading method, the load is applied in number of steps with increasing load. The total ultimate load is not directly applied. Behavior of structure is analyzed at each and every steps of loading.

Along with The Loading Condition Normal Gravity Loads Such as Dead Load And the Live Loads as Applied the Structure. The Love Load Applied Is Equal to 4KN/m2over The Surface area.

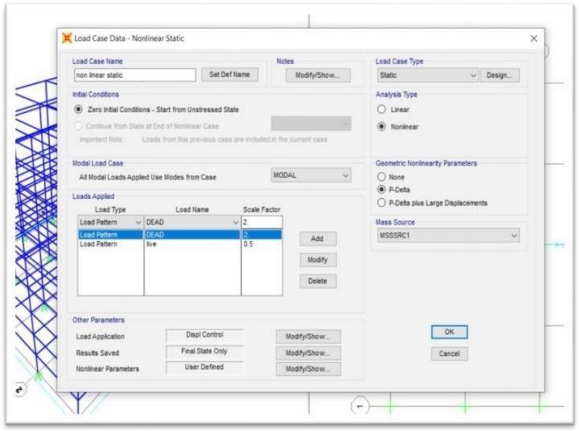

Fig 7: non-linear static load application with SAP2000

Method to apply Non-linear static loading

- Force-controlled analysis
- Deformation controlled analysis.

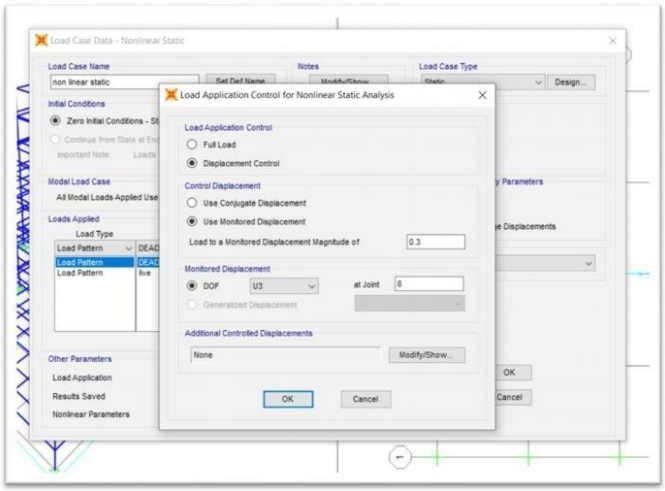

Fig 8: Displacement controlled load application

For this research work the displacement-controlled action for non-linear static analysis is adopted. In this displacement-controlled action, the total displacement of 300mm is applied at the removed column. And its behavior along to consecutive columns are studied. Along with specified displacement the extra gravity load combination of dead load and live load is applied to the structure.

V. RESULTS

The structure is loaded as mentioned above and it is analyzed with the help of the sap2000. The axial force of the column near the column removed is calculated and it is compared with the axial force at normal load condition.

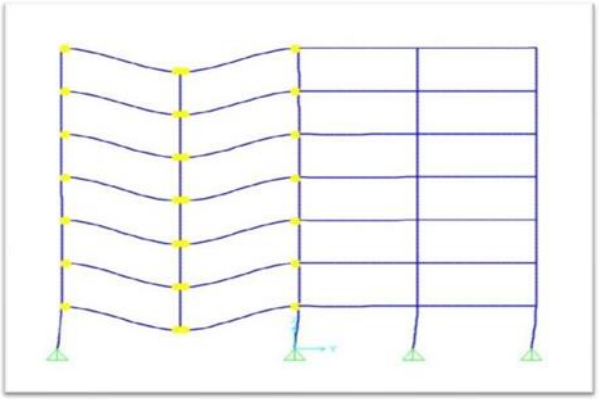

Fig 9: Deformed Shape Of Structure (SAP2000)

The axial force in different columns before column removal and after column removal is shown in the following table:

Column	Linear Static Method	Non Linear Static Method
1	21.3	40
3	15.3	31
7	19.48	36.74

Table 1: Deflection in Structure A after removal of column 2

column	Linear static method	Nonlinear static method
2	3.731	25
6	3.731	24.37
8	5.232	35
13	5.232	36.24

Table 2: Deflec1tion in Structure A after removal of column 7

Column	Linear Static Method	Non Linear-Static
1	61.3	129
3	46.9	97.71
7	58.4	106

Table 3: Deflection in Structure B after removal of column 2

Column	Linear Static Method	Non Linear-Static Method
2	5.242	30
6	5.242	31
8	7.748	41
13	7.748	42

Table 4: Deflection in Structure B after removal of column 7

Column	Linear Static Method	Non Linear Static Method
1	68.3	130
3	51.9	103
7	63.4	107

Table 5: Deflection in Structure C after removal of column 2

Column	Linear Static Method	Non Linear Static Method
2	6.56	32
6	6.56	34
8	8.28	43
13	8.28	45

Table 6: Deflection in Structure C after removal of column 7

Column	Structure A		Structure B		Structure C	
	Linear Static	Non-linear Static	Linear Static	Non-Linear Static	Linear static	Non Linear Static
1	0.54	1.06	0.72	1.07	0.89	1.18
3	0.77	1.05	1.06	0.90	1.34	1.36

7	0.94	1.36	1.40	1.19	1.84	1.54

Table 7: DCR values for adjacent columns after removal of column 2

Column	Structure A		Structure B		Structure C	
	Linear static	Non-Linear Static	Linear Static	Non-linear Static	Linear Static	Non-Linear Static
2	0.70	2.69	0.98	2.40	1.25	1.62
6	0.70	2.76	0.98	2.26	1.25	1.61
8	0.98	2.40	1.44	2.03	1.90	1.42
12	0.98	2.46	1.44	2.13	1.90	1.42

Table 8: DCR values for adjacent columns after removal of column 7

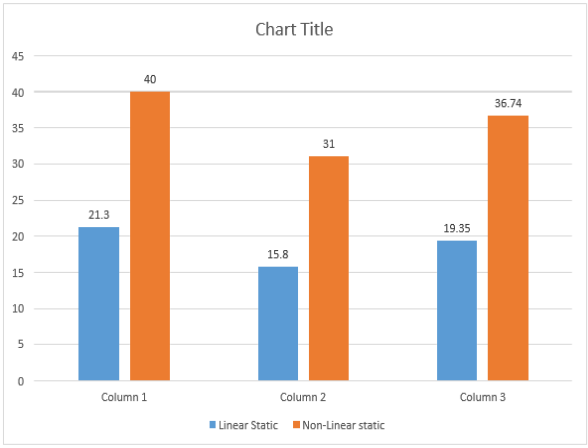

Fig 10: Deflection in structure A after removal of column 2

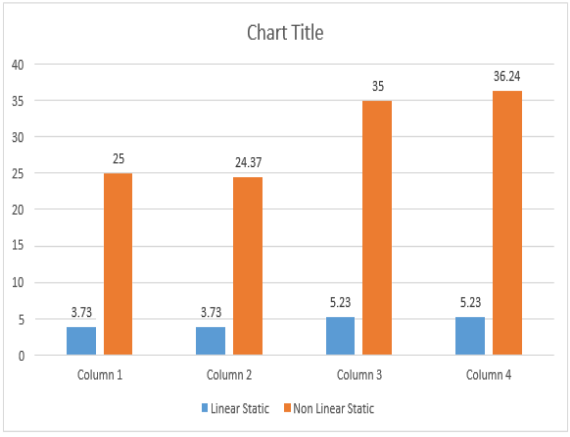

Fig 11: Deflection in structure A after removal of column 7

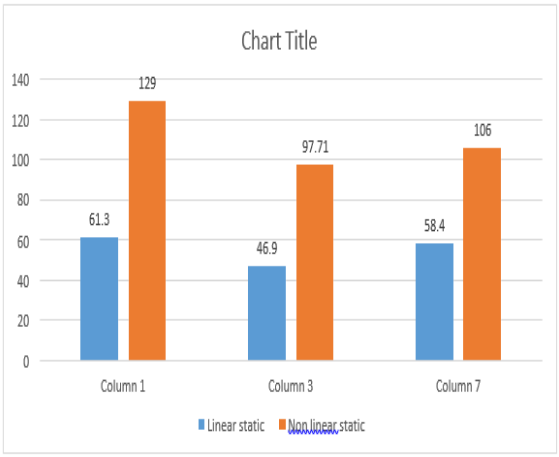

Fig 12: Deflection in structure B after removal of column 2

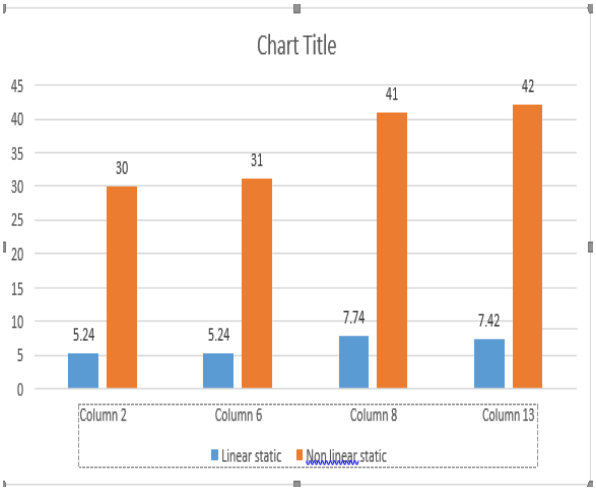

Fig 13: Deflection in structure B after removal of column 7

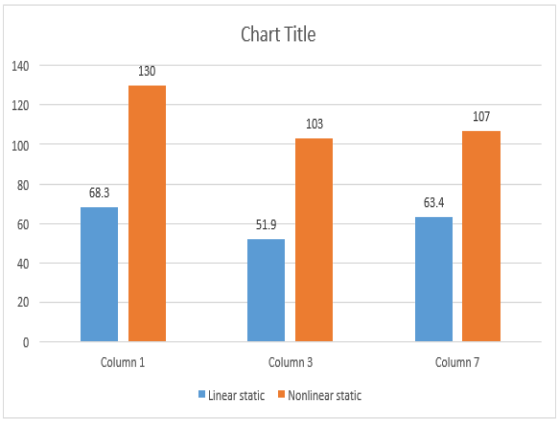

Fig 14: Deflection in structure C after removal of column 2

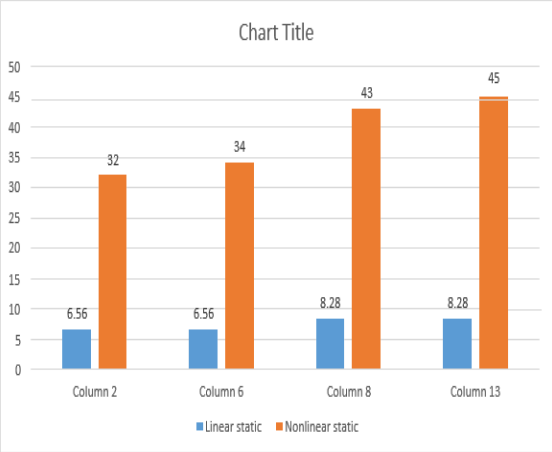

Fig 15: Deflection in structure C after removal of column 7

VI. CONCLUSION

After the whole analysis of these structures, it is observed that the effect of removing any structural member lies only on the member which are connected to it with directly. Far members who are not connected is not having very much effect on removing the member. After result interpretation, we found that.

1. The progressive collapse analysis of structure with nonlinear static analysis shows higher deflection values than that of the linear static analysis.
2. There is limitation to the linear static method for analysis of progressive collapse analysis, as it only used to analysis the symmetric structure.
3. The provision of plastic hinges during the nonlinear static analysis improves the extent of progressive collapse analysis.
4. The deflection after removal of adjacent column is under serviceability condition in case of the linear static analysis which is objectionable.
5. The DCR values of the linear static method is much lesser than that of the nonlinear static method of analysis.
6. Change in load is observed much more in case of nonlinear static analysis than that of the linear static analysis.
7. Plasticity of the structure is taken in account in nonlinear static analysis than that of the linear static analysis.
8. Increase in distance between bays makes structure if any destruction of support member is assumed.

From the above-discussed points we can conclude that an increase in distance between bays may make structure critical after bomb blasting scenario. The structure becomes weaker and weaker as we increase the distance between bays. After the removal of the external column, the internal column adjacent to it will be the critical column after the failure. While in case of the internal column next to external columns the column most internal and adjacent to it will be the most critical after a failure of that column.

After the results we concluded that the nonlinear static method is more reliable than that of the linear static method of analysis.one can analyses any unsymmetrical structure with the help of the nonlinear static method. Only symmetric structure should be analyzed with the help of linear static method. Finally we conclude that nonlinear static method is more realistic then that of the linear static method.

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