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PROGRESSIVE COLLAPSE ANALYSIS WITH SEISMIC LOADING USING E-TABS

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ABSTRACT

Progressive collapse involves a series of failures that lead to partial or total collapse of a structure. It is generally initiated by loss of one or more vertical load carrying elements. This loss is caused by abnormal loads such as bombings, gas explosion, and earthquakes. Etc. Progressive collapse due to seismic actions has not received much attention in spite of its importance and repeated occurrences. In the current study, it is intended to investigate the progressive collapse potential of steel moment resisting and braced frames designed according to Egyptian local standards due to damage caused by seismic actions-TABS CONNECTEDITION as per Indian Standard codes for four unique cases after corner section evacuation conditions. To contemplate collapse, normal sections are taken out each in turn, and preceded with examination and plan. The ultimate goal of this progressive collapse research on building is to develop better building evaluation and design guideline for structural engineers to use to prevent collapse in new and existing building. Future progressive collapse research recommendation is also presented.

***Keywords**: Progressive Collapse, G+4 Story Building, GSA 2013, DCR*

1. INTRODUCTION

1.1 General:

This project presents an attempt to do progressive collapse analysis of multistory (G+4) residentialbuilding by E-TABS (Structural Analysis and Design Software Application). In this project G+4 RC framebuilding is analysis statically (linear method) along with Progressive Collapse analysis. All the membersof the project are analyzed as per Indian codes IS 456:2000, and IS 1893:2016 (part1) code using this software. For Progressive Collapse Analysis General Service Administration (GSA) 2013 guidelines are followed. Progressive collapse is the collapse of all or a large part of a structure precipitated by damage or failure of the relatively small part of it. Progressive Collapse occurs when one of the major load carryingelement failed due to some reason such as blast of cylinder or terrorist attack, due to failure of major element load carried by major element is distributed to adjacent elements which increases load on adjacent member more than its capacity and due to which adjacent member also get failed and transfers loads to its adjacent member. Prevention of progressive collapse is one of the unchallenged imperatives in structural engineeringtoday The process is continuing until all the structure gets failed.

1.2 GSA 2013:

The purpose of these Guidelines is to reduce the potential for progressive collapse in new and renovated Federal buildings. It is intended to bring a consistent level of protection in the application of progressive collapse design to Federal facilities and to bring alignment with the suite of security standards issued by the Interagency Security Committee (ISC) and the General Services Administration (GSA) in their philosophy, decision-making methodology and application. In addition, it aims to bring alignment within the industry by reducing incongruities between GSA and Department of Defense (DoD) methodologies. To meet this purpose, these Guidelines replace the previous document "GSA Progressive Collapse Analysis and Design Guidelines for New Federal Office Buildings and Major Modernization Projects 2003" and provide a new, threat-dependent methodology for minimizing the potential for progressive collapse that utilizes the alternate path(AP) analysis procedures of UFC 04-023-03, Design of Buildings to Resist Progressive Collapse and ASCE-41, Seismic Rehabilitation of Existing Buildings.

2. OBJECTIVES

- To understand the whole meaning and typologies of progressive collapse.
- To understand the mechanism of progressive collapse
- To study various design approaches as provides by British standards, GSA 2013
- To study the process of progressive collapse analysis of multi story (G+4) RCC building by using stadd pro 2013 software

- To understand progressive collapse analysis of building by non linear dynamic analysis
- To check whether a RC building analysis and detailed by Indian codes for seismic loads provides any resistance to progressive collapse or not
- To propose successful strategy for plan of new structure to keep away from Progressive collapse.

3. METHODOLOGY

- Detailed study of literature review
- G+4 RCC building is taken for project
- Modeling in E-TAB'S
- Progressive collapse analysis is carried out
- Identification of damaged location and studying -behavior of building during earthquake
- Interpretation of result using Time history method.

4. MODELING AND LOADING

The input data used for modeling are as follows:

- Building type: G+4 Residential Building
- Plan area: 10(m)*9(m)
- Beam size: 250(mm)*200 (mm), 230(mm)*500 (mm)
- Column size: 250(mm)*480 (mm)
- Slab thickness: 150mm
- Typical story height: 3m
- Bottom story height: 2.6m
- Live load, LL: 2kN/m²
- External Wall load: 5.75 KN/m
- Partition and floor finishing load, FL: 1.0kN/m2
- Concrete: M25
- Steel: HYSD415

We used time history method:

Time history method gives all possible forces which are generated, and there by displacement of structure, during entire duration of ground motion at equal interval, typically o.o5 to o.1 sec.

Time-history analysis is the behavioral study of a structure under a past earthquake or wind acceleration data. Structure need not be SDoF system. Time-history is a plot of amplitude or acceleration vs time.

In time history analyses the structural response is computed at a number of subsequent time instants. In other words, time histories of the structural response to a given input are obtained a result. In response spectrum analyses the time evolution of response cannot be computed

Nonlinear Dynamic Analysis:

Nonlinear Dynamic Analysis It is known as Time history analysis. It is an important technique for structural seismic analysis especially when the evaluated structural response is nonlinear. To perform such an analysis, a representative earthquake time history is required for a structure being evaluated. Time history analysis is a step-by step analysis of the dynamic response of a structure to a specified loading that may vary with time. Time history analysis is used to determine the seismic response of a structure under dynamic loading of representative earthquake (Wilkinson and Hiley, 2006) (Tables 1 and 2).

Earthquake response spectrum:

- Earthquake response spectrum is the most popular tool in the seismic analysis of structures.
- Response spectrum is an important tool in the seismic analysis and design of structures. It describes the maximum response of damped single degree of freedom system to a particular input motion at different natural periods.
- Response spectrum method of analysis is advantageous as it considers the frequency effects and provides a single suitable horizontal force for the design of structure.

Seismic zones in India:

The Indian subcontinent has a history of devastating earthquakes. The major reason for the high frequency and intensity of the earthquakes is that the Indian plate is driving into Asia at a rate of approximately 47 mm/year.[1] Geographical statistics of India show that almost 54% of the land is vulnerable to earthquakes. A World Bank and United Nations report shows estimates that around 200 million city dwellers in India will be exposed to storms and earthquakes by 2050. The latest version of seismic zoningmap of India given in the earthquake resistant design code of India [IS 1893 (Part 1) 2002] assigns four levels of seismicity for India in terms of zone factors. In other words, the earthquake zoning map of India divides India into 4 seismic zones (Zone 2, 3, 4 and 5) unlike its previous version, which consisted of fiveor six zones for the country. According to the present zoning map, Zone 5 expects the highest level of seismicity whereas Zone 2 is associated with the lowest level of seismicity.

PROGRESSIVE COLLAPSE:

Progressive collapse is the collapse of all or a large part of a structure precipitated by damage or failure of a relatively small part of it. The phenomenon is of particular concern since progressive collapse is often (though not always) disproportionate, i.e., the collapse is out of proportion to the event that triggers it. Thus, in structures susceptible to progressive collapse, small events can have catastrophic consequences.

Progressive collapse occurs when a local failure spreads throughout a structure from element to element, eventually resulting in the collapse of either the entire structure or a disproportionately large part of it. Progressive collapse is caused by an abnormal or extreme loading event, typically due to accidental impact, faulty construction, foundation failure, or violent changes in air pressure.

ETABS:

ETABS is an engineering software product that caters to multi-story building analysis and design. Modeling tools and templates, code-based load prescriptions, analysis methods and solution techniques, all coordinate with the grid-like geometry unique to this class of structure. Basic or advanced systems under static or dynamic conditions may be evaluated using ETABS. For a sophisticated assessment of seismic performance, modal and direct-integration time-history analyses may couple with P-Delta and Large Displacement effects. Nonlinear links and concentrated PMM or fibre hinges may capture material nonlinearity under monotonic or hysteretic behaviour. Intuitive and integrated features make applications of any complexity practical to implement. Interoperability with a series of design and documentation platforms makes ETABS a coordinated and productive tool for designs which range from simple 2D frames to elaborate modern high-rises.

IS CODE 1893:

The first Indian seismic code (IS 1893) was published in 1962 and it has since been revised in 1966, 1970, 1975 and 1984 . More recently, it was decided to split this code into a number of parts, and Part 1 of the code containing general provisions (applicable to all structures) and specific provisions for buildings has been published2. Considerable advances have occurred in the knowledge related to earthquake resistant design of structures during the 18 years interval between the two editions of the code3 . Some of these new developments have been incorporated in the 2002 version of the code, while many others have been left out so that the implementation of the code does not become too tedious for Indian professional engineers. For example, in the United States, the codes are revised every three years, and hence, a typical building code in the United States has acquired sophistication gradually over about six revisions during these 18 years. Since the Indian code has had to make a quantum jump with respect to many of the provisions, it still requires considerable effort for an average professional engineer to fully appreciate the new code and to be able to implement it correctly.

Zone factor (z):

Zone factors are given on the basis of expected intensity of the earthquake in different zones. In IS Code, it is given based on the Maximum Considered Earthquake (MCE) and service life of the structure in a zone.

Seismic Weight (W):

It is the Assumed weight of the structure at a time of expected earthquake; code gives guidelines to consider full dead load and the appropriate amount of imposed load in the calculation of seismic weight.

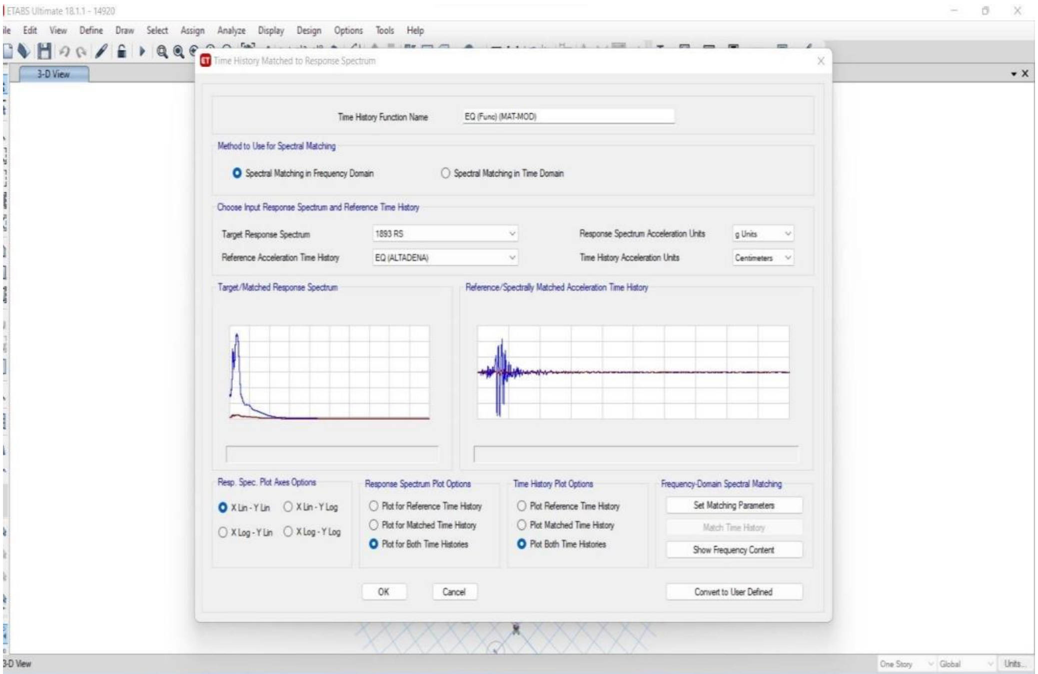
Time period:

Time period formula as per IS codes relates overall height of the building and the base dimension of the building. Time period plays an important role in design of earthquake resistant structures. As per the codes such as United States (US) and Egyptian codes and as per the recommendations provided in many researches, the fundamental period of vibration is estimated by considering the overall height of the building or by the number of storeys. Both the factors are not considered together. Many design codes are available for the design of earthquake resistant structures. Simple relationships are available in many codes which relate the height of the building with the fundamental time period. These relationships are for force based design which will estimate the time period and hence the base shear force can be predicted.

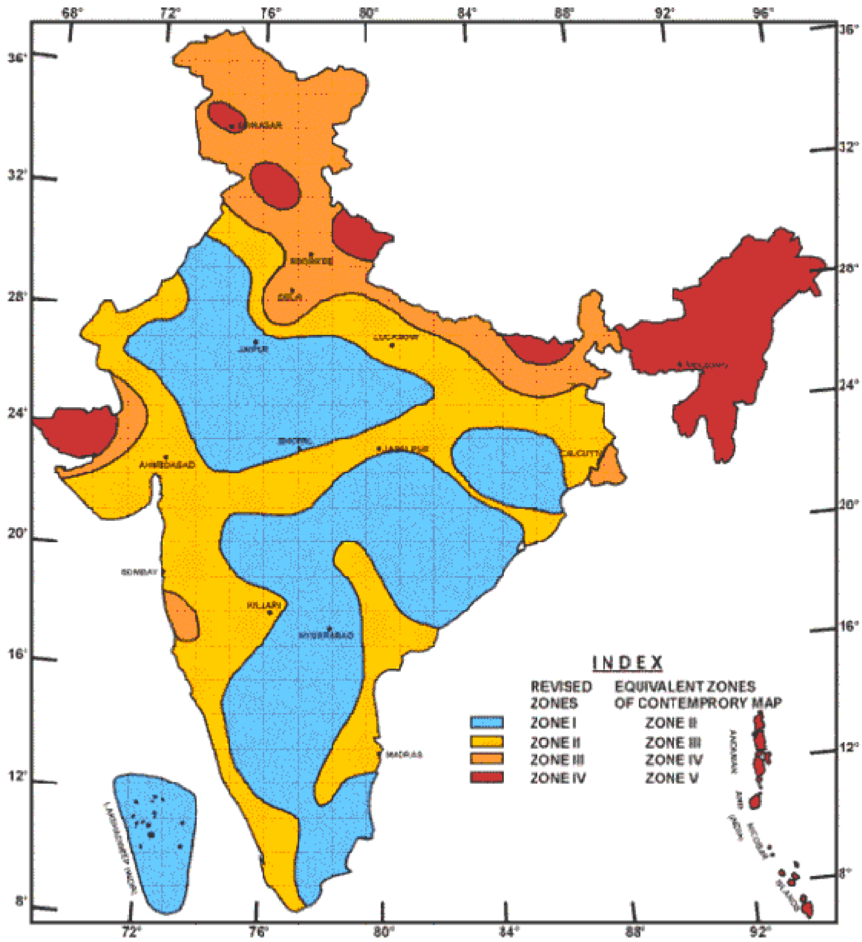
The fundamental natural period (Ta) of the buildings is determined using the formula mentioned below.

$Ta=0.075h^{0.75}$

for a moment resisting RC frame building without brick infill wall Where, h – Height of building in m Ta – time period of structure in sec$Ta=0.09h/\sqrt{d}$ for a moment resisting RC frame building with brick infill wall Where, d – base dimension of the building at the plinth level along the considered direction of earthquake shaking in m Based on the above formula the time period is evaluated in ETABS software.

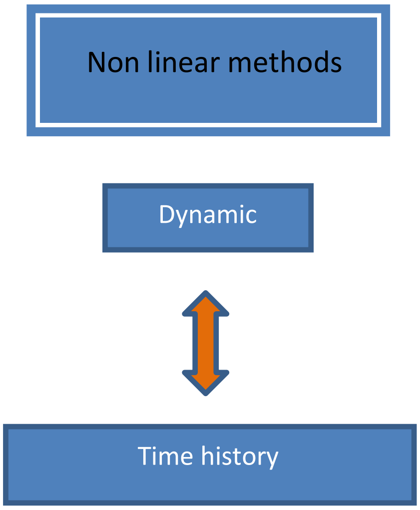


(Fig. 2) Matching earthquake response spectrum with soil type II



(Fig.3) Seismic zones in India: IS 1893

Methods used in E-tabs to apply seismic load on model:



Removal of column

ALTERNATE PATH METHOD:

The Alternate Path method is used to satisfy the progressive collapse requirements of this document (GSA)for the removal of specific vertical load-bearing elements that are prescribed in Section. This method follows the general LRFD philosophy by employing a modified version of the ASCE 7 [9] load factor combination for extraordinary events and resistance factors to define design strengths. Three analysis procedures are employed: Linear Static (LSP), Nonlinear Static (NSP) and Nonlinear Dynamic (NDP). These procedures follow the general approach in ASCE 41 [10] with modifications to accommodate the particular issues associated with progressive collapse. Much of the material-specific criteria from Chapters 5 to 8 of ASCE 41 [10] are explicitly adopted in Chapters 4 to 8 of this document. The topics of each ASCE 41 [10] Chapter are:

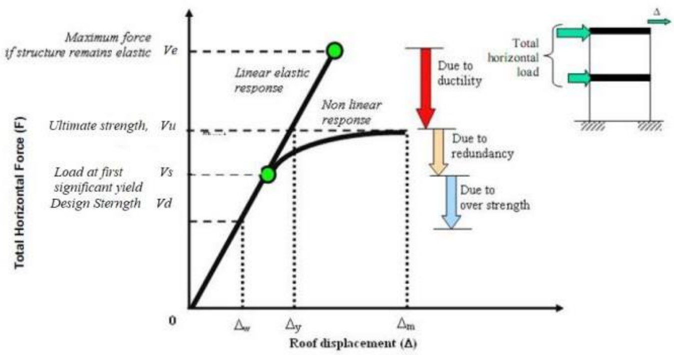
- Steel or cast iron, ASCE 41 [10] Chapter 5
- Reinforced concrete, ASCE 41 [10] Chapter 6
- Reinforced or un-reinforced masonry, ASCE 41 [10] Chapter 7
- Timber, light metal studs, gypsum, or plaster products, ASCE 41 [10] Chapter 8

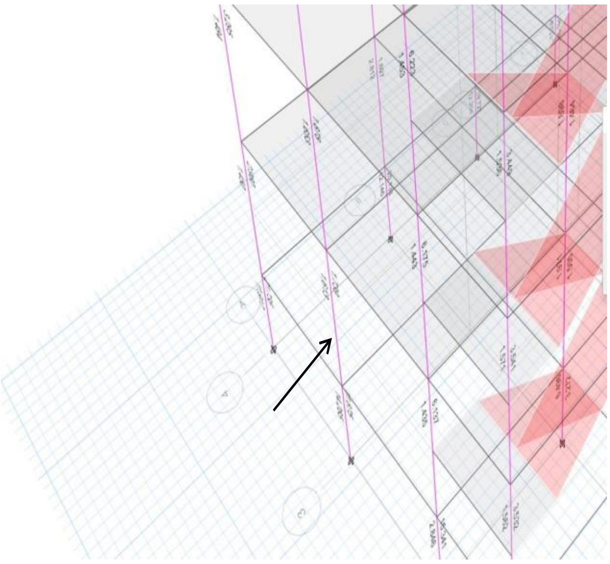
Removed column:

Name: A3 column
Axial force: max =35.7349kn, min=-33.2531knTorsion:
Max=2.1223 kn-m, min=-2.0707kn-m Shear force:
Max=9.7391kn, min=-10.34kn Moment:
Max=16.50kn-m, min=15.65kn-m
This column is removed because; it is the weakest column in building.

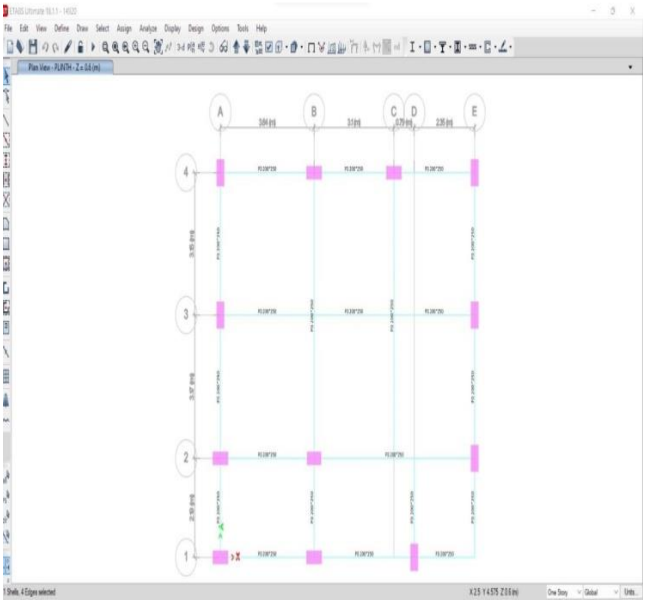
Response Reduction Factor (R):

The response reduction factor represents the ratio of the maximum lateral force, Ve, which would develop in a structure, responding entirely linear elastic under the specified ground motion, to the lateral force, Vd, which has been designed to withstand

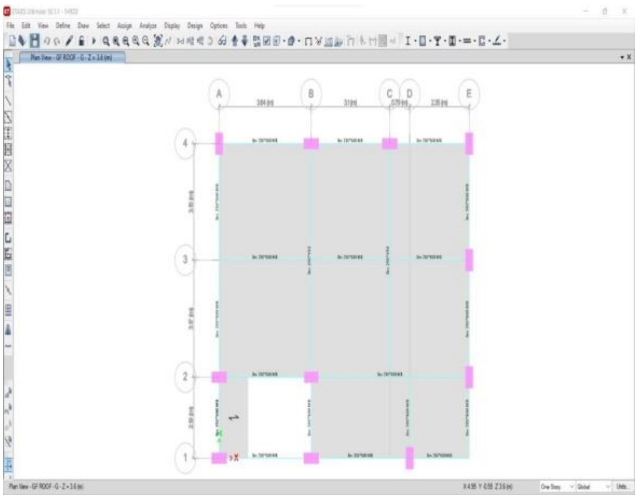




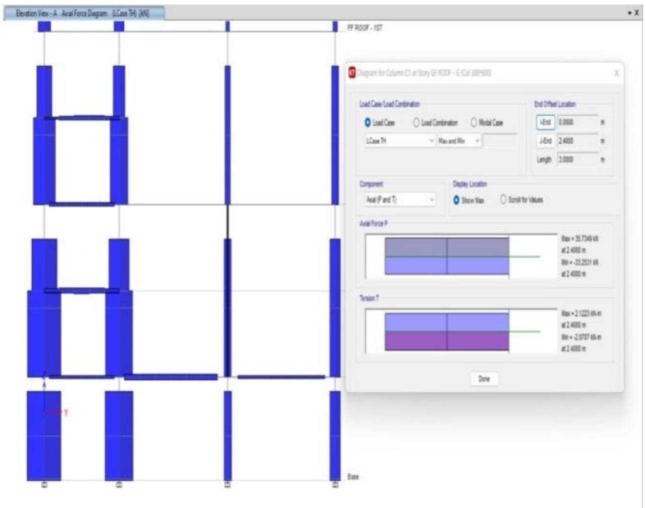
(Fig.4) Removed column



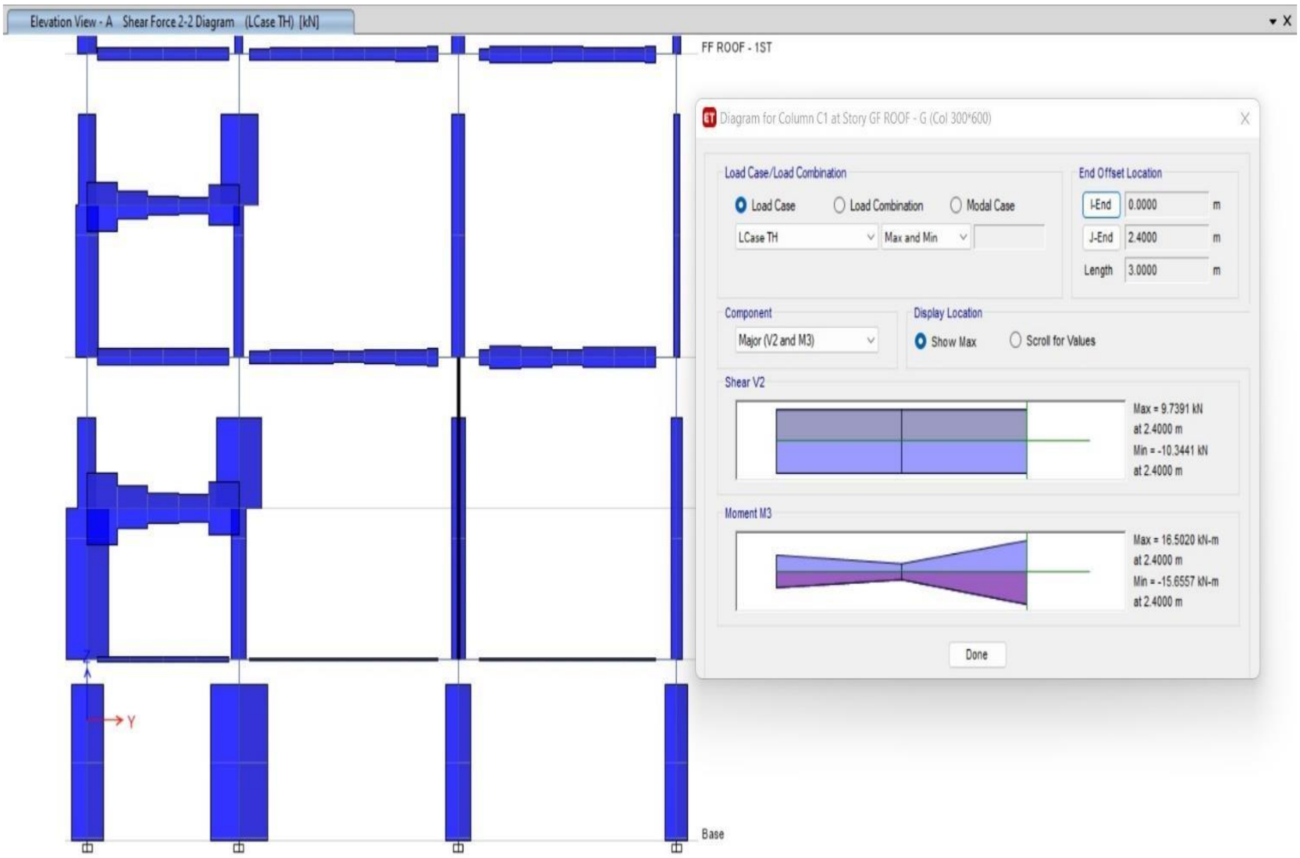
(Fig.5) Plinth level plan



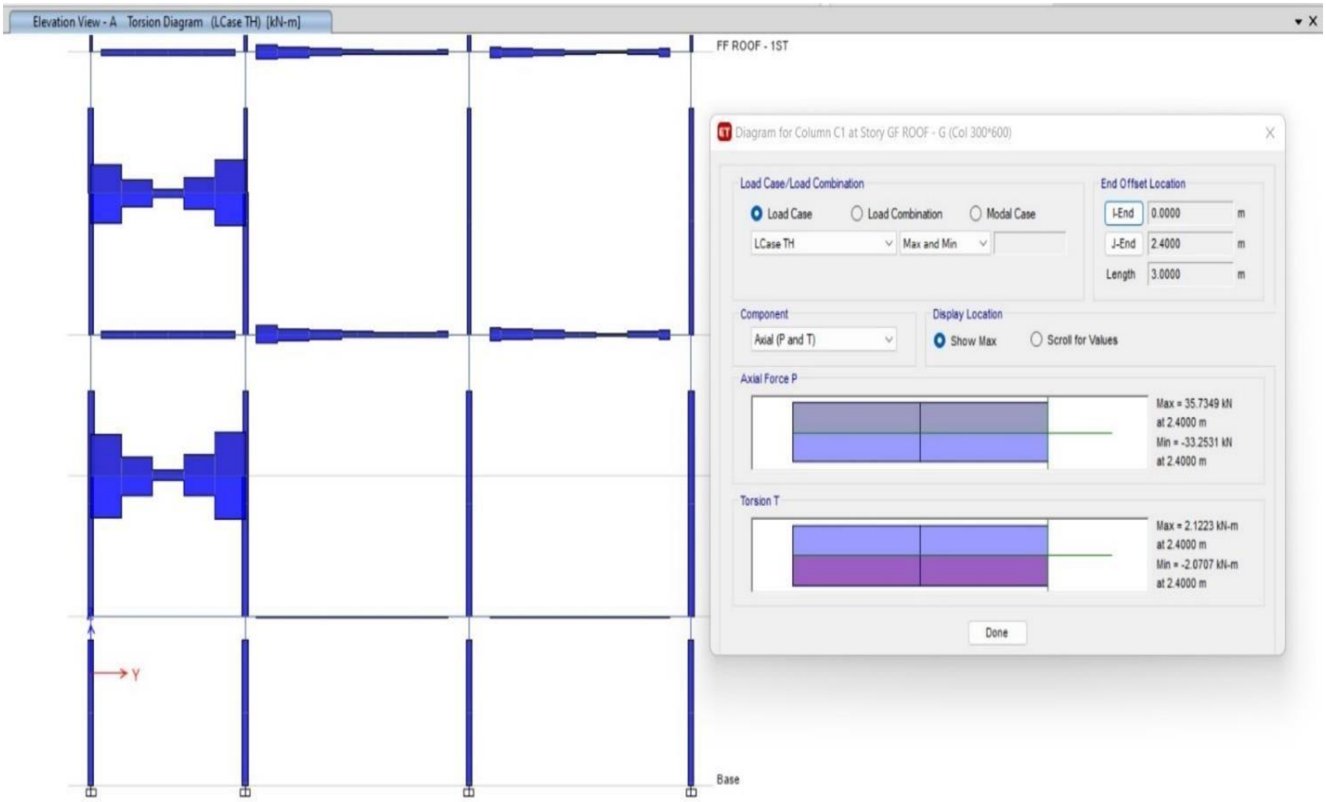
(Fig.6) Ground level plan



(Fig.7) Axial force in column

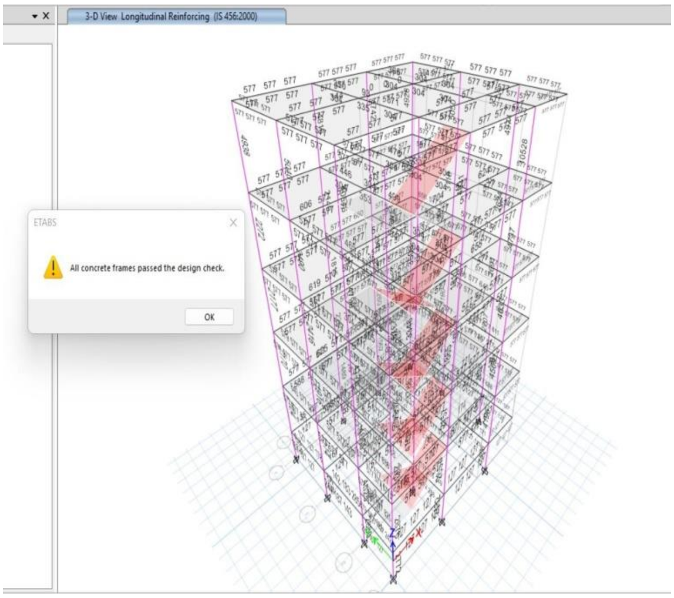


(Fig.8) Shear force in column

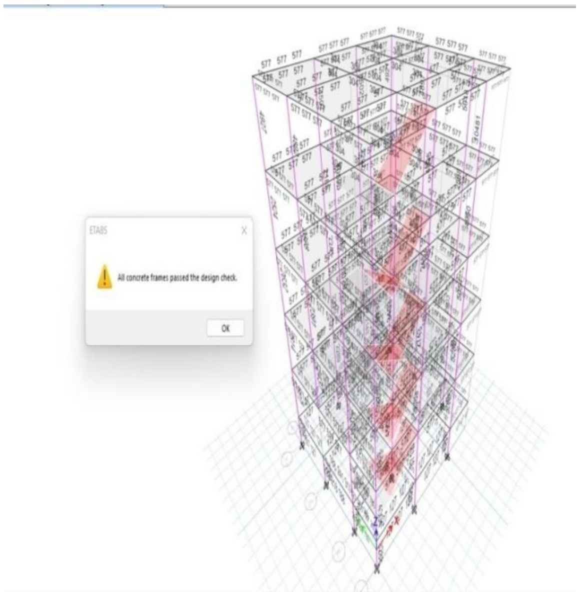


(Fig.9) Torsion in column

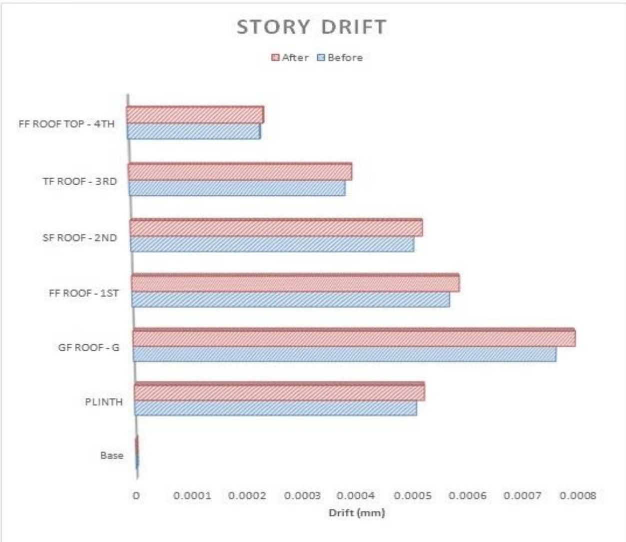
5. RESULTS



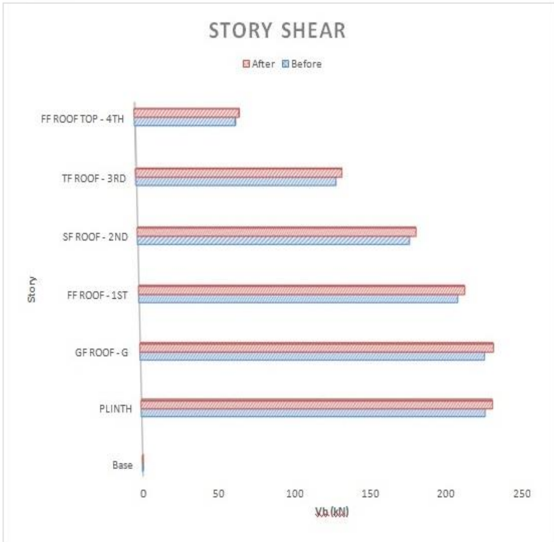
(Fig.10) Before removing column



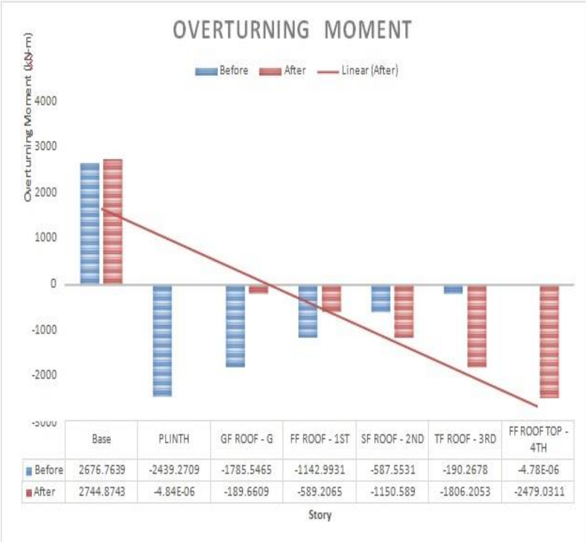
(Fig.11) After removal column



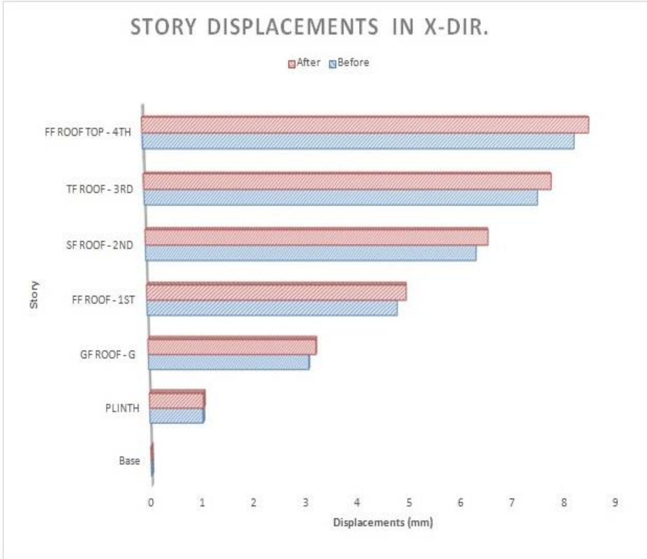
(Graph 1) Story Drift



(Graph.2) Story shear



(Graph.3) Overturning moment



(Graph.4) Story displacement in x direction

story	Max Storydrift	Max Story shear[KN]		Max Overturning moment [knm]	Max Story displacement [mm]
		Bottom	Top		
First floor	0.000579	211.01	-218.13	-345.85 knm	4.912 mm
Secondfloor	0.000513	179.12	-186.46	-179.00 knm	6.446 mm
Thirdfloor	0.000389	131.46	-132.10	-59.390 knm	7.610 mm
Fourthfloor	0.000235	066.07	-61.96	-1.2300 knm	8.310 mm

Table no. 1-Values of story drift, shear, overturning-moment, displacement In X-Direction

Story	Max Storydrift	Max Story shear[KN]		Max Overturning moment [knm]	Max Story displacement [mm]
		Bottom	Top		
First floor	0.000309	67.91	-70.12	-1150.58 knm	2.710 mm
Secondfloor	0.000236	55.92	-57.82	-589.20 knm	3.410 mm
Thirdfloor	0.000161	40.81	-41.10	-189.66 knm	3.860 mm
Fourthfloor	9.80E-05	20.50	-19.24	-4.84E-06 knm	4.096 mm

Table no. 2-Values of story drift, shear, overturning-moment, displacement In Y-Direction

6. CONCLUSION

In the present work, non-linear dynamic analysis of RC earthquake resistant building is carried out by using commercial software E-TABS 2016. Vulnerability of building against progressive collapse is studied and the conclusion are drawn from the analysis are discussed below. Non-linear dynamic analysis procedures for progressive collapse determinations, if modeled using initial conditions methodology, are simple to perform by practicing engineer through computer program. A range of factors that lead to progressive collapse includes accidental Or deliberate impacts and explosions, design or construction errors, as well as poor maintenance. Engineer’s main aim is to design the structure such that it causes less causality to people after accidental collapse.

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