PUSHOVER ANALYSIS OF A MULTISTORIED BUILDING

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ABSTRACT:

To model the advanced behaviour of reinforced concrete analytically in its non-linear zone is difficult. This has led engineers in the past to believe heavily on empirical formulas that were derived from numerous experiments for the design of reinforced concrete structures. For structural design and assessment of reinforced concrete members, the non-linear analysis has become a vital tool. The method can be used to study the behaviour of reinforced concrete structures as well as force redistribution. This analysis of the nonlinear response of RC structures to be distributed out in an exceedingly routine fashion. It helps within the investigation of the behaviour of the structure below completely different loading conditions and also the cracks pattern. In the present study, the non-linear response of RCC frame using the loading has been carried out with the intention to investigate the relative importance of many factors in the non-linear analysis of RCC frames. The structure was modelled and analyzed in STAAD Pro V8i, SAP2000 and designed manually. The description of the reinforcement was done in AutoCAD 2010.

Keywords- multi-storied building, STAAD PRO, Floor plan, SAP 2000, Push over analysis.

I. INTRODUCTION

Pushover analysis is an approximate analysis method during which the structure is subjected to heavily increasing lateral forces with an invariant height-wise distribution till a target displacement is achieved. Pushover analysis consists of a series of consecutive elastic analysis, overlapped to approximate a force-displacement curve of the structure. A two or three dimensional model which incorporates bilinear or trilinear load-deformation diagrams of the lateral force withstanding elements is first created and gravity loads are applied at first. A predefined lateral load pattern that is distributed on the building height is then applied. The lateral force area unit is increased until some members yield. The structural model is changed to account for the reduced rigidity of yielded members and lateral forces are again increased until additional members yield. The method is sustained till an impact displacement at the highest of building reaches a precise level of deformation or structure becomes unsteady. The roof displacement is aforethought with base shear to urge the global capacity curve. Pushover analysis has been the popular methodology for seismic performance analysis of structures by the most important rehabilitation guidelines and a code as a result of its conceptually and computationally simple. Pushover analysis permits tracing the sequence of generating and

failure on member and structural level similarly because the progress of overall capacity curves of the structure. The various aspects of pushover analysis and also the accuracy of pushover analysis in predicting seismic demands are carried out by many researchers. However, most of those researches made use of specifically designed structures within the context of the study or specific types of pushover procedure. Foremost, the prevalence of pushover analysis over elastic procedures in calculating the seismic performance of a structure is mentioned by identifying the benefits and limitations of the procedure. Then, pushover analysis is performed on case study frames using SAP2000. The multi-storied building is constructed at site for B+G+13 floors with pile foundation. The total height of building is 43m. Floor to floor height is 2.9m for all floors. The building is provided with staircase and lift provisions to connect between each floor. The structural system consists of RCC conventional beam slab arrangement. Modeling is done in STAAD Pro. V8i. During analysis, dead loads and live loads were calculated using IS 875(part 1):1987 and IS 875(part 2):1987 respectively. Earth quake load was calculated using IS 1893:2002. Combinations of loads were applied on the space frame as per IS 456:2000. The load combinations were taken to obtain maximum design loads, moments and shear forces. Modeling and Analysis was done in STAAD Pro. V8i and the members were designed manually. The pushover is expected to provide information on many response characteristics that cannot be acquired from an elastic static or dynamic analysis. Nonlinear static analysis, or pushover analysis, has been grown over the past twenty years and has become the preferred analysis procedure for design and seismic performance assessment purposes as the procedure is comparatively simple and considers post- elastic behavior. However, the procedure involves certain approximations and clarifications that some amount of variation is always expected to exist in seismic demand prediction of pushover analysis. The most frequently used software includes: STAAD Pro.V8i, AUTOCAD 2010 and SAP 2000.

General principles of structural design

The design of the structure must satisfy the following requirements:
*Stability-to prevent the overturning, sliding or buckling of the structures, or any part of it, under action of loads.
*Strength- to withstand safely the stresses induced by the loads in the various structural members.
*Serviceability- to ensure satisfactory performance under service load condition which implies providing adequate stiffness and reinforcement to control deflections, crack widths and vibrations within adequate limits, and also providing impermeability and durability.
Other two important considerations that a sensible designer ought to bear in mind are economy and aesthetics.

II. DESIGNING IN STAAD PRO

Designing consists of structural discretization, member property specification, giving support, loading analysis and design.

Structural discretization: For the analysis of B+G+13floor building, ground floor plan was selected. The first step was fixing the position of columns. Then the structure was discretized. Discretization includes fixing of joint coordinates and member indices. Column center lines were taken for fixing joint coordinates. Outer beams were also marked. Now the members were connected along the joint coordinates using the member incidence command.

Member property specification: The properties of various frame member sections such as cross-sectional dimensions of beam, columns, slabs and the material property were calculated and assigned on a particular member. The support condition was given as fixed support.
Slab: Thickness of slabs provided is 110mm.
Beams: The dimensions of beams are 200x600mm
Columns: The dimensions of columns are 300x800mm, 300x900mm.

Specifying geometric constants: In the absence of any explicit instructions, STAAD will align the beams and columns of the structure in a predefined way. Orientation refers to the direction onward which the width and depth of the cross section is aligned with respect to the global axis system. We can change the orientation by changing the orientation by changing the Beta angle.

Replicating to other floors: The completed floor with all structural members was replicated to the typical first to last floor. The other additional beams and slabs were modeled later.

Loading: After the modeling stage the loading was done on the structure in accordance to IS codes. All the dead load were calculated according to the fixed dimension and unit weight of building materials according to IS 875 (Part 1): 1987 and assigned. Live load was assigned according to IS 875 (Part 1): 1987. The seismic load was determined based on is 1893(Part1): 2002 and the wind load was based on IS: 875(part 3)-1987. All the loads were assigned either as floor loads or member loads.

Analysis: The structure was analyzed using the versatile software STAAD PRO after completion of the modeling process. From the analysis we got member end forces and support reactions. From these values, we design the structure.

Load Calculation: The various loads considered for the analysis are:
Live Load: Consist of all loads other than the dead loads of the structure. The values of the overlapped loads depend on the functional requirements of the structure. The standard values for a residential building as per IS 875(Part2):1987 are given below

- Living room ,bedroom, kitchen, dining room= 2KN/m^2
- Balconies, staircase, corridors= 3KN/m^2
- Terrace= 2KN/ m^2

Dead Load: Dead loads include the weight of all structural and architectural elements and other permanently applied external loads. Self weight of materials shall be calculated on the basis of unit weight given in IS 875(Part1):1987. Dead load includes the self weight of slab, brick wall, floor finish, etc.

Materials Weight:
Reinforced concrete (R.C.C) : 25KN/ m^3
Brick: 20KN/ m^3
Dead load of 100mm thick slab
Self weight of slab   = 0.1x25   =2.5KN/m
Floor finish load = 20x0.05 =1KN/m
Self weight of wall = 20x3x0.2 = 12 KN/m
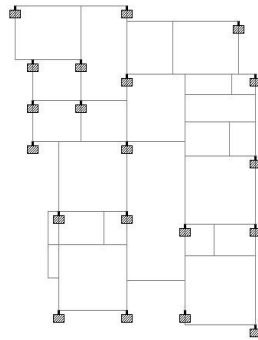Total dead load on slab = 15.5 KN/m

Fig 1: Floor plan of building in STAAD PRO

The return period of an earthquake in a given region depends on its seismicity. Relying upon the possibility of occurrence of an earthquake in a given region, it is desirable to design the building for a lesser force and allow the building to undergo inelastic deformation. The intention is to design an economical structure. There are two methods to determine the earthquake compulsion in a building: Seismic co-efficient technique or static method, spectral acceleration technique or dynamic method.
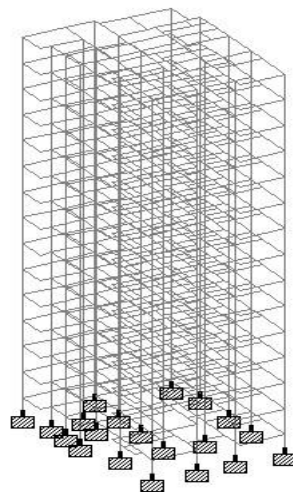
Fig 2: 3D view of the model

III.PUSHOVER ANALYSIS

Earthquake or seismic load on a building depends on its geographical location, lateral stiffness and mass is reversible. Its effect should be considered along both axes of building taken one at a time. A force is defined as the product of mass and acceleration. During an earthquake, the mass is imparted by the ground disturbance. In order to have the minimum force, the mass of the building has to be as low as possible. There can be no control on the ground acceleration. The point of application of this inertial force is the centre of gravity of the mass on each floor of the building. Once there is a force, there has to be an equal and opposite reaction to balance this force. The inertia is resisted by the building and the resisting force acts at the centre of rigidity at each floor of the building or shear centre of the building at any storey.
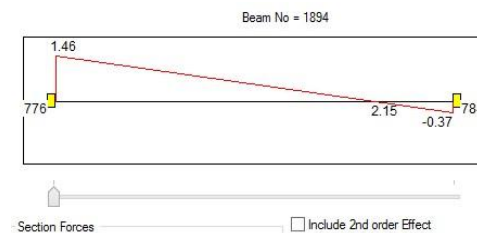
Fig 3: Shear force diagram obtained from STAADPRO

A. Seismic Co-efficient Methodology

The seismic co-efficient technique is generally applicable to buildings up to 40m tall in height and those that are more or less symmetrical in its arrange and elevation. A building is also modeled as sequence of 2D plane frames in two orthogonal directions. Each node will have three degrees of freedom, two translations and one rotation.
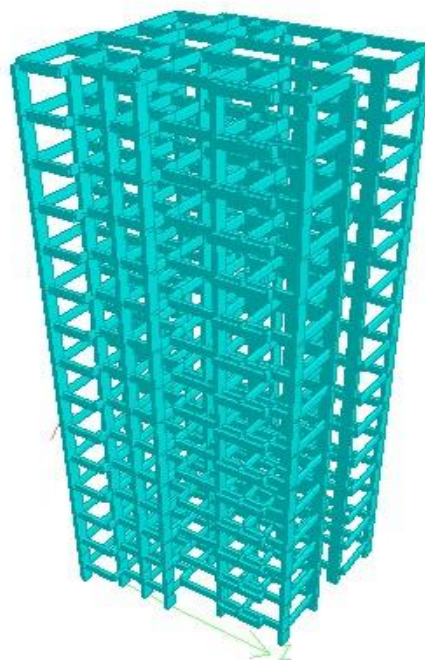

Fig 4: Rendered view of the model in STAAD PRO

The wind loads and earthquake loads are assumed to not act at the same time. A building is intended for the worst of the two loads. The actual fact that the design forces of wind are greater than the seismic design forces (i.e. wind governs the design) does not obviate the requirement for a seismic description. Whereas, wind force governs, design should give a minimum of at least the type seismic description that corresponds to the seismic forces calculated for that building. As per IS 1893(Part 1): 2002, the total design lateral force or seismic base shear (VB) on any of the principal direction shall be determined by the subsequent expression as:

$VB = Ah * W$ where, Ah- Design horizontal acceleration spectrum factor as per 6.4.2 of code using fundamental time period Ta as per 7.6 within the direction of vibration.

W- Seismic weight of the building as per 7.4.2.

The design horizontal seismal co-efficient Ah for a construction can be found by the following expression: $Ah = Z/2 * I/R * Sa/g$

Where, Z= Zone issue is for the Maximum Considered Earthquake (MCE) and service life of a building in a zone.

The factor 2 in the denominator is used so as to reduce the Maximum Considered Earthquake (MCE) zone issue for the Design Basis Earthquake (DBE).

I= Importance factor, relying upon the practical use of structures, characterized by risky consequences of its failure, post-earthquake practical needs, historical standards or economic importance.

R= Response reduction factor, relying on the perceived seismic damage performance of the structure, characterized by ductile or hard deformations, However, the ratio (I/R) shall not exceed 1.0

Sa/g= Standard response acceleration coefficient for rock or soil sites.

The approximate primary natural time period of vibration (Ta), in seconds, of all other buildings, as well as the moment withstanding frame buildings with brick infill panels, may be estimated by the empirical expression:

$Ta = 0.09 * h * \sqrt{d}$

The approximate primary natural period of vibration (Ta), in seconds, of all other buildings, including the moment withstanding frame buildings without brick infill panels, maybe estimated by the empirical expression:

$Ta = 0.075 * h * 0.75$

(For RC frame structures)$=0.085 * h * 0.75$ (For Steel frame building)

Where,

h= Height of the building in meters, this excludes the basement storey's where the basement walls are connected with the ground floor deck or fitted between the building columns, however it includes the basement storey, when they are not connected.

d= Base dimension of the building at the bottom level, in meters, along the considered direction of the lateral force.

The design base shear (VB) shall be dispensed along the height of the building as per the following expression:

$Q_i = (VB \times W_i \times h_{i2}) / (\sum_{i=1} W_i \times h_{i2})$

Where, Q_i= Design lateral force at floor i

W_i = Seismal weight of floor i

h_i= Height of floor i measured from base

n= Number of stores in the building is the number of levels at which the masses are located.

B. Earthquake Load Calculation

The building is situated in Ernakulum, Kerala state

Project comes under Zone   :   III
Seismic Zone factor   :   0.16
Response minimization factor: 3
Importance factor I   :   1.0
Rock and soil site factor 'SS' :   1.0
Damping ratio DM   :   0.05

C. Load combinations

Load combinations taken for the analysis are according to IS 456:2000 and IS1893 (Part1):2002. The subsequent are the combinations taken for the analysis:-

1) 1.5(D.L+L.L)
2) 1.2(D.L+L.L+EQX)
3) 1.2(D.L+L.L-EQX)
4) 1.2(D.L+L.L+EQZ)
5) 1.2(D.L+L.L-EQZ)

6) 0.9D.L+1.5EQX
7) 0.9D.L-1.5EQX
8) 0.9D.L+1.5EQZ
9) 0.9D.L -1.5EQZ
10) 1.5(D.L+EQX)
11) 1.5(D.L-EQX)
12) 1.5(D.L+EQZ)
13) 1.5(D.L-EQZ)

Where, D.L- Dead load

L.L- Live load

EQX- Design Earthquake Load in +X direction

EQZ- Design Earthquake Load in +Z direction

SAP2000 is general purpose civil-engineering software ideal for any type of structural system. Basic and advanced systems, ranging from 2D to 3D are analyzed, performed and optimized using a practical and intuitive object-based modeling.
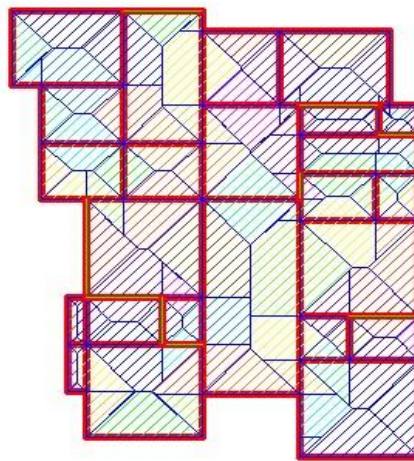

Fig 5: Load diagram of a typical floor

The figure depicts the load diagram of a typical floor which is analyzed using SAP 2000 software. It drives a sophisticated finite element analysis procedure. It is an ideal software tool that simplifies and streamlines the engineering environment process. It is also an excellent medium for education. Although the geometry of the structure tested during this work was kept same as the portion of the original structure, there were few variations in the reinforcement detailing given below:

1. Although the original structure was detailed in keeping with the new conforming seismic description practice as per IS 13920, the structure for the experiment accompanied with the non-seismic description practice as per IS 456 2000. The reason for this is due to the fact that pushover analysis is mainly used for retrofit of old buildings, which have not followed the seismic detailing, practice. Accordingly, special confining reinforcement as counseled by IS 13920(1993) was not provided. Conjointly, no shear reinforcement within the beam- column joints was provided.

2. Since the structure tested is the repetition of a small portion of the big original structure, the continuous reinforcement within the slab and beams were suitably transformed as per the requirement.

3. Another major variation is in the foundation system. In order to avoid any nonlinear characteristics of the foundation.

IV.MODELLING ON SAP2000

A .General description of the structure

One of the most important objectives of this work was to check a real- life structure below pushover loads. So as to keep the structure as near to reality as attainable, no special design for the structure as such was performed. The portion was deliberately selected so that it had definite eccentricities and was un-symmetric in setup. Conjointly the column sizes and sections were varied along the storey as in the case of original proper life structure.

B. Material Properties

The material used for construction is ferroconcrete with M-20 grade concrete and fe-415 grade reinforcing steel. The Stress-Strain relationship is as per IS456:2000. The needed material properties used are given below:
Modulus of Elasticity of steel, Es = 21, 0000 MPa

C. Model Geometry

The structure analyzed is a four-storied, one bay on X-direction and two bays on Y-direction moment-withstanding frame of reinforced concrete with properties as mentioned on top of. The concrete floors are modeled as rigid. The description of the model is given as:
Number of stories = 4
Number of bays on X-direction =1
Number of bays on Y-direction = 1
Storey height = 2.9 meters

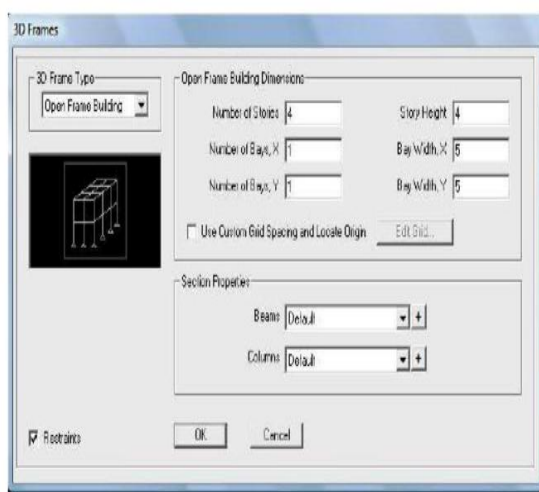### D. Step by step procedure of analysis in SAP2000

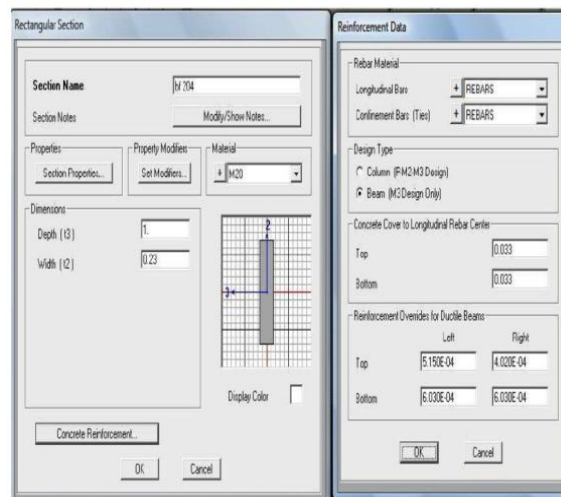Fig 6: Basic Dimensions of a Building in SAP2000   Fig 7: Basic Dimensions of a Beam

In this figure, defining a beam and its dimensions, clear cover and grade of concrete. Later on describing this beam will define all the beams similarly using the same step.
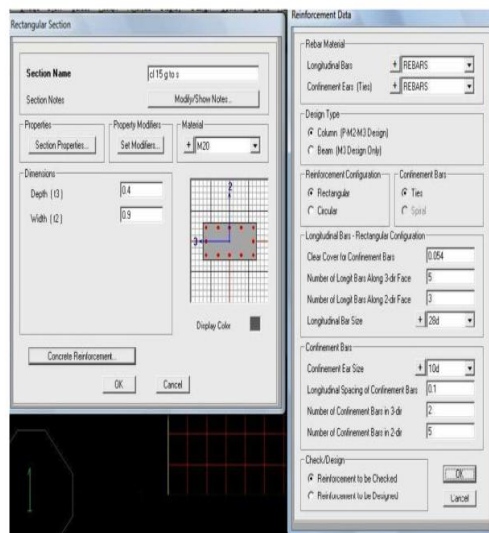

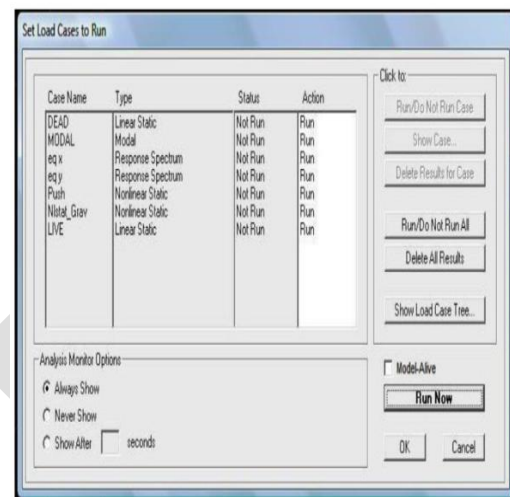Fig 8: Basic Dimensions of a Column   Fig 9: Run Analysis

Columns were designed according to IS 456: 2000 and SP16:1980. Column designed is of size 300x800mm. M35 concrete and Fe415 steel are adopted for column design. The bending moments and axial force were taken from the analysis results obtained from STAAD. After processing the dimensions of a beam currently outline the essential dimensions of a Column. Firstly, provide the section name then choose the material used. After this, give the dimensions (depth & width). Then choose concrete reinforcement option, in this, insert the diagram of longitudinal & confinement bars.
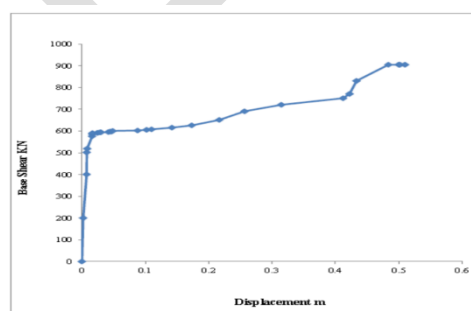

Fig 10: Push over curve of a building

V.RESULTS AND DISCUSSIONS

A. General

Analysis of RCC frame beneath the static loads has been performed using SAP2000 software. This is often followed by load deflection curve.

B. Analysis results of RCC frame

In the present study, non-linear response of RCC frame modelled mentioned using modelling beneath the loading has been administered. The objective of this study is to ascertain the variation of load- displacement graph and check the most base shear and displacement of the frame. Once running the analysis, the pushover curve is obtained.
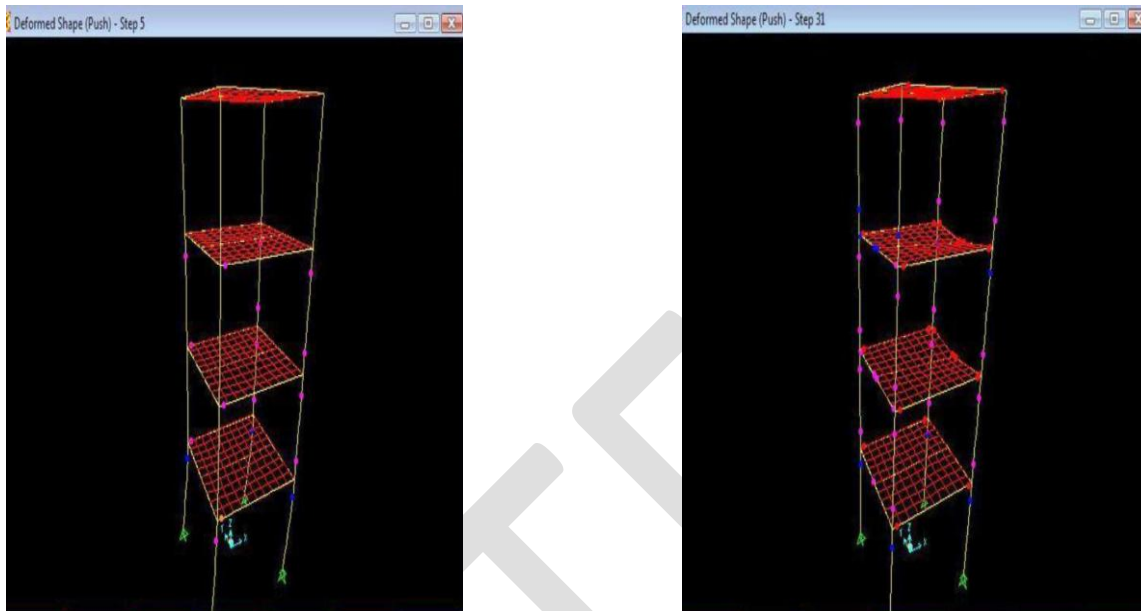
Fig 11: Step By Step Deformations for Pushover

VI.CONCLUSION

The frame acted as linearly elastic up to a base shear price of around 235 KN. At the worth of base-shear 670KN, it pictured non-linearity in its behavior. Increase in deflection is discovered to be more using load increments at base-shear of 670 KN with the elasto-plastic characteristics. The joints of the structure have displayed rapid degradation and also the lay floor deflections have enhanced quickly in non- linear zone. Various damages are discovered within the joints at lower floors whereas moderate damages are observed within the first and second floors. Minor damage is discovered at roof level. The frame has shown sort of failures like beam-column joint failure, flexural failures and also shear failures. Prominent failures are joint failures. Flexural failures are seen in beams owing to X-directional loading. It is been seen that the top storey experienced major damages during the opposite to the case of frame. Micro cracks are discovered to appear even when the frame is in elastic zone. The cracks have are found increasing with the rise in deflections.

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