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Non Linear Analysis of Ordinary Moment Resisting Frame for Ductility Ratio

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ABSTRACT

In India the enormous loss of life and property perceived in the last couple of decades, attributable to failure of structures instigated by earthquakes. Responsiveness is now being given to the assessment of the sufficiency of strength in framed RCC structures to resist solid ground motions. The seismic reaction of RCC building frame in terms of performance point and the earthquake forces on Reinforced building frame with the help of pushover analysis is carried out in the study. In this method of analysis a model of the building is exposed to a lateral load. Pushover analysis can afford a substantial insight into the weak links in seismic concert of a structure and we can get to know the weak zones in the structure. In this project effort has been made to investigate the effect of Shear Wall and Structural Wall on lateral displacement and Base Shear in RCC Frames. RCC Frames with G+13 are considered, one with soft storey and other with normal building in L-shape. The pushover analysis of the RCC building frame is carried out by structural analysis and design software ETABS.

Keywords: Pushover, ETABS, Soft Storey, Ordinary moment resisting frame, Non-linear analysis

I. INTRODUCTION

The term earthquake can be used to describe any kind of seismic event which may be either natural or initiated by humans, which generates seismic waves. Earthquakes are caused commonly by rupture of geological faults; but they can also be triggered by other events like volcanic activity, mine blasts, landslides and nuclear tests. There are many buildings that have primary structural system, which do not meet the current seismic requirements and suffer extensive damage during the earthquake. According to the Seismic zoning Map of IS: 1893-2016, India is divided into four zones on the basis of seismic activities. They are zone II, zone III, zone IV and zone V. Some industries usually make full-scale models and execute wide testing, before manufacturing thousands of identical structures that have been analyzed and designed with consideration of test results. Unluckily, this choice isn't available to building industry so that economy of huge scale creation is unfeasible. In India many existing structure design as per Indian standard code 456:2000 but to make building earthquake resistant IS 1893-2016 should be used to avoid future building vulnerable in earthquake.

1.1 Ductility

Ductility is a term that relates to a material's ability to be drawn or twisted without breaking. As such, it represents the material's malleability or softness. Steels vary in their ductility depending on the kind and concentration of alloying elements used. Ductility is a term that refers to a material's ability to endure significant permanent deformation under tensile stress to the point of fracture, or to the material's relative ability to be stretched plastically at room temperature without breaking.

The ratio of total deflection to deflection at the elastic limit. The deflection at the elastic limit is the deflection at which the strength behaviour is reasonably assumed to transition from elastic to plastic.

= m / y

Where m is the TH displacement as determined by the NLTH study.

y is the yield displacement as determined by the PO curve.

1.2 Nonlinear Static Pushover Analysis (NSPA)

Pushover is a nonlinear static analysis approach in which a structure is subjected to gravity loading and a monotonic displacement-controlled lateral load pattern that continuously increases via elastic and inelastic behaviour until an ultimate state is reached.

Inelastic static (pushover) analysis was done by applying increasing monotonic lateral forces with an appropriate distribution and pushing the models to large displacements. This research may be used to determine the structure's lateral strength and force displacement relationship, which indicate the structure's capacity to endure significant lateral deformations. Displacement control, rather than force control, was used to investigate the mechanisms' creation and the structural behaviour aspects that result from mechanism formation.

1.3 Nonlinear Time History Analysis (NTHA)

Nonlinear time history analysis is well-known for precisely simulating the behaviour of a structure after a large earthquake. It is a key method for structural seismic analysis, especially for assessing nonlinear structure responses. A representative earthquake time history for the structure under consideration is required to undertake this assessment. Time history analysis is a method for examining a structure's dynamic response to a changing load through time. The time history analysis technique is used to determine the seismic response of a structure to dynamic loads induced by a typical earthquake.

B. OBJECTIVES

The main objective of this study was to develop a new design procedure based on steel moment resistant frame (MRF) using constant ductility ratio.

To find the ductility ratio of Special moment resting frame from nonlinear static pushover analysis (NSPA) and nonlinear time history analysis (NTHA).

- To study the performance of steel moment resistant frame (MRF) structure under lateral loads (Earthquake loads).
- To study the performance of steel moment resistant frame (MRF) structure with or without soft storey with respect to Different parameters such as story drift, story displacement, base shear, etc.
- To study the variation of pushover curve for a framed structure with soft storey.

II. LITERATURE REVIEW

1 Prishati Raychowdhury (2011) Seismic response of low-rise steel moment-resisting frame (SMRF) buildings incorporating nonlinear soil–structure interaction (SSI)

Nonlinear behaviour at the soil–foundation interface due to mobilisation of the ultimate capacity and the associated energy dissipation, particularly in an intense earthquake event, may be utilised to reduce the force and ductility demands of a structure, provided that the potential consequences such as excessive settlement are tackled carefully. This work focuses on simulating this nonlinear soil–structure interaction behaviour with a beam-on-nonlinear-Winkler-foundation (BNWF) technique. The findings are compared with those from fixed-base and elastic-base models. It is noticed that the force and displacement demands are lowered greatly when the foundation nonlinearity is accounted for. Moreover, the foundation compliance is also discovered to have a substantial influence on the structural reaction.

2 MALEKPOUR, H. GHAFFARZADEH (2011) Direct Displacement Based Design of Regular Steel Moment Resisting Frames

The technique of Displacement Based Design is a novel approach to performance-based design. The purpose of this project is to evaluate the Direct Displacement Based Design (DDBD) approach for conventional steel moment resistant frames and to establish a reliable design procedure for them that will allow them to survive a range of seismic intensities while maintaining specified performance levels. Regular steel frames with 4, 8, 12, and 16 storeys are developed for this purpose using the DDBD technique and the displacement spectrum specified in the Iranian Code of Practice for Seismic Resistant Design of Buildings (Standard No. 2800). To determine the seismic reaction of the planned buildings, a series of non-linear time-history evaluations under various conditions consistent with Standard No. 2800 were undertaken. All non-linear assessments were conducted using Seismostruct's fiber-element models. According to the findings, in the majority of instances, the structure's inter-story drift profile was smaller than the allowed value. Additionally, the structure's maximum displacement profile throughout its height is perfectly consistent with the major anticipated design profile. The structures have mostly had identical residual drift values throughout datasets. In summary, the technique satisfied all story ductility requirements, even for tall models, in terms of maximum displacements, maximum interstory drifts, and story ductility requirements.

3. Xingquan Guan (2020) Python-based computational platform to automate seismic design, nonlinear structural model construction and analysis of steel moment resisting frames

We provide an end-to-end computational platform for seismic design, nonlinear structural model development, and static and dynamic response modelling of steel moment resistant frames. A modular structure is used in conjunction with the object-oriented programming paradigm to guarantee

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the platform's versatility. The seismic design module generates code-compliant section sizes and detailing for beams, columns, and beam-column connections iteratively based on relevant input design variables such as the building configuration (e.g., the number of stories, the number of lateral-force resisting systems, and the building dimensions), loads (e.g., dead and live loads on each floor), and site conditions (mapped spectral acceleration parameters). The nonlinear model creation and analysis module takes the design findings as input and generates structural models that accurately represent the degradation of flexural strength and stiffness in the frame beam-column parts, as well as pushover and response history studies. The platform's reliability, accuracy, and efficiency are demonstrated through illustrative examples. The platform significantly reduces the time and effort required to produce iterative structural designs and conduct nonlinear analyses, both of which are required for performance-based seismic design. Additionally, the platform may be used to compile a comprehensive database of archetypical steel moment frame structures in order to facilitate the development of analytics-driven design methodologies.

4. Ayoub Shakouri (2021) Effects of ductility and connection design on seismic responses of base-isolated steel moment-resisting frames

The research investigates the impacts of ductility level and connection type on the seismic responses of fixed-base and base-isolated structures with steel moment-resisting frames using nonlinear time history analysis. For the purpose of comparing reactions, a collection of twenty-four seismically built models is used, comprising three- and nine-story base-isolated and conventional structures with ordinary (OMF), intermediate (IMF), and special (SMF) ductility levels. Each model has two distinct sorts of connections: WUF-W and RBS. All structures are three-dimensionally modelled in OpenSees software, and their seismic reactions are evaluated for two earthquake scenarios. Seismic responses of structures are estimated and studied, including peak floor acceleration, peak floor shear force, peak story drift, and residual and maximum displacement of isolators. The findings reveal that the ductility levels and connection types of base-isolated and fixed-based structures have a substantial effect on their seismic reactions. The RBS connection decreases peak drift needs in comparison to the WUF-W connection, and the difference is larger as the building's height increases. In comparison to the IMF and OMF superstructures, the SMF superstructure reduces peak floor acceleration and peak shear force. Additionally, the peak floor drift ratio of OMF superstructures in base-isolated buildings is greater than that of IMF and SMF superstructures. The maximum difference between the OMF and SMF superstructures is approximately 80%.

III. PROBLEM STATEMENT

MODELS IN ETABS 2016

Model Details

Bay Size: 40 x 40 m

Storey: G+13

Concrete: M25

Steel: Fe500

Column Size: 380 x 400 mm

Beam Size: 250 x380 mm

Slab Thickness: 150 mm

Shear Wall: 200 mm

IV. MODELLING

G+13 without soft storey Building

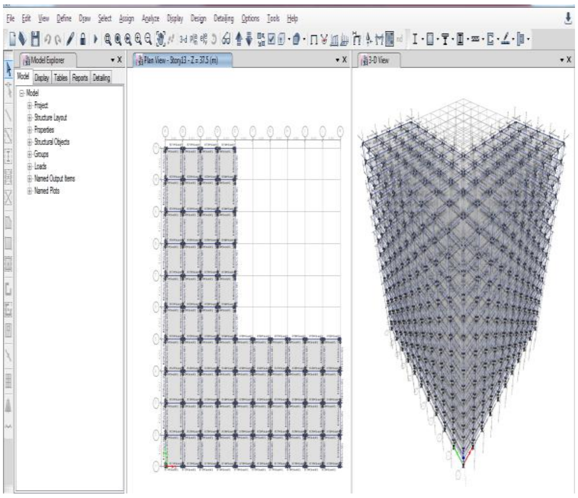

Fig 4.1 L shape building G+13 without soft storey

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G+13 Building – (soft storey at 3rd floor)

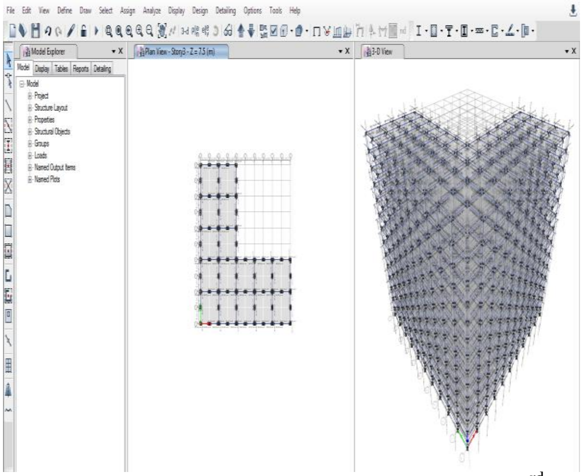


Fig 4.2 L shape building G+13 with soft storey at 3rd floor

G+13 Building – (soft storey at 5th floor)

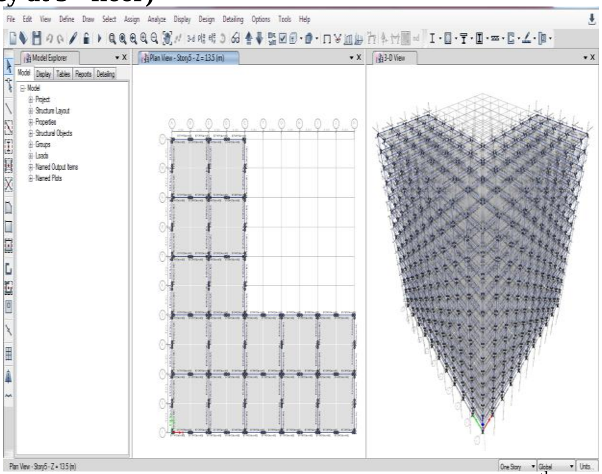


Fig 4.3 L shape building G+13 with soft storey at 5th floor

G+13 Building – (soft storey at 8th floor)

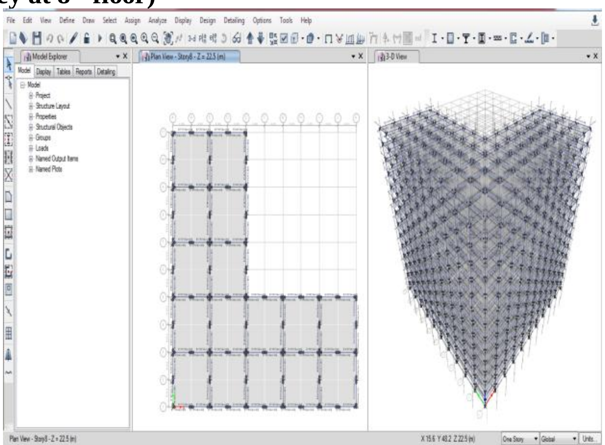


Fig 4.4 L shape building G+13 with soft storey at 8th floor

4.1.2 G+13 Building – (soft storey at 10th floor)

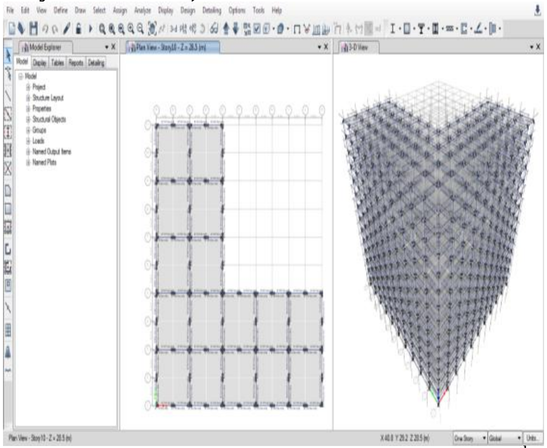
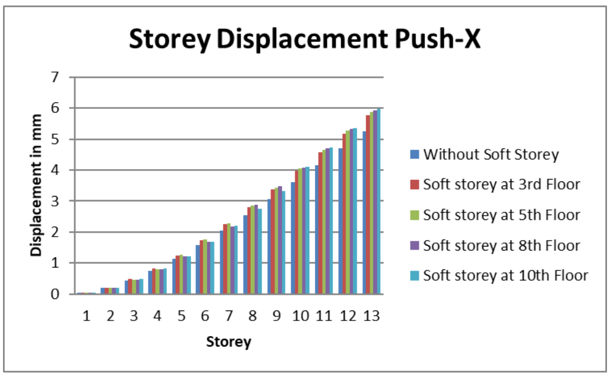


Fig 4.5 L shape building G+13 with soft storey at 10th floor

RESULTS OF THE MODELS

Table 1 Storey Displacement PUSH-X

Story	Without Soft Storey	Soft Storey At 3rd Floor	Soft Storey At 5th Floor	Soft Storey At 8th Floor	Soft Storey At 10th Floor
1	0.0434	0.0455	0.0460	0.04643	0.04687
2	0.1977	0.2075	0.20956	0.21153	0.21351
3	0.44	0.484	0.4664	0.4708	0.4752
4	0.7573	0.8330	0.80273	0.81031	0.81788
5	1.1372	1.2509	1.27366	1.21680	1.22817
6	1.5685	1.7253	1.75672	1.67829	1.69398
7	2.0407	2.2447	2.28558	2.18354	2.20395
8	2.5441	2.7985	2.84939	2.87483	2.74762
9	3.0698	3.3767	3.43817	3.46887	3.31538
10	3.6097	3.9706	4.04286	4.07896	4.11505
11	4.1565	4.5721	4.65528	4.69684	4.73841
12	4.7039	5.1742	5.26836	5.315407	5.362446
13	5.247	5.7717	5.87664	5.92911	5.98158



Graph 1 Storey Displacement PUSH-X

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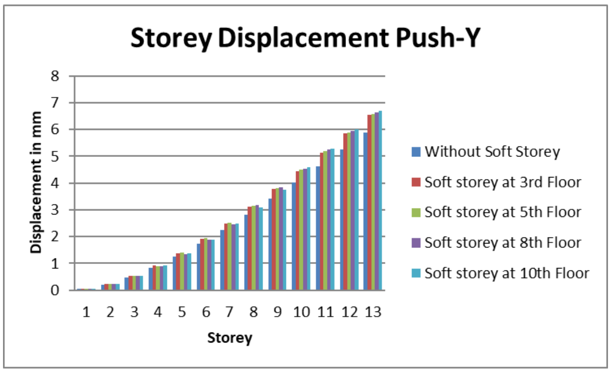
Table 2 Storey Displacement Push-Y

Story	Without Soft Storey	Soft storey at 3rd Floor	Soft storey at 5th Floor	Soft storey at 8th Floor	Soft storey at 10th Floor
1	0.0471	0.05039	0.05086	0.05133	0.05181
2	0.2135	0.22844	0.23058	0.23271	0.23485
3	0.4776	0.53013	0.51580	0.52058	0.52536
4	0.8256	0.91641	0.89164	0.89990	0.90816
5	1.2446	1.38150	1.39395	1.35661	1.36906
6	1.7227	1.91219	1.92942	1.87774	1.89497
7	2.2488	2.49616	2.51865	2.45119	2.47368
8	2.8123	3.12165	3.14977	3.17789	3.09353
9	3.4037	3.77810	3.81214	3.84618	3.74407
10	4.014	4.45554	4.49568	4.53582	4.57596
11	4.6353	5.14518	5.19153	5.23788	5.28424
12	5.2606	5.83926	5.89187	5.94447	5.99708
13	5.8842	6.53146	6.59030	6.64914	6.707988



Graph 2 Storey Displacement Push-Y

3.2 Storey Drift
Storey Drift PUSH-X

Table 3 Storey Drift Push-X

Story	Without Soft Storey	Soft storey at 3rd Floor	Soft storey at 5th Floor	Soft storey at 8th Floor	Soft storey at 10th Floor
1	0.021704	0.023006	0.023223	0.02344	0.023549
2	0.051429	0.054515	0.055029	0.055543	0.0558
3	0.080759	0.088835	0.086412	0.08722	0.087624
4	0.105771	0.116348	0.113175	0.114233	0.114762
5	0.126638	0.139302	0.141835	0.136769	0.137402
6	0.143757	0.158133	0.161008	0.155258	0.155976
7	0.157396	0.173136	0.176284	0.169988	0.170775

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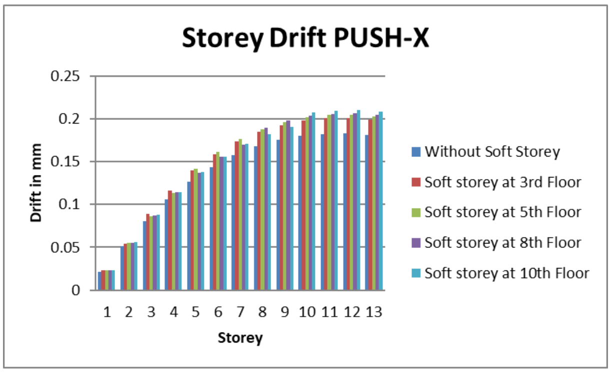
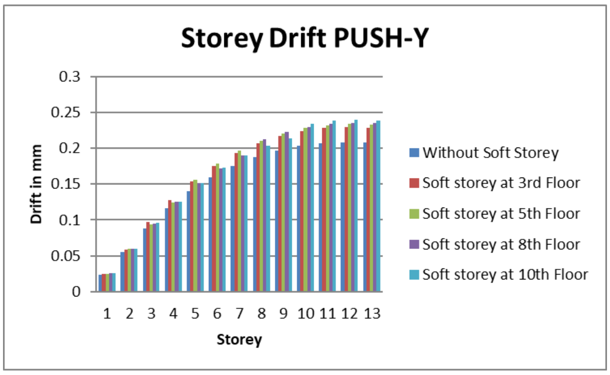
8	0.167807	0.184588	0.187944	0.189622	0.182071
9	0.175238	0.192762	0.196267	0.198019	0.190133
10	0.179958	0.197954	0.201553	0.203353	0.206952
11	0.182262	0.200488	0.204133	0.205956	0.209601
12	0.182489	0.200738	0.204388	0.206213	0.209862
13	0.181035	0.199139	0.202759	0.20457	0.20819



Graph 3: Storey Drift PUSH-Y

Table 4 Storey Drift Push-Y

Story	Without Soft Storey	Soft storey at 3rd Floor	Soft storey at 5th Floor	Soft storey at 8th Floor	Soft storey at 10th Floor
1	0.023565	0.024979	0.025215	0.02545	0.025568
2	0.055472	0.0588	0.059355	0.05991	0.060187
3	0.088006	0.096807	0.094166	0.095046	0.095487
4	0.116007	0.127608	0.124127	0.125288	0.125868
5	0.139673	0.15364	0.156434	0.150847	0.151545
6	0.159368	0.175305	0.178492	0.172117	0.172914
7	0.175348	0.192883	0.19639	0.189376	0.190253
8	0.187853	0.206638	0.210395	0.212274	0.203821
9	0.197128	0.216841	0.220783	0.222755	0.213884
10	0.203441	0.223785	0.227854	0.229888	0.233957
11	0.207093	0.227802	0.231944	0.234015	0.238157
12	0.208431	0.229274	0.233443	0.235527	0.239696
13	0.207865	0.228652	0.232809	0.234887	0.239045



Graph 4: Storey Drift PUSH-Y

V. CONCLUSION

Design Pushover analysis was carried out on 13 storey building models as per IS 1893: 2016 (part 1). 5 different models were selected and analysis was done using ETABs 2016. Storey displacement, storey drift, Storey stiffness and Base shear of each models are obtained as results and comparative study was carried out for finding model with better performance.

- As we shift soft storey to higher level it can be seen from pushover and capacity spectrum curve that time period goes on reducing from 0.716 Sec. for 3rd floor soft storey to 0.446 Sec. at 10th floor soft storey.
- Which means soft storey is safer at higher level in high rise building. Most of the hinges developed in the beams and few in the columns.
- It is observed that plastic hinges are developed in columns of ground level soft storey which is not acceptable criteria for safe design.

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