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# REVIEW ON PUSHOVER ANALYSIS OF G+ 15 IRREGULAR STRUCTURES SUBJECTED TO EARTHQUAKE LOAD FOR ZONE IV AND V

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***Abstract:*** Earthquake engineering is a sector of civil engineering that deals with the mitigation of earthquake-induced damage on structures and the minimization of loss of life. During the last forty years this sector has advanced considerably due to the rapid developments of computers and computing, the improved experimental facilities, and the development of new methods of seismic design and assessment of structures. This advancement though has not been enough to resist the catastrophic consequences that earthquakes impose. However, it has led to some improvement of design and assessment procedures with a shift from traditional force-based procedures to displacement-based procedures, as inelastic displacements have been deemed to be more representative of different structural performance levels. However it is still difficult to physically 'separate' these procedures since forces and displacements are strongly related to each other. Nevertheless, the characterization of the various performance levels has led to performance-based earthquake engineering; the most recent path of seismic design and assessment. The aim of this project is to study the pushover analysis of G + 15 RC structures with 10% and 20% irregularities using ETABS software. It is observed that as building height increases value of base shear and roof displacement also increases because of increase in seismic weight of building.

***Index Terms*** - Pushover Analysis, Static and Dynamic Loads, Performance-based Earthquake Engineering, Soil-structure Interaction etc.

## I. INTRODUCTION

On 6 February 2023, at 04:17 TRT, a magnitude 7.8 earthquake struck southern and central Turkey and northern and western Syria. The epicenter was 37 km west–northwest of Gaziantep. The earthquake had a maximum Mercalli intensity of XII (*Extreme*) in parts of Antakya in Hatay Province. It was followed by a $M_w$ 7.7 earthquake at 13:24. This earthquake was centered 95 km north-northeast from the first. There was widespread damage and tens of thousands of fatalities. The $M_w$ 7.8 earthquake is the largest in Turkey since the 1939 Erzincan earthquake of the same magnitude, and jointly the second-strongest recorded in the history of the country, after the 1668 North Anatolia earthquake. It is also one of the strongest earthquakes ever recorded in the Levant. It was felt as far as Egypt, Israel, Palestine, Lebanon, Cyprus, and the Black Sea coast of Turkey. There were more than 10,000 aftershocks in the three weeks that followed. The seismic sequence was the result of shallow strike-slip faulting.

There was widespread damage in an area of about 350,000 $km^2$ (140,000 sq mi) (about the size of Germany). An estimated 14 million people, or 16 percent of Turkey's population, were affected. Development experts from the United Nations estimated that about 1.5 million people were left homeless. As of 10 March 2023, more than 55,700 deaths were confirmed: more than 48,400 in Turkey, and more than 7,200 in Syria. It is the deadliest earthquake in what is present day Turkey since the 526 Antioch earthquakes, making it the deadliest natural disaster in its modern history. It is also the deadliest in what is present day Syria since the 1822 Aleppo earthquake; the deadliest worldwide since the 2010 Haiti earthquake; and the fifth-deadliest of the 21st century. Damages were estimated at over US$100 billion in Turkey and US$5.1 billion in Syria, making them the fourth-costliest earthquakes on record.

Damaged roads, winter storms, and disruption to communications hampered the Disaster and Emergency Management Presidency's rescue and relief effort, which included a 60,000-strong search-and-rescue force, 5,000 health workers and 30,000 volunteers. Following Turkey's call for international help, more than 141,000 people from 94 countries joined the rescue effort.

**Figure 1: Damages of Structures due to Earthquake Occurred in Turkey**

The another one Nepal earthquake and some state of India (Bihar, Uttar Pradesh) in which many structures have been severely damaged or collapsed, have indicated the need for evaluating the seismic adequacy of existing buildings. Earthquakes are the most unpredictable and devastating of all natural disasters, which are very difficult to save over engineering properties and life, against it. In the past reinforced concrete building generally was designed for gravity loading only and not for Earthquake load .So it is necessary to check the seismic resistant of building also it is important to check seismic performance of newly constructed building. Vulnerability of India states that, there are about 11 million seismically vulnerable houses in zone V and 50 million in zone IV. Overall, 80 million building units are vulnerable. Any building unit becomes seismically vulnerable when there is an irregularity in terms of plan, elevation or along the height of the building. Any irregularity will cause an abrupt change in strength or stiffness of the structure. In recent years, a large number of high-rise buildings have been constructed throughout India. Some of these buildings were irregular and do not follow traditional structural design concepts. From the past experience, it has been shown that structural irregularities could directly or indirectly cause the collapse or severe damage to these structures under strong earthquakes. A thorough investigation of their performance under seismic loads is thus necessary to verify the safety of these irregular buildings.

The buildings with regular geometry and uniformly distributed mass and stiffness in plan as well as in elevation suffer much less damage compared to irregular configurations. But nowadays need and demand of the latest generation and growing population has made the architects or engineers inevitable towards planning of irregular configurations. Hence earthquake engineering has developed the key issues in understanding the role of building configurations.

There are various types of irregular configurations in building:

a) Mass irregularity at different storey
b) Stiffness irregularity at different storey
c) Vertical irregularity
d) Re-entrant corner

### 1.1 Re – entrant Corner Building

The severity of the seismic damages in re - entrant corners depends on characteristics of ground motion, seismic weight of the building, structural systems, length of the wings and their aspect ratio, height of the wings and their height to depth ratio. Also, buildings having projection less than 15% of its plan dimension in that direction is safe. Whereas 15 to 20% is considered deficient and greater than 20% is treated as highly deficient. Building Plans with re-entrant corner forms are a most useful set of building shapes for urban sites, particularly for residential apartments and hotels, which enable large plan areas to be accommodated in relatively compact form, yet still provide a high percentage of perimeter rooms with access to air and light. L and C shaped buildings with re-entrant corners are also common for school buildings to accommodate spaces for play grounds and assembly areas. But these configurations pose a great deficiency in the seismic behavior of the structure.

**Figure 2: Re-entrant corner Building**

## II. Literature Review

### 2.1 Literature on Irregular Buildings

**Behroz Eldar *et. al.* [2022]** studied analysis of irregular multistorey buildings with and without floating columns under seismic loading. Floating column is a vertical structural member that rests on the beam. Floating column is advantageous to provide large open space in a building, but it is disadvantageous in earthquake conditions. On the other hand, by the advancements in civil engineering knowledge, architects try to adopt irregular shapes of buildings. Providing floating columns in irregular buildings is a challenging issue for civil engineers they should deal with. That's why study of application of floating column in irregular buildings is one of the important topics in modern civil engineering. This study focuses on analysing the seismic behaviour of G + 10 irregular buildings considering floating columns and without floating columns to compare with a regular building. The building models are analysed in ETABS V19 software, then analytical findings are explained in terms of (maximum storey drift, maximum storey displacement, and torsional irregularity). From the study it is found that providing floating columns in irregular buildings increase storey drift and storey displacement significantly. Similarly, the torsion increases in buildings when the floating columns are not provided symmetrically.

**Rachakonda Divya *et. al.* [2022]** performed Comparative analysis of behaviour of horizontal and vertical irregular buildings with and without using shear walls by ETABS software. At present days building a structure with all the regular configurations is not feasible in most of the cases due to the irregular plot dimensions, aesthetic visual and functional requirements in the urban cities. The structure with more irregular configuration either horizontally or vertically are more vulnerable to earthquake & wind forces which leads to collapses of structure, property loss and casualties. Although a considerable amount of research effort was made on capturing the responses of irregular configuration structures under the earthquake forces, but well-accepted guidelines for multi storey irregular configuration structures are still yet to be framed. In this aspect a question might arise in the mind of structural engineers designing a high-rise structure i.e., which irregular configuration of structures and type of structures provide considerably good responses to the earthquake forces in reducing the damage caused by earthquakes and cost effective in implementing. A well-known answer is that shear walls provide good response to resist lateral forces when added to a structure. In the present study a structure with horizontal irregularity, vertical irregularity, Stiffness irregularity and Mass irregularity buildings with and without shear wall is considered and responses of the buildings are compared. Modeling of these 4 types of models with and without shear walls are done with ETABS software for G + 15 storey. The goal of the study is to compare model results like Stiffness, Displacement, Shear & Drift values and find out which model performs better. Vertical geometrical irregular building with shear wall has shown considerably better performance than other irregular buildings.

**P. Neeraja *et. al.* [2022]** investigated on progressive collapse failure in a multistorey irregular structure. Progressive collapse occurs due to failure of Primary load carrying members when subjected to abnormal loads or during the occurrence of earthquakes. This leads to overloading in nearby structural elements. Therefore, the load pattern of the overloaded elements changes which ultimately leads to failure of the elements. Stiffness Irregular RCC framed structures having variance in height of the storey is considered to examine the Potential ability of seismically designed buildings against Progressive Collapse and compared them with nominal model. G + 12 reinforced concrete framed regular and various models of Stiffness irregular structures were considered in the study to analyze Progressive collapse of buildings. A package based on finite element method SAP 2000 is used to model the structures and the behaviour of structures is evaluated by performing Linear Static Analysis by static loads and Time History Analysis by dynamic loads. Results of the analysis determined the intensity of structural damage caused under column removal. Calculation of DCR'S of the beam elements in critical region associated with column removal seems to fail both in Flexure and Shear.

**Shreyasvi *et. al.* [2015]** studied seismic response of buildings with reentrant corners in different seismic zones. For analysis of building they compared a building containing re-entrant corners with a building of regular plan configuration by performing linear dynamic analysis. A regular residential building with re - entrant corners and with a rectangular plan configuration had chosen. While modeling, the plan area of both the models had made approximately equal in order to facilitate comparison. The design spectrum applied to the building models was studied in order to understand the seismic demand in different seismic zones. The results obtained are compared for different seismic zones in terms of storey drift, joint displacement, and storey displacement. Along with this, the force to which the column located near a re - entrant corner studied. When the re - entrant building was compared with regular building, it was observed that the former undergoes larger storey displacement and drift than the latter. Buildings with re - entrant corner were more vulnerable to seismic damages and are susceptible to earthquake corresponding to time periods of lower order; hence, they concluded that the building plan must be of regular configuration in order to possess significant seismic resistance.

**Joheb Ahmed *et. al.* [2014]** carried out work on seismic vulnerability of RC buildings by considering plan irregularities using Pushover analysis. In the research work, a G+9 storey building situated in severe zone V was considered, having plan irregularities like, rectangular, diaphragm discontinuity, Y-shaped models. Nonlinear static analysis had been adopted for a project work, using FEM based analytical software ETABS 9.7.4 version. Various results were found such as base shear, point displacement, performance point, performance levels, and pushover curve. In order to identify the most vulnerable building among the models considered, the various analytical approaches such as equivalent static analysis, response spectrum method, and pushover analysis were performed to identify the seismic demands in both linear and nonlinear way. It is also examined the effect of different lateral load patterns on the performance of various irregular buildings in pushover analysis. They obtained results such as base shear for rectangular model was greater than diaphragm discontinuity and Y-shaped models.

**Nitin Choudhary *et. al.* [2014]** had studied pushover analysis of two multi-storied R.C. frame building, in which plan of one building was taken symmetrical and it consist of 2 bay of 5m in x direction & 2 bay of 4m in y direction and second building having L shaped unsymmetrical plan. The shear wall was provided for studying their resisting lateral forces. The comparative study had done for base shear, story drift, spectral acceleration, spectral displacement, story displacement. Provision of shear wall resulted in a huge decrease in base shear and roof displacement both symmetrical building and un-symmetrical building. In L-shaped building when shear wall was provided on the larger side of the building results in a decrease of 4.3% in base shear and

58.15% in roof displacement and when provided on smaller side results in a decrease of 7.97% in base shear and 55.43% in roof displacement. Hence in unsymmetrical buildings shear wall must be provided on smaller side of building. The performance based seismic design obtained by above procedure satisfied the acceptance criteria for immediate occupancy and life safety limit states for various intensities of earthquakes. Performance based seismic design obtained leads to a small reduction in steel reinforcement when compared to code based seismic design (IS 1893:2002) obtained by STAAD.Pro.

**Dr. Suchita Hirde *et. al.* [2014]** investigated seismic performance of tower type setback buildings. These setback building was stiffened with shear walls and nonlinear static pushover analysis was carried out. Performance and hinge formation pattern of tower type setback buildings and the buildings stiffened with shear walls was studied and compared. There was increment in base shear for all models incorporated with shear walls. This was due to increase in seismic weight of building. Shear walls were found to be very effective in reducing the lateral displacements in setback buildings.

**C. M. Ravikumar *et. al.* [2012]** studied two kinds of irregularities in the building models namely plan irregularity with geometric and diaphragm discontinuity and vertical irregularity with setback and sloping ground. Many buildings in that work had irregular configurations both in plan and elevation. This in future may subject to devastating earthquakes. These irregularities were created as per clause 7.1 of IS 1893 (part1)2002 code. In order to identify the most vulnerable building among the models considered, the various analytical approaches are performed to identify the seismic demands in both linear and nonlinear way. It was also examined the effect of three different lateral load patterns on the performance of various irregular buildings in pushover analysis.

**Kurdian Suprapto *et. al.* [2009]** studied twelve storey reinforced concrete office building with asymmetric configuration using dual system located in seismic zone 6 was designed conforming to the Indonesian seismic Code SNI 03-1726-2002 and the Indonesian Concrete Building Code SNI 03-2847-2002. The seismic performance of the building was evaluated using the Static Nonlinear (Pushover) Analysis and Inelastic Dynamic Time History Analysis. The performance point obtained from the pushover analysis was defined using various methods, such as FEMA 356, ATC-40, FEMA 440, and SNI 03-1726-2002. The result of the study indicated that the highest performance point was that obtained according to FEMA 356 and FEMA 440, whereas the lowest value was that in accordance with SNI-03-1726-2002. The roof displacement difference of that obtained from El-Centro dynamic analysis and performance-point pushover analysis reached up to 5 cm and 2.4 cm in X- and Y-directions, respectively. This indicates that the pushover analysis is quite accurate for evaluating the corresponding building since the first mode shape is quite dominant.

**Govind M. *et. al.* [2009]** studied the behavior of G+20 storied R.C frame buildings (Rectangular and H shape in plan, having same plan area) subjected to earthquake, located in seismic zone III was analyzed using ETABS software. Buildings with simple geometry in plan had performed well, during the past strong earthquakes. But buildings with H shape in plan, had sustained significant damages. So their work attempted to evaluate the effect of plan irregularity on the response of the structure. Gravity loads and laterals loads as per IS 1893-2002 were applied on the structure and it was designed using IS 456. At last displacement control pushover analysis was carried out and obtained results. From results they have concluded that when earthquake load was applied in X direction, it was found that rectangular plan structure resist more base shear than irregular plan structure. Also when earthquake load was applied in Y direction, it was found that irregular plan structure can resist more base shear than rectangular plan structure. This was because the numbers of columns were increased in Y direction in order to stabilize the structure, when structure was modified to irregular.

**Kammar *et. al.* [2009]** had carried out nonlinear static analysis of asymmetric building with and without shear wall. In that work they studied the performance level and behavior of structure in presence of shear wall for plan irregular building with re-entrant corners. The parameters considered that paper were base shear, displacement and performance level of building. They found that the base shear of the building increased with the addition of the shear wall as the load resisting capacity increases and the addition of shear wall significantly reduced the displacement in the structures when compared with the structures without shear wall.

**Govind M. *et. al.* [2009]** studied non linear static pushover analysis of irregular space frame structure with and without T shaped columns. They carried out the behavior of G+20 storied R.C frame buildings (H shape in plan, with and without T shaped column) subjected to earthquake, located in seismic zone III using ETABS software. Gravity loads and lateral loads as per IS 1893-2002 were applied on the structure and it was designed using IS 456. Displacement control pushover analysis was carried out. When earthquake load was applied in X direction, it was found that model with T shaped column can resist more base shear than Model with rectangular column. When earthquake load was applied in Y direction, it was found that model with T shaped column can resist more base shear than Model with rectangular column. But the percentage increment was acceptable. The results obtained in terms of demand, capacity spectra showed real behaviour of structures.

### 2.2 Literature on Pushover Analysis

**Henry Kimeze *et. al.* [2023]** performed comparative analysis of existing models and a new pushover analysis model of reinforced concrete sections. Pushover analysis is mainly carried out using the concentrated plasticity model whereby when a point reaches yield, a hinge is placed at that point. The other is the yielded block spread plasticity model, whereby when a point reaches yield, an elastic sub-element of the beam is replaced by a yielded sub-element having a reduced cross-section and second moment of area. Both of these models ignore cracking. This study aims at giving an insight into the effects of considering cracking during modelling on the accuracy of estimating deformations in reinforced concrete (RC) structures during pushover analysis by proposing a spread cracking and yielding block model. The proposed model introduces a cracked sub-element to account for the gradual spread of cracking in the beam. A single-storey RC frame is used because it doesn't pose the challenge of lateral load distribution. A comparison between the proposed model and the existing models shows an increment in the accuracy of the rotational, displacement, moment and lateral load capacities of 63.64%, 56.86%, 64.33% and 55.56% respectively. Experimental results show that all theoretical models underestimate the ultimate floor displacements and lateral load capacities. The proposed model, however, has better accuracy on both fronts than both existing theoretical models.

**Dapeng Qiu** ***et. al.*** **[2020]** studied **i**mproved pushover analysis for underground large-scale frame structures based on structural dynamic responses. This paper proposes an improved pushover analysis for underground large-scale frame structures (ULSFSs) that includes structural dynamic responses. The ULSFS employed is used in underground supermarket construction, and it has an extremely large-scale in two horizontal directions. Traditional pushover analysis for underground structures (UPA) is used for structures with small-scale, but results show that it is not sufficiently accurate for use with ULSFSs (either with and without structural joints), as structural vibration is neglected. Therefore, the structural dynamic coefficient of ULSFSs relative to the structural vibration mode is obtained, and an improved pushover analysis (ULPA) is proposed that considers both structural vibration and site characteristics. The applicability of using the ULPA is verified by comparing the seismic response with a dynamic time history analysis, and the seismic responses of ULSFS under combined horizontal and vertical earthquakes are also investigated using the ULPA. The results show that the ULPA is more highly reliable than the UPA for ULSFSs, particularly for structures with structural joints, and it is feasible for use under both unidirectional and bidirectional earthquakes.

**Zijun Wang** ***et. al.*** **[2020]** studied pushover analysis of structures subjected to combined actions of earthquake and wind. This paper puts forward a framework to investigate the structural performance of buildings subject to the combined action of earthquakes and wind. The study uses a pushover analysis to determine strength capacities of low- and medium-rise concrete structures to compare versus their strength, as inferred from the Chinese code for seismic design. The analysis addresses soil-structure interactions through the scrutiny of fixed-base and flexible-base conditions of three soil types ranging between dense and soft. The parametric study covers micro meteorological winds whose mean value spans between 0.5 m/s and 20 m/s. The simulated multi-load scenarios induce ductility levels going from 1 to 6 to totalise 288 case studies. The proposed framework reveals that consideration of earthquake and wind simultaneous effects could modify performance levels used for design through enhancing ductility demands. This evidences that, under current design recommendations, structures located in earthquake prone areas susceptible to unexpected levels of damage.

**A. S. Moghadam** ***et. al.*** **[2009]** studied pushover analysis for asymmetric and set-back multi-story buildings. To extend the pushover analysis to eccentric multi-story buildings a procedure has recently been developed. It takes into account the higher modal and three-dimensional effects induced by torsion. The procedure uses an elastic spectrum analysis of the building to obtain the target displacements and load distributions for pushover analyses. Then two-dimensional inelastic static analyses are conducted on the lateral load resisting elements of interest. To investigate the efficiency of this method for different types of eccentric buildings, three systems are studied. The first model is a ductile moment resisting frame building. The second model is a set-back building and the last one is a wall-frame structure. Each building is subjected to ten spectrum compatible time history records as ground motion excitations at the base. The means of the maximum responses of these buildings are computed using three-dimensional inelastic dynamic analyses and using the proposed procedure. A comparison of the two sets of results demonstrates both the capabilities and limitations of the proposed procedure.

**Applied Technology Council 40** (ATC40) volume 1 and 2 highlights the nonlinear static pushover analysis. It is an efficient method for the performance evaluation of a structure subjected to seismic loads. Also ATC40 covers step by step procedures for pushover analysis to determine the capacity curve, capacity spectrum method and displacement coefficient method were briefly elaborated. By using these procedures this report is detailed with modeling aspects of the hinge behavior, acceptance criteria and locate the performance point. Hence, ATC40 serves as guideline for the starting of seismic evaluation process.

**Mehmet Inel** ***et. al.*** **[2006]** explained that due to its simplicity of pushover analysis, the structural engineering profession has been using the nonlinear static procedure or pushover analysis. Pushover analysis is carried out for different nonlinear hinge properties available in some programs based on the FEMA-356 and ATC-40 guidelines and they pointed out that plastic hinge length (Lp) has considerable effects on the displacement capacity of the frames. The orientation and the axial load level of the columns cannot be taken into account properly by the default-hinge properties (Programme Default).

**Krawinkler** ***et. al.*** **[1998]** have conducted a detailed study that discusses the advantages, disadvantages and applicability of pushover analysis by considering various aspects of the procedure. Authors said that the basic concepts and main assumptions on which the pushover analysis is based, is target displacement estimation of MDOF structure through equivalent SDOF domain and the applied modification factors and lateral load pattern. The accuracy of pushover predictions were evaluated on a 4-storey steel perimeter frame damaged in 1994 Northridge earthquake. The frame was subjected to nine ground motion records. Local and global seismic demands were calculated from pushover analysis results at the target displacement associated with the individual records. The comparison of pushover and nonlinear dynamic analysis results showed that pushover analysis provides good predictions of seismic demands for low-rise structures having uniform distribution of inelastic behavior over the height. It was also recommended to implement pushover analysis with caution and judgment considering its many limitations since the method is approximate in nature and it contains many unresolved issues that need to be investigated.

## III. CONCLUDING REMARKS

From the literature review it has been seen that many research papers are available to understand the behavior of plan irregular buildings. However there is little work carried out by researcher related to finding vulnerability of existing RCC plan irregularity building using pushover analysis. The concept of pushover analysis is rapidly growing in the area of seismic evaluation now-a-days. It gives the capacity curve of the building from which lateral load carrying capacity of the buildings can be calculated. Hence for the safety of the structure during earthquake, it is important to assess performance level of the building and to suggest retrofitting schemes for deficient buildings. Thus main objective is to carry out the seismic performance of plan irregular building in terms of performance point, pushover curve for the structure to retain the structure in operational level.

Modern tall and super-tall buildings are usually more light-weight, more flexible, and more lightly damped than their predecessors, because the proposed innovative structural systems require high-strength materials. Recent construction materials also have lighter cladding, and the availability of modern construction techniques has facilitated and increased the trend of ever taller buildings. Moreover, in highly populated cities with limited land, the number of stories in modern buildings has increased. Consequently, modern buildings are more sensitive to dynamic excitation under strong wind and severe earthquake loads than previous structures. Many engineered structures, especially tall structures, are susceptible to dynamic loads and earthquake and wind-induced vibrations. Such load-sensitive structures must be appropriately designed by structural engineers. The most relevant dynamic characteristics of a high-rise building are its natural oscillatory period, mass, stiffness, and damping coefficient. Tall buildings are characterized by low natural frequency; hence they can vibrate significantly under lateral dynamic earthquake loads. Besides the aforementioned structural characteristics, the oscillation of high-rise buildings depends on the applied dynamic load characteristics. The design response of a structure under lateral loads is a governing factor when designing modern tall buildings and structures. Robustness against wind and earthquake loads is necessary to ensure the structural safety, serviceability, and occupational comfort of the building. Structural engineers rely on design codes to design tall buildings subjected to such lateral loads.

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## References

[1] Shreyasvi C, B. Shivakumaraswamy, *"Seismic Response of Buildings with Re - entrant Corners in different Seismic Zones",* International Journal of Research in Engineering and Technology, Volume 04, 2015.

[2] Ravikumar C M, Babu Narayan K S, *"Effect of irregular configurations on seismic vulnerability of RC building",* Architecture Research, 2012.

[3] Govind M, Kiran K. Shetty, K. Anil Hegde, *"Seismic Evaluation of High Rise Regular and Irregular Structure using Pushover Analysis",* IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), 2009.

[4] Joheb Ahmed, Syed Ahamed Raza, *"Seismic Vulnerability of RC buildings by considering Plan Irregularities using Pushover Analysis",* Global Journal for Research Analysis, Volume 3, 2014.

[5] Nitin Choudhary, Mahendra Wadia, *"Pushover Analysis of RC Frame Building with Shear Wall",* IOSR Journal of Mechanical and Civil Engineering, Volume 11, Issue No. 2, 2014.

[6] Dr. Suchita Hirde and Romali Patil, *"Seismic Performance of Setback Building Stiffened with Reinforced Concrete Shear Walls",* International Journal of Current Engineering and Technology, Volume 04, Issue No. 3, 2014.

[7] Kurdian Suprapto and Sudart, *"Evaluation of Performance of Asymmetrically Dual system structures using Pushover and Time History analysis",* ITS Journal of Civil Engineering, Volume 29, 2009.

[8] Govind M, Kiran K. Shetty, K. Anil Hegde, *"Non Linear Static Pushover Analysis of Irregular Space Frame Structure With and Without T shaped Columns",* International Journal of Research in Engineering and Technology, Volume 03, 2014.

[9] ATC 40, *"Seismic Evaluation and Retrofit of Concrete Buildings",* Volume 1 & 2, Applied Technology Council, Redwood City, CA, USA, Report No. SSC 96-01, 1996.

[10] Helmut Krawinkler, D. P. K. Seneviratna, *"Pros and Cons of A Pushover Analysis of Seismic Performance Evaluation",* Engineering Structures, Volume 20, Issue No. 4-6, pp. 452-464, 1998.

[11] Mehmet Inel, Hayri Baytan Ozmen, *"Effects of Plastic Hinge Properties in Nonlinear Analysis of Reinforced Concrete Buildings",* Department of Civil Engineering, Pamukkale University, 20070 Denizli, Turkey, 2006.

[12] Maheri M.R. and Sahebi A., *"Use of Steel Bracing in Reinforced Concrete Frames",* Engineering Structures, Volume 19, Issue No.12, pp. 1018-1024, 1997.

[13] Maheri M.R. and Akbari R. *"Seismic Behavior Factor, R, For Steel X-Braced and Knee-Braced RC Buildings",* Engineering Structures, Volume 25, pp. 1505–1513, 2003.

[14] Sugano S, *"Seismic Strengthening of Existing Reinforced Concrete Buildings in Japan",* Bulletin of the New Zealand National Society for Earthquake Engineering, Volume No. 04, 1981.