

# Review on Performance-Based Design of the Plan Irregular Building

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**ABSTRACT:** An earthquake is a shaking of the surface of the Earth, resulting from the sudden release of energy in the Earth's lithosphere that creates seismic waves. Earthquakes are so far unpreventable and unpredictable, the only option with us is to design and build the structures, which are earthquake resistant. The amount of damage caused by earthquakes could increase in future. This will not be due to a rise in the number and severity of quakes but rather to the increase in world population, linked to the growing number of crowded metropolitan areas and the increase in value of property and material in these areas. Structural irregularities are one of the causes of increase damage under seismic action. The sources of irregularities in a building setup are of different types and are generally categorized into two main classification, namely plan and elevation irregularities. Both of these types of irregularities involve the growth of brittle collapse mechanisms due to the local rise in seismic demand in particular components and due to insufficient strength and ductility. Among the two kinds of structural irregularities mentioned above, in-plan irregularities appear to have the most adverse effects on the applicability of classical pushover analysis. Such techniques have been created for the seismic evaluation of the buildings whose behavior is single translational. This is the reason the extended N2 method used to plan irregular building structures. In extended N2 method, the pushover analysis is a non-linear static analysis in which the seismic performance of the building can be found out. In this report an eleven storey buildings with same plan area with different shapes in the plan was considered. Four different plan of the building modeled were L-shape, H-shape, C-shape and T shape. The results after performing the pushover analysis were compared for performance curve, capacity curve, performance level etc. The capacity curve shows the performance point of the building under the load applied. Also, the compressive stresses of corners from all irregular building were compared those of with the regular building. All building frames were analyzed by using design and analysis software ETABS and were designed as per IS 456:2000 and IS1893:2016.

**KEYWORDS:** Extended N2 method, Nonlinear static analysis, Pushover analysis, Response spectrum.

## I.INTRODUCTION

### 1.1 GENERAL

Earthquakes are the most unpredictable and devastating natural disasters, which are very difficult to save engineering properties and life. Hence in order to overcome these issues, identifying the seismic performance of the built environment through the development of various analytical procedures, which ensure the structures to withstand during frequent minor earthquakes and produce enough caution whenever subjected to major earthquake events. The behavior of a building during an earthquake depends on several factors such as stiffness, lateral strength, and ductility, simple and regular configurations. The buildings with regular geometry, uniformly distributed mass and stiffness in plan as well as in elevation suffer much less damage compared to irregular configurations. But nowadays thirst and demand of the new generation engineers are planning towards an irregular configuration for better aesthetic perspective. Hence earthquake engineering has developed the key issues in understanding the role of different types of building configurations. The structures seismic performance depends on the damage suffered by the earthquake design. As structural damage results from inelastic displacement, performance assessment of an existing or new structure requires inelastic structural analysis to determine the magnitude of demand parameters in the structures. These parameters of demand are used to compare performance with the criteria of acceptance. Global displacement (displacement of the roof level) are the main demand parameters that can be predicted and

controlled in performance based design. In principle, the correct approach is the non-linear time-history analysis. Because evaluation of dynamic structural response under loading which may vary according to the specified time function. However, such a strategy is not practical for the everyday use of design for the time being. It requires additional input data which cannot be reliably predicted. Nonlinear dynamic analyses are currently appropriate for studies and significant structural design. On the other side, the techniques used in the vast majority of current building codes are based on linear elastic structural conduct and do not provide true strength, ductility and power dissipation data. They also fail to estimate the anticipated harm quantitatively. For the time being, the most rational methods of analysis and performance evaluation for practical applications, which should be used in addition to the established elastic procedures, appear to be simplified inelastic procedures combining a relatively simple multi-degree-of-freedom (MDOF) mathematical model with a response spectrum analysis. This is termed as N2 method. They can be used for a multitude of reasons such as design verification of new buildings and bridges, damage evaluation of current structures, determination of fundamental structural features in direct displacement-based design, and fast evaluation of worldwide structural reaction to various seismic ground movement intensity.

In pushover-based techniques, the fundamental assumption is that the structure vibrates predominantly in one mode. This assumption is not always achieved, particularly in the case of RCC buildings and/or plan-asymmetric structures with torsional flexibility. A lot of work has been done worldwide to take into account the influence of higher modes in elevation and in the plan. In plan irregularity appears to have the most adverse effects on the applicability of the classical nonlinear static procedures (NSPs) precisely because a plan irregular building is that for which one or more rotational modes have a significant participating mass ratio. Therefore the dynamic behavior of the structure cannot be defined referring to one translational mode only. The basic NSP approach is not reliable for plan irregular buildings, for which the first translational mode is not representative of a more complex dynamic behavior, that involves both translational and rotational components [[7]] .

Development of the extended N2 technique applies to constructions with significant greater mode impacts and the fundamental concept was to maintain the operation as straightforward as possible. Using correction variables based on the outcomes of elastic modal assessment, the greater mode issue was approached. In any pushover-based strategy, the same concept can be used. The extended N2 technique that takes into consideration the impacts of greater mode in elevation is provided in the present research.

## 1.2 STRUCTURAL IRREGULARITIES

Based on the structural configuration, each structure shall be designed as a regular, or irregular structure as defined below as per IS 1893 [2016] [8]:

**Regular Structure:** Regular structures have no significant physical discontinuities in plan or vertical configuration or in their lateral force resisting systems.

**Irregular Structures:** Irregular structures have significant physical discontinuities in configuration or in their lateral force resisting systems. Irregular structures have either vertical irregularity or plan irregularity or both in their structural configuration.

### 1.2.1 Types of Plan Irregularity

**Re-entrant corner irregularity:** Exists when both plan projections of the structure beyond a re-entrant corner are greater than 15% of the plan dimension of the structure in the given direction. With reference to Figure 1.2, this type of irregularity exists when  $A > 0.15L$ . [8]

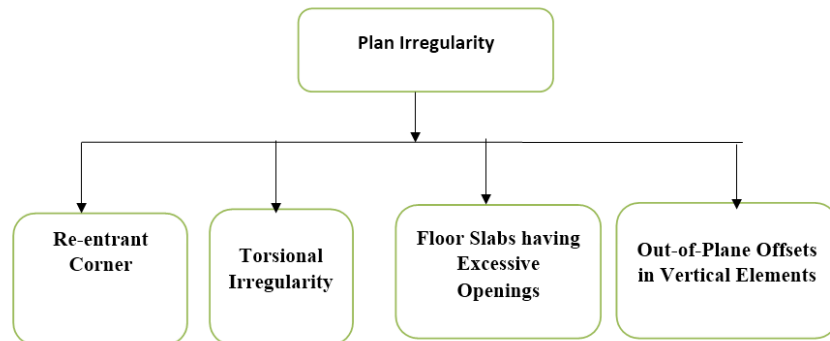


Figure Ошибка! Текст указанного стиля в документе отсутствует.1.1 Horizontal Irregularity

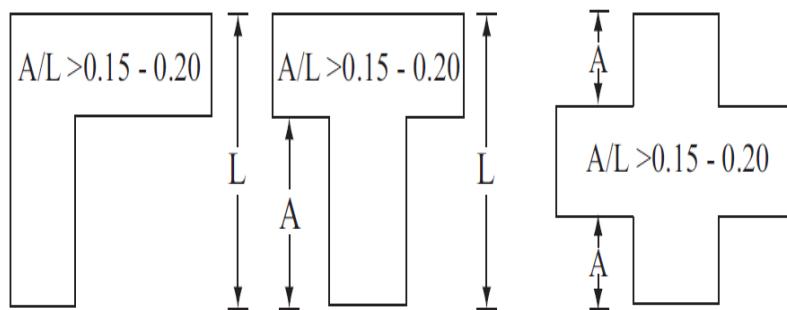


Figure Ошибка! Текст указанного стиля в документе отсутствует.1.2 Re-entrant corner irregularity definitions

Where,

A=Projected Length

L= Total Length

**Torsional irregularity:** In torsionally irregular buildings, when the ratio of maximum horizontal displacement at one end and the minimum horizontal displacement at the other end is in the range 1.5-2 the building configuration shall be revised to ensure that the natural period of the fundamental torsional mode of oscillation shall be smaller than those of the first two translational modes along each principal plan directions .

**Floor Slabs having Excessive Openings:** In buildings with discontinuity in their in-plane stiffness, if the area of the geometric cut-out is, less than or equal to 50 percent, the floor slab shall be taken as rigid or flexible depending on the location of and size of openings and more than 50 percent, the floor slab shall be taken as flexible.

**Out-of-Plane Offsets in Vertical Elements:** A building is said to have out-of-plane offsets in vertical elements, when structural walls or frames are moved out of plane in any storey along the height of building.

### 1.3 MOTIVATION

The IS 1893, 2016 gives different types of irregular buildings. In case of plan irregular buildings, the non-linear static procedure (NSP) cannot be used because of the effects of stiffness degradation and changes in dynamic properties related to progressive damage and due to its inability of considering the contribution of higher modes of vibration.

Thus, there is a need to study the find out performance of the irregular building. From the literature, it is observed that the extended N2 method used for the plan irregular building.

#### 1.4 OBJECTIVES OF STUDY

The main objective of the study is to evaluate the performance of G+10 RCC Building structure with re-entrant corner irregularities using pushover analysis. Different re-entrant corner irregular structures are considered in this study. The extended N2 method is carried out for all the structures and they are compared. The specific objectives are as given below:

1. To analyses re-entrant corner irregular RCC buildings.
2. To compare the performance of buildings with L-shape, H-shape, C-shape and T-shape using Extended N2 Method.

## II. LITERATURE SURVEY

**Title: Pushover Analysis for Plan Irregular Building Structures.(2014) (European Earthquake Engineering and Seismology, Springer)**

**Authors: Mario De Stefano and Valentina Mariani.**

The aim of this research paper is to provide a broad perspective on the issue of seismic evaluation of irregular structures in the plan. First, a brief review of the elastic and inelastic methods for evaluating the torsional effects caused by irregularity in the plan is presented, primarily aimed at defining the variables that govern the problem. The fundamental characteristics of the most significant NSPs are then discussed, followed by the description of the latest changes created for irregular structures. Because there is not yet a completely satisfactory solution, the advantages and disadvantages of the different approaches are described, highlighting the most promising techniques and the problems yet to be explored.

Originally specified for symmetric, periodic constructions for the assessment of seismic vulnerability of buildings, it is shown that torsional conduct calls into question their validity for the seismic assessment of torsionally delicate structures. Therefore there is an immediate need for such techniques to be updated with a view to a reliable implementation to irregular structures. Two significant methods have been identified with regard to the enhancement of NSPs: the first is based on the incorporation in the evaluation of the contribution of greater methods and has led, inter alia, to the creation of (Multi-Modal Pushover) MMP and (Modal Pushover Analysis) MPA procedures ; the second focuses on the need to account for the increase in the demand for displacement through corrective measures.

**Title: Introduction of A Performance-Based Design [2000] (12th World Conference on Earthquake Engineering, Auckland)**

**Authors: Katsuhiko YAMAWAKI<sup>1</sup>, Haruyuki KITAMURA<sup>2</sup>, Yasuhiro TSUNEKI<sup>3</sup>**

The authors created a performance-based design methodology in this article that obviously defines different elements of seismic performance in buildings. In addition, a "seismic performance menu" was also ready to provide common bases for customers and developers in determining each particular building's seismic performance design. The authors have also established technical design targets corresponding to each performance level and the design values i.e., required structural strength levels to satisfy the technical design targets. A series of analyses on model buildings have been carried out and it has been confirmed that the proposed levels of structural strength are effective in achieving the required levels of performance.

The authors also provided requirements corresponding to each performance level goal for chosen design parameters. While these parameters are important problems in structural design, it is clear that the practical design method requires more streamlined representative requirements. The authors chosen the design ratio targeting ultimate tale shear forces to those needed by the present Building Code in Japan and performed some reinforced concrete and steel structures test design. Finally, a series of analyses of the reaction history of time were performed. From the outcomes of analyses it was found that the structures built on the basis of the simplified criteria show fairly well the initial target level of performance.



**Title: The extended N2 method considering higher mode effects in both plan and elevation [2011] (Bulletin of Earthquake Engineering)**

**Authors: Maja Kreslin · Peter Fajfar**

The extended N2 technique has been created, taking into consideration the impacts of greater mode in both plan and elevation. The extension is based on the premise that while vibrating in greater modes, the structure remains in the elastic range. By combining the outcomes of fundamental pushover assessment with those of conventional elastic modal analysis, the seismic demand in terms of displacement and storey drift can be achieved. The suggested method was summarized in the article and applied to a sample instance representing an real reinforced concrete building of 8 storey's. The results obtained through the extended N2 method were compared without consideration of higher modes with the results of nonlinear response history analysis and basic N2 analysis. In the case of the test example, the extended N2 method could provide fair, conservative estimates of response. The prediction of seismic demand has been greatly improved in the upper part of the building and at the flexible edges compared to the basic N2 method.

In the elastic spectrum, it is possible to decouple the vibration in distinct modes. The assessment can be carried out individually for each mode and for each loading direction. Using design spectra, the results obtained for different modes are then combined using approximate combination rules, such as the rule "Square Root Sum of Squares" (SRSS). This method will be called Response Spectrum Analysis (RSA) in this research paper, which constitutes a normal elastic modal reaction assessment.

**Title: Extension of N2 method to plan irregular buildings considering accidental eccentricity [2012] (Soil Dynamics and Earthquake Engineering)**

**Authors: Gennaro Magliulo, GiuseppeMaddaloni, EdoardoCosenza**

The research paper deals with the subject of analyses under contemporary code regulations, particularly Eurocode 8 (EC8) regulations. An uneven multi-storey R/C frame building intended according to Eurocode 2 (EC2) and EC8 provisions is performed by non-linear static and non-linear dynamic analyses. As applied in previous research papers, the extension of the N2 method to torsionally flexible structures does not consider the accidental eccentricity prescribed by EC8 in the case of non-linear static analysis as well.

In this research paper, three methods are proposed and discussed that combine the Eurocode 8 (EC8) prescribed accidental eccentricity with the procedure that extends the N2 method to torsionally flexible structures. Each offers four modal reaction spectrum analyses (one per model, corresponding to each center of mass position) and eight non-linear static analyses (two signs for four models). NLSA appears to be the most reliable of the three suggested methods because it fits better with absolute displacements acquired through non-linear dynamic analysis. It is also noted in the research paper that the value of the behavior factor that Eurocode 8 (EC8) assigns to torsionally flexible structures .

**Title: Effects of plastic hinge properties in nonlinear analysis of Reinforced Concrete Buildings [2006] (Engineering structures)**

**Authors: Mehmet Inel, Hayri Baytan Ozmen**

In this research paper, a nonlinear static operation (NSP) or pushover assessment was used by the structural engineering profession. Modeling for such assessment involves determining the nonlinear characteristics of each element in the framework, quantified by strength and deformation capabilities depending on the assumptions of modeling. Pushover assessment is performed for either user-defined nonlinear characteristics or default characteristics, accessible in some programs based on the rules FEMA-356 and ATC-40. While these research papers provide the hinge characteristics for several detailing ranges, average values may be implemented by programs. The user must be cautious; misuse of default-hinge characteristics can result in unreasonable displacement capabilities for current constructions.

Due to default and user-defined nonlinear component characteristics, this research paper studies possible distinctions in the outcomes of pushover assessment. For this research, it is regarded that four-and seven-storey structures constitute small and medium-rise buildings. In the user-defined hinge characteristics, plastic hinge length and transverse reinforcement spacing are supposed to be efficient parameters. Observations indicate that the length of the plastic hinge and the spacing of the transverse reinforcement do not affect the ability of the base shear, while these parameters have significant impacts on the ability of the frames. Comparisons point out that an increase in transverse reinforcement increases the capacity for displacement. While the capability curve for the default-hinge model is sensible for structures that comply with contemporary code, it may not be appropriate for others. In view of the fact that most existing buildings in

Turkey and in some other countries do not comply with modern code detailing requirements, the use of default hinges requires special care. The observations obviously indicate that in reflecting nonlinear conduct compatible with the element characteristics, the user-defined hinge model is better than the default-hinge model. However, if, because of simplicity, the default-hinge model is preferred, the user should be conscious of what is supplied in the program and should prevent misuse of default-hinge characteristics.

**Title: Pros and Cons of the Pushover Analysis of the seismic performance evaluation [1998] (Engineering structures)**

**Authors: Helmut Krawinkler, G. D. P. K. Seneviratna**

This research paper presents the two separate stability coefficients that can be used to quantify the P-basic effect of regular steel moment resistant frames (SMRF) during elastic and inelastic lateral displacement. This research paper describes the thorough quantification procedure for these two stability coefficients.

It was found that the two stability coefficients are feature of the fundamental elastic span and the modal shape of the frame so-called modal-elastic stability coefficient and modal-inelastic stability coefficient. With the combined use of these two stability coefficients, the impact of the P-Delta phenomenon on SMRF conduct can be explored. It is noted that a single stability coefficient can be used to estimate the strength and stiffness of a steel moment resistant frame generated by the P– delta effect.

### III. CONCLUSIONS

Pushover curve for L-Shape, H-Shape, C-Shape, T-Shape are observed. L-Shape building is comparatively more stiffer and less ductile than all the remaining types of building. The L-Shape irregular building attracts more base shear and T-Shape irregular building attracts less base shear hence T-Shape irregular building is more ductile. The L-Shape irregular building, the performance point has below IO level. Hence L-Shape irregular building has minimal damage in structural and minor damage in non-structural component. It is possible to slightly adjust under the low level of earthquake. The H-Shape, C-Shape, T-Shape irregular buildings, the performance point has between IO level and LS level. Also the L-shape irregular building with optimized cross-section, the performance point has between IO level and LS level. Hence this irregular buildings has minor damage in structural and extensive damage in non-structural component. Near IO level condition is safe to reoccupy a building designed for this performance level. It is possible to some repair and restoration of utility services and near LS level condition is repair may be require before reoccupancy through in some cases extensive restoration or reconstruction may not be cost effective and both condition the risk causalities at this target performance level is low. For regular structure max compressive stresses is  $16.26 \text{ N/mm}^2$  and C-shape irregular structure max corner compressive stresses is  $19.35 \text{ N/mm}^2$  as compared to other irregular structure.

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