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Pushover Analysis of knee Braced System In High Rise Steel Structure

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Abstract:

Structures designed to resist moderate and frequently occurring earthquakes must have sufficient stiffness and strength to control deflection and to prevent damage. However, it is inappropriate to design a structure to remain elastic under severe earthquake because of economic constraints. The inherent damping of yielding structural elements can be advantageously utilized to lower the strength requirements, leading to a more economical design.

A frame with knee bracings (KBFs) provides an effective bracing solution. It can be obtained by providing a new element called "knee" in between the beam and column along with bracings. These bracings limit inter storey drifts, and knee element absorbs the earthquake energy, by providing cyclic deformations in shear or bending. The main advantage with respect to eccentric braced frames is that damage is concentrated in secondary element and it can easily replace after destructive earthquakes.

1. Introduction

Structures designed to resist moderate and frequently occurring earthquakes must have sufficient stiffness and strength to control deflection and to prevent damage. However, it is inappropriate to design a structure to remain elastic under severe earthquake because of economic constraints. The inherent damping of yielding structural elements can be advantageously utilized to lower the strength requirements, leading to a more economical design. This yielding provides ductility or toughness of structure against sudden brittle type structural failure. In steel structures, the moment resisting and concentrically braced frames have been widely used to resist earthquake loadings. The moment resisting frame possesses good ductility through flexural yielding of beam element but it has limited stiffness. It is necessary to design a structure to perform well under seismic loads. Shear capacity of the structure can be increased by introducing steel bracings in the structural systems. Bracing can be used as retrofit as well. There are n number of possibilities are there to arrange steel bracings. Such as X, K and V type Eccentric bracings. The present study develops a Pushover Analysis for Knee bracing steel frames designed according to IS 800 – 2007 and ductility behavior of each frame.

A frame with knee bracings (KBFs) provides an effective bracing solution. It can be obtained by providing a new element called "knee" in between the beam and column along with bracings. These bracings limit inter storey drifts, and knee element absorbs the earthquake energy, by providing cyclic deformations in shear or bending. The main advantage with respect to eccentric braced frames is that damage is concentrated in secondary element and it can easily replaced after destructive earthquakes. The position and stiffness of knee was the most important factor affecting the lateral resisting ability of KBF.

2. Knee Brace System

Steel has become the predominate material for the construction of bridges, buildings, towers and other structures. Its great strength, uniformity, light weight and many other desirable properties makes it the material of choice for numerous structures such as steel bridges, high rise buildings, towers and other structures. Bracing element in structural system plays vital role in structural behavior during earthquake. Steel bracing is an effective and economical solution for resisting lateral forces in a framed structure. Bracings are of different types, namely concentric bracings, eccentric bracings and knee bracings. In concentric bracings, inelastic energy dissipation response is generally poor due to the possible buckling of the diagonal elements in compression. In eccentric bracings since it absorbs large seismic force, repair and replacement after a severe earthquake is expensive and time consuming. As a remedy for all these disadvantages knee braced frame developed. Frames with knee bracings (KBFs) provides an effective bracing solution.

Figure 1: Knee Brace

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3. Pushover Analysis

Pushover analysis is a static nonlinear procedure in which the magnitude of the lateral load is increased monotonically maintaining a predefined distribution pattern along the height of the building (Fig. 1.4). Building is displaced till the control node reaches target displacement or building collapses. The sequence of cracking, plastic hinging and failure of the structural components throughout the procedure is observed. The relation between base shear and control node displacement is plotted for all the pushover analysis .

Generation of base shear – control node displacement curve is single most important part of pushover analysis. This curve is conventionally called as pushover curve or capacity curve. So the pushover analysis may be carried out twice: (a) first time till the collapse of the building to estimate target displacement and (b) next time till the target displacement to estimate the seismic demand. The seismic demands for the selected earthquake (storey drifts, storey forces, and component deformation and forces) are calculated at the target displacement level. In pushover analysis the building is pushed with a specific load distribution pattern along the height of the building. The magnitude of the total force is increased but the pattern of the loading remains same till the end of the process. Pushover analysis results (i.e., pushover curve, sequence of member yielding, building capacity and seismic demand) are very sensitive to the load pattern.

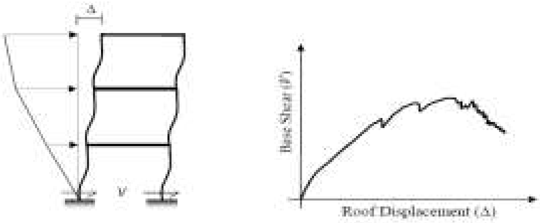

Figure 2: Schematic Representation of Pushover Analysis Procedure

Target displacement is the displacement demand for the building at the control node subjected to the ground motion under consideration. This is a very important parameter in pushover analysis because the global and component responses (forces and displacement) of the building at the target displacement are compared with the desired performance limit state to know the building performance. So the success of a pushover analysis largely depends on the accuracy of target displacement.

4. Response Spectrume Analysis

This method is applicable for those structures where modes other than the fundamental one affect significantly the response of the structure. In this method the response of Multi-Degree-of-Freedom (MDOF) system is expressed as the superposition of modal response, each modal response being determined from the spectral analysis of single - degree-of-freedom (SDOF) system, which is then combined to compute total response. Modal analysis leads to the response history of the structure to a specified ground motion; however, the method is usually used in conjunction with a response spectrum. A response spectrum is simply a plot of the peak or steady-state response (displacement, velocity or acceleration) of a series of oscillators of varying natural frequency, that are forced into motion by the same base vibration or shock. The resulting plot can then be used to pick off the response of any linear system, given its natural frequency of oscillation. One such use is in assessing the peak response of buildings to earthquakes. The science of strong ground motion may use some values from the ground response spectrum (calculated from recordings of surface ground motion from seismographs) for correlation with seismic damage. If the input used in calculating a response spectrum is steady-state periodic, then the steady-state result is recorded. Damping must be present, or else the response will be infinite. For transient input (such as seismic ground motion), the peak response is reported. Some level of damping is generally assumed, but a value will be obtained even with no damping. Response spectra can also be used in assessing the response of linear systems with multiple modes of oscillation (multi-degree of freedom systems), although they are only accurate for low levels of damping. Modal analysis is performed to identify the modes, and the response in that mode can be picked from the response spectrum.

The earthquake load is considered as per IS:1893 (Part I):2016,for medium soil with importance factor 1.2 and Reduction factor for SMRF structure as 5.
Seismic zone factor Z for Zone IV = 0.24
Scale factor = (Z/2)*(I/R)*g
The effect of vertical shaking should be considered as seismic zone of structure is considered to be IV

The seismic load is calculated as per IS 1893(Part 1):2016.The building is analysed in two principal horizontal directions.

Fundamental time period of building are calculated as per IS 1893(Part 1):2016 by using response spectrum method.
Seismic coefficient $A_h = (S_a/g)*(Z/2)*(I/R)$
Base shear $V_B = A_h*W$
For medium soil sites
$Sa/g = 1+15*T \quad T \leq 0.10$
$= 2.5 \quad 0.10 \leq T \leq 0.55$
$= 1.36/T \quad 0.55 \leq T \leq 4.00$
$= 0.34 \quad T > 4.00$
a)

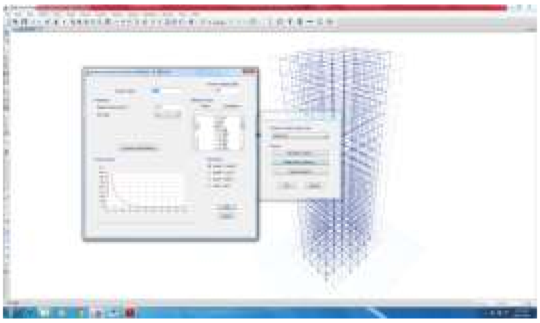

Figure 4: ETAB 2016 graphic page while assigning response spectrum function in horizontal direction

The seismic load is calculated as per IS 1893(Part 1):2016.The building is analysed in vertical directions.
Fundamental time period of building are calculated as per IS 1893(Part 1):2016 by using response spectrum method.
Seismic coefficient Ah =(Z/3)*(I/R) *2.5
Base shear VB =Ah*W

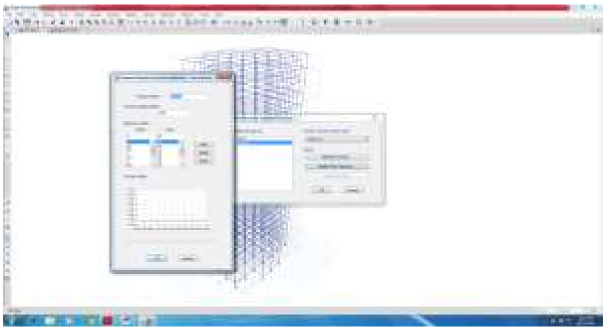

Figure 4: ETAB 2016 graphic page while assigning response spectrum functionin vertical direction

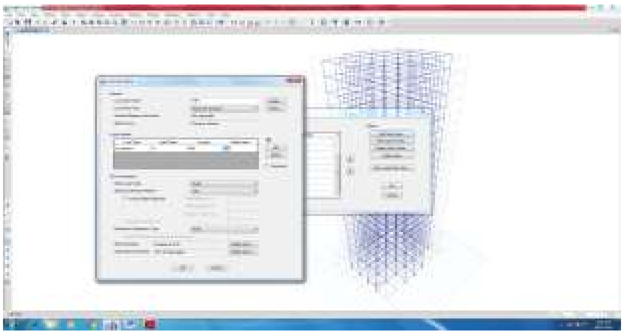

Figure 4: ETAB 2016 graphic page while assigning response spectrum load data

5. Conclusion

Tall building developments have been rapidly increasing worldwide. The growth of multistory building in the last several decades is seen as the part of necessity for vertical expansion for business as well as residence in major cities. It is observed that there is a need to study the structural systems for steel framed structure, which resist the lateral loads due to seismic effect. Safety and minimum damage level of a structure could be the prime requirement of tall buildings. To meet these requirements, the structure should have adequate lateral strength, lateral stiffness and sufficient ductility. Among the various structural systems, shear wall frame or braced steel frame could be a point of choice for designer. Therefore, it attracts to review and observe the behavior of these structural systems under seismic effect. Hence, it is proposed to study the dynamic behavior of steel frame with and without knee and eccentricbracings. The purpose of this study is to compare the seismic response of above structural systems.

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