Available online www.ejaet.com

European Journal of Advances in Engineering and Technology, 2018, 5(3): 156-161

Research Article ISSN: 2394 - 658X

Static Nonlinear Analysis Case Study

Sabah Moussaoui and Mourad Belgasmia

Department of Civil Engineering Setif 1University, Algeria
mourad.belgasmia@yahoo.fr

ABSTRACT

The goal of this work is to find the displacement demand of structures using nonlinear static procedure, which is intend to provide a simplified approach for direct determination of nonlinear response behavior of a structure at different levels of lateral displacements. The studied structures are represented by a simple model of bridge and frame; which are modeled as an equivalent single degree of freedom (SDOF) system with a linear elastic stiffness

Key words: Nonlinear, Static nonlinear, Capacity spectrum, Displacement demand, Pushover curve

INTRODUCTION

In this section, the nonlinear pushover procedure is presented in order to be used to verify the structural performance of newly designed buildings and of existing buildings. In particular, pushover analysis can be used for the following purposes: to verify or revise the over strength ratio values, to estimate the expected plastic mechanisms and the damage distribution, to assess the structural performance of existing or retrofitted buildings, as an alternative to the design based on linear-elastic analysis. The goal of this paper is to determine the displacement capacity demand of an equivalent single degree of freedom of bridge and frame.

NONLINEAR STATIC PUSHOVER ANALYSIS

The nonlinear pushover analysis consists of applying monotonically increasing constant shape lateral load distributions to the structure under consideration. The structure model can be either 2D or 3D. 2D analysis of single plane frames can be performed, while for buildings with plan irregularity a complete 3D model is necessary. Given that the nonlinear methods are particularly interesting for existing buildings, which are rarely regular, a 3D model is required in most cases.

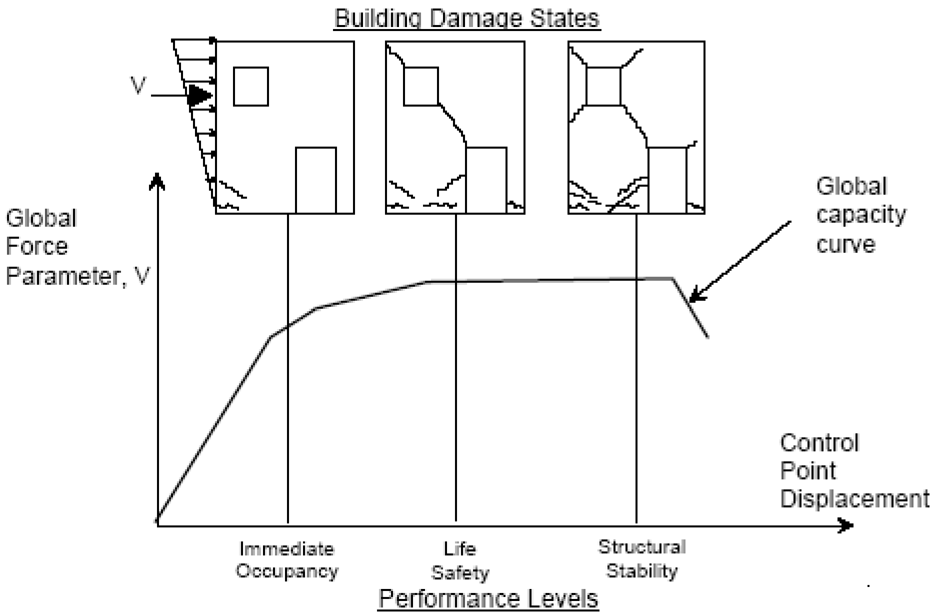

Fig. 1 Capacity curve for nonlinear structure and associated damage states

The nonlinear pushover procedure in EC8 follows the N2 method developed by [4-5]. The N2 method was developed using a shear building model, i.e. a frame model with floors rigid in their planes. Furthermore, vertical displacement is typically neglected in the method and only the two horizontal ground motion components, *x* and *y*, are considered. Extension to the general case of a fully deformable frame is straightforward.
The N2 method consists of applying two load distributions to the frame:
a) a 'modal' (or 'triangular') pattern, that is a load shape proportional to the mass matrix multiplied by the first elastic mode shape,
b) a 'uniform' pattern, that is a mass proportional load shape
The system performance is represented by a lateral force-displacement relationship calculated using a so-called 'pushover analysis.' As illustrated in Figure 1.

DETAILS OF NONLINEAR STATIC PROCEDURES [2]

The Nonlinear Static Procedure (pushover) it consists of the following steps:
Step 1 Develop the pushover curve by graphic representation of the relationship between base shear, V_b, and top displacement.
Step2 Convert the pushover curve to a capacity diagram using:

$$\Gamma = \frac{\sum m_i \Phi_{x,i}}{\sum m_i \Phi_{x,i}^2} \qquad m^* = \sum m_i \Phi_{x,i} \tag{1}$$

The constant Γ controls the transformation from mily degree of freedom (MDOF) to single degree of freedom (SDOF) and back

Step 3 Capacity curve: transformation from response of MDOF to equivalent SDOF

$$D^* = \frac{D_t}{\Gamma} \qquad F^* = \frac{V_b}{\Gamma} \tag{2}$$

The above derivation allows the transformation of the MDOF pushover capacity curves see **Error! Reference source not found.** into pushover curves for the equivalent SDOF system

Step 4 the capacity curve is transformed into capacity spectrum by normalizing the force F^* with respect to the SDOF weight $m^* g$. The resulting capacity spectrum s is shown in figure 2

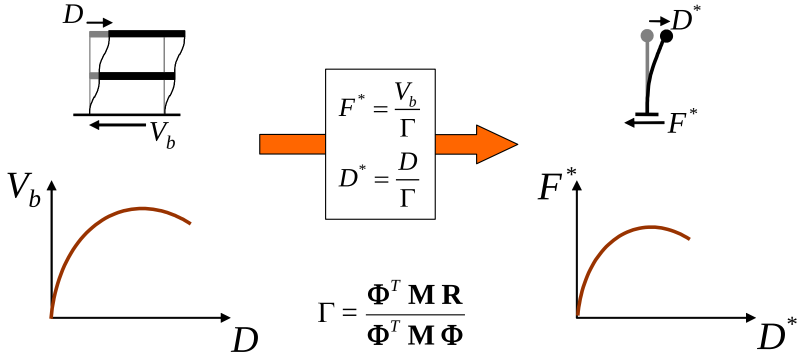

Fig. 2 Capacity curve: transformation from response of MDOF to equivalent SDOF [3]

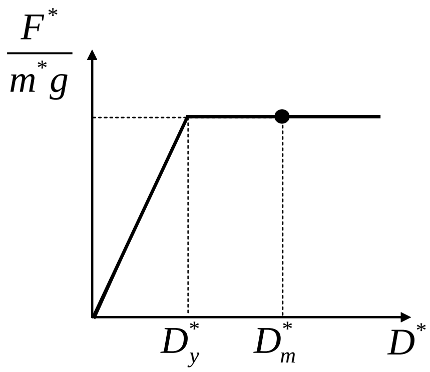

Fig. 3 SDOF capacity spectrum

Step 5 The transformation to the ADRS spectrum (Acceleration Displacement Response Spectrum) is shown in Fig. 3. Lines from the origin represent constant period.

Step 6 determination of target displacement, this later is determined by finding the inelastic demand spectrum of ductility $\bar{\mu}$ that intersects the capacity spectrum in a point corresponding to a capacity ductility $\bar{\mu}$ see figure 4 and figure 5.

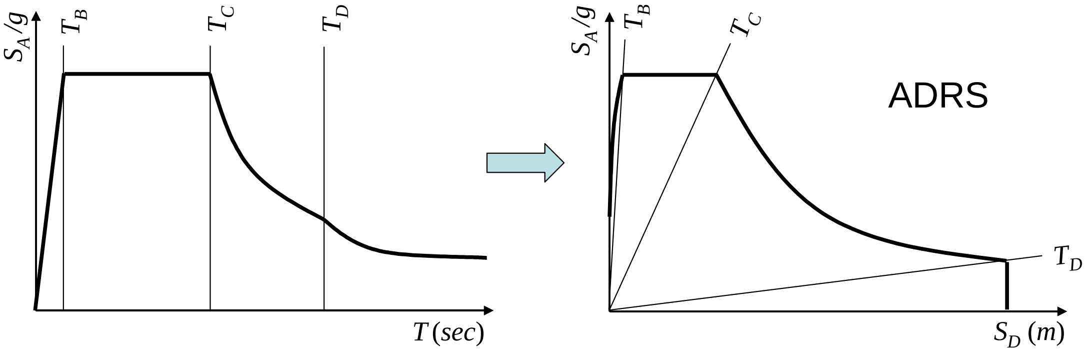

Fig. 4 Transformation to ADRS linear spectrum

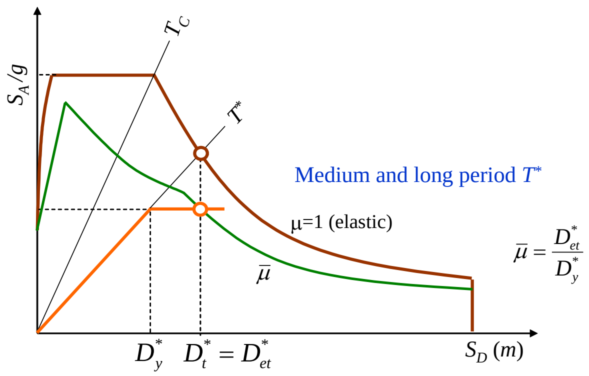

Fig. 5 Capacity and Demand spectra for medium and long period T^*: determination of the target displacement for SDOF

APPLICATION

In this section, we will apply the static nonlinear procedure on two cases frame and bridge, which are modeled as an equivalent single degree of freedom (SDOF) system with a linear elastic stiffness.

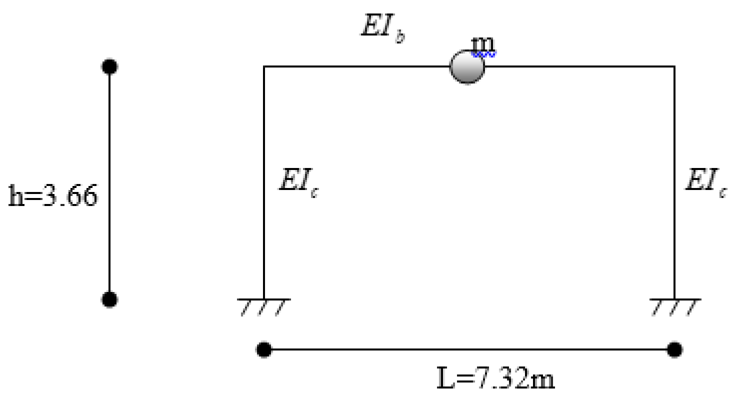

Fig. 6 Frame model

W = 169.9 KN

CHRACATERISTICS OF STRUCTURE

Material is steel
Modulus of elasticity =2.E08 kPa
Yield strength = 81000 kPa
Strain hardening = 0.04
Target displacement = 0.06m

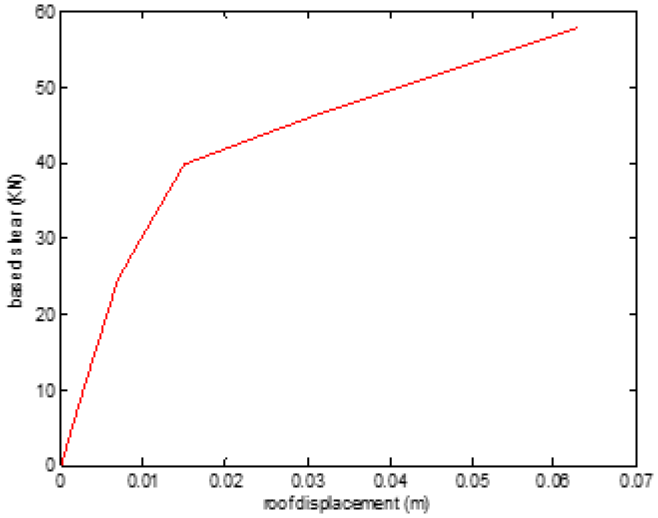

Fig. 6 pushover curve of frame

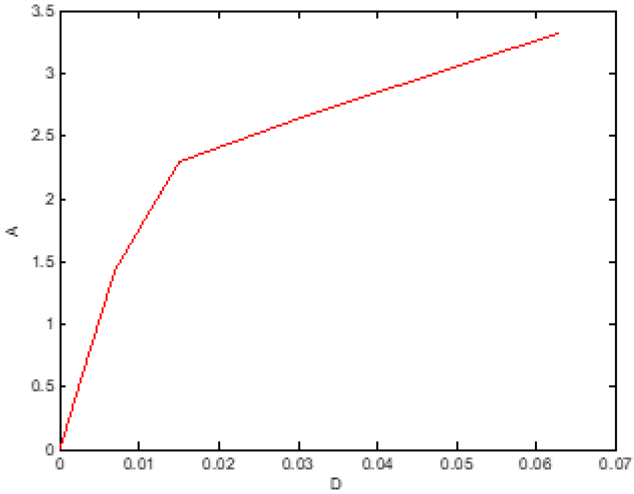

Fig. 7 Capacity curve of frame in ADRS format

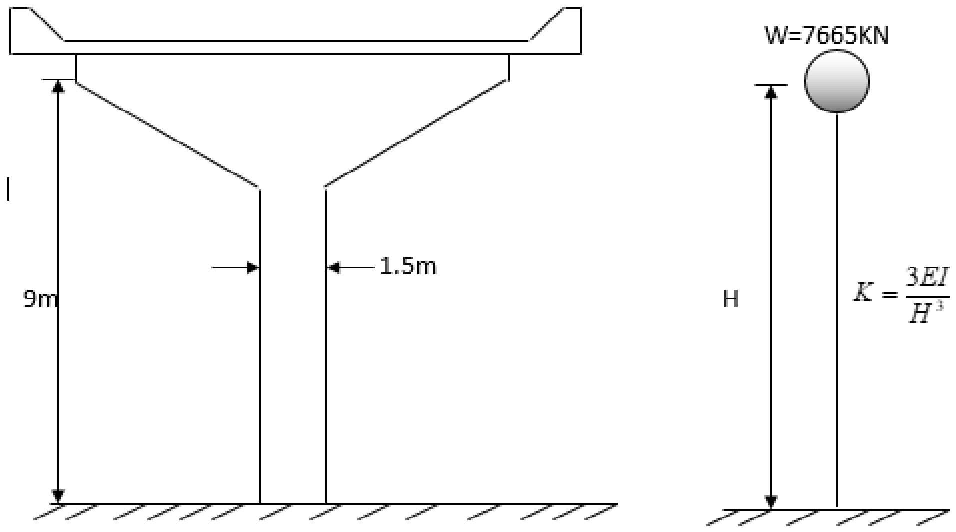

Fig. 8 Bridge model

CHARACTERISTICS OF STRUCTURES

Section of column is circular with diameter D=1.5m, Material is Reinforced Concrete, Weight of superstructure is 7665KN, Self-weight of the column is 576 KN.

For concrete: Compressive strength=10000 kPa, Initial stiffness=2.E07 kPa.

For steel: Modulus of elasticity=2.E08 kPa , Yield strength =500000 kPa, Strain hardening =0.04

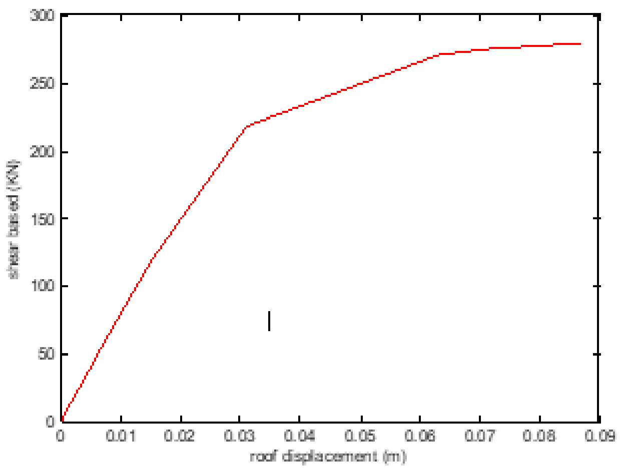

Fig. 9 Pushover curve of bridge

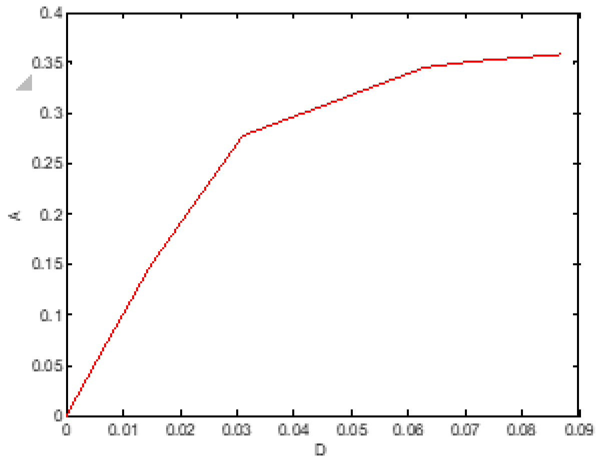

Fig. 10 Capacity curve of frame in ADRS format

The conversion of elastic response (or design) spectrum from the standard pseudo-acceleration A, versus natural period, T format to the ADRS format.

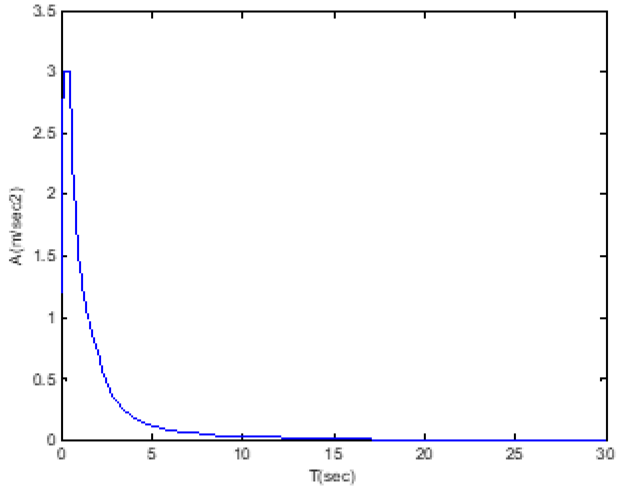

Fig. 11 Elastic response spectrum curve (A,T)

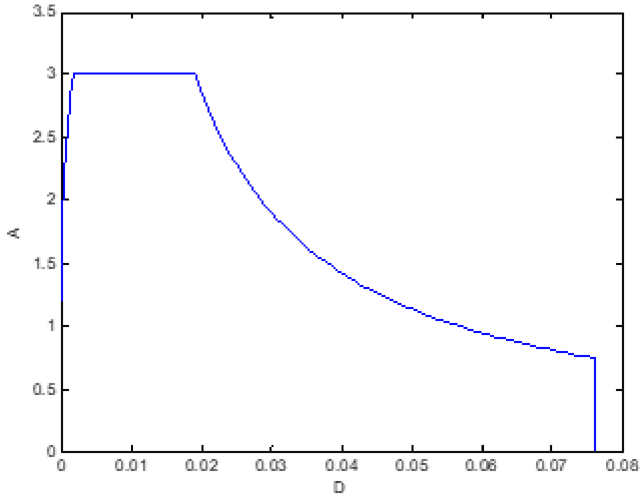

Fig .12 Elastic response spectrum curve in ADRS format

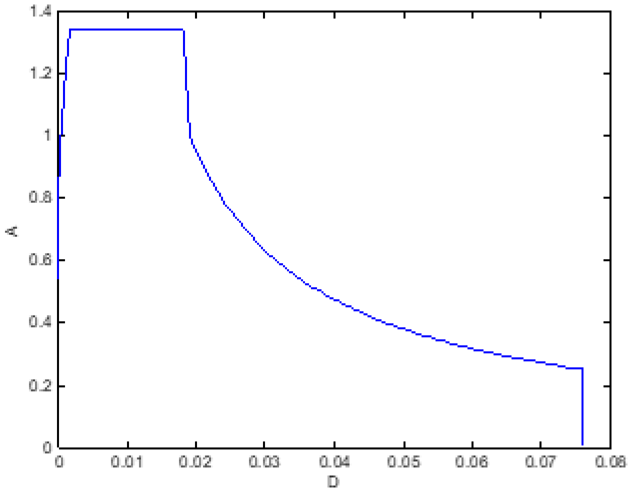

Fig .13 Inelastic response spectrum curve in ADRS format

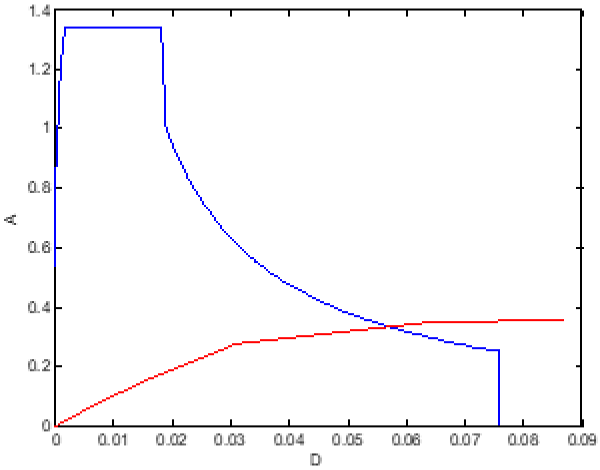

Fig. 14 determination of performance point for frame

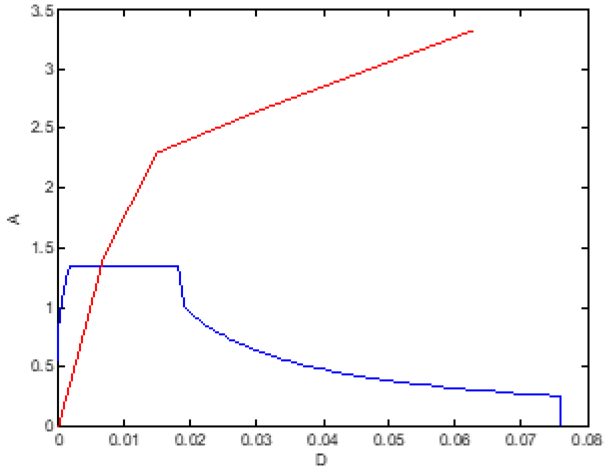

Fig. 15 determination of performance point for bridge

RESULTS AND DISCUSSION

We notice from figure 6 that the value of shear force base of our study is equal to $V_{by} = 39.71 KN$ when we compare it to the theoretical result given by [1] which is equal to $V_{by} = 39.26 KN$, these two value are very close each other. From figure 9 The base shear bridge is about 269.5 kN which correspond to 0.061m.
thing which is remarkable is the fact of deducing results very quickly, thanks to the graphic force of the method as shown in the figures 14 and 15.

CONCLUSION

From Figures 14 and 15 we can deduce the studied structures (bridge and frame) resist to the earthquake because the intersection between the capacity curve and response spectrum for both bride and frame; this means that can absorb the earthquake.

There are no doubt advantages in using nonlinear analysis vs using linear method. Most importantly, nonlinear analyses allow designer to follow more closely the nonlinear response of building and bridge to the design earthquakes corresponding to the ultimate and collapse limit states.

REFERENCES

[1] Anil K Chopra and Rakesh K Goel, *Capacity –Demand-Diagram Methods for Estimating Seismic Deformation of Inelastic Structures: SDF Systems*, Prentice Hall, **1999**.
[2] Anil K Chopra and Rakesh K Goel, *A Modal Pushover Analysis Procedure to Estimate Seismic Demands for Building: Theory and Preminary Evaluation*, Prentice Hall, **2001**.
[3] M Belgasmia and S Moussaoui, Comparison Between Static Nonlinear and Time History Analysis using Flexibility-Based Model for an Existing Structure and Effect of Taking into Account Soil Using Domain Reduction Method for a Single Media, *KSCE Journal of Civil Engineering*, **2015**, 19(3), 651-663.
[4] P Fajfar, Capacity Spectrum Method Based on Inelastic Demand Spectra, *Earthquake Engineering and Structural Dynamics*, **1999**, 28, 979-993.
[5] P Fajfar, Strucural Analysis in Earthquake Engineering A Breakthrough of Simplified Non-Linear Methods, *Proceedings of 12th European Conference on Earthquake Engineering*, **2002**, 843.