The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 2021

Volume 13, Pages 45-50

ICBASET 2021: International Conference on Basic Sciences, Engineering and Technology

# The Review of Algerian Building Seismic Code(RPA) in Seven Points Compared to American and European Codes

**Boulaouad ABDERRACHID**
Mohamed Boudiaf University of M'sila

**Belagraa LARBI**
Mohamed Boudiaf University of M'sila

**Bouglada Mohamed SALAH**
Batna University

**Abstract**: The first Algerian seismic code named "Règles Parasismiques Algériennes" (RPA, 1981) was established after the terrible 1980 Chlef earthquake (M 7.3), which caused a great disaster. Since this catastrophic event a continually reviewed versions, in particular after the 2003 Boumerdes earthquake (M 6.8) which caused an immense hazardous loss in human lives and construction damages (2000 seath) persons killed). This harmful event urged on to a serious review leading to the last and present version of such standard earthquake (RPA, 2003) with fundamental modifications concerning many important fields. The points revealed in the present review research study are the classification of sites, design methods, design spectrum, ductility concept, behavior factor, self-steady structures and dual systems (frames and walls). The outcome of the study here in is summarized as a brief review that could be a contribution to enrich the Algerian seismic regulation (RPA) with a focus on these seven important points selected as they seem to present some anomalies or deficiencies detected and treated on the basis of two main parameters. Firstly, we consider the damage observed after the 2003 Boumerdes earthquake; later in the second step, a comparison is made with other codes practiced over the world alike the European EC8 or the American Uniform Building Code, 1994 (UBC 94) or the 2000 NEHRP Provisions.

**Keywords**: Algerian seismic code (RPA), Design methods, Spectrum, Behavior factor, Dual system.

## Introduction

In countries subjected to frequent severe earthquakes, such as Algeria, attention must be focused on seismic design, and seismic codes must be frequently revised to be more improved. The first Algerian seismic code named "RèglesParasismiquesAlgériennes" (RPA) was born only one year after the terrible 1980 Chlef earthquake (M 7.3), which caused a great disaster (big damage and loss of about 3500 lives). Since that, this code is continually reviewed. Recently, other earthquakes have occurred in some regions of Algeria, particularly the 2003 Boumerdes earthquake (M 6.8) which killed more than 2000 persons and caused an immense economic loss. This event egged on to serious review of the seismic design code leading to the last and present version of this regulation known as "RPA 2003" with fundamental modifications concerning many important fields (Algerian Ministry of Inhabitants, 2003).

This paper is a brief review of the Algerian seismic regulation (RPA) with a focus on seven important points which have been selected as they seem to present some anomalies or deficiencies which are detected and treated


- Selection and peer-review under responsibility of the Organizing Committee of the Conference

on the basis of two main parameters: the damage observed after the 2003 Boumerdes earthquake and the comparison with other codes over the world such as the European EC8 (Code, 2005).

The points concerned by this study are: site classification, design methods, response spectrum, ductility concept, behavior factor, self-steady structure and dual system (frame and wall).

**Site Classification**

The RPA classifies the soils in only four categories of sites according to their mechanical properties whereas the EC8 classifies them in seven categories according to the average shear wave velocity if it is available or the number of blows required for a standard penetration test (SPT) if not. Table 1 gives a comparison between the two cited codes concerning the site classification.

Table 1. Site classification according to RPA and EC8 codes

| Eurocode8 Category | site | RPA 2003 Category | site |
|---|---|---|---|
| A | rocky site | S1 | rocky site |
| B | firm site | S2 | firm site |
| C | deep site of moderately dense sand and gravel or moderately stiff clay | | |
| D | sol site of medium to poor density without cohesion | S3 | loose site |
| E | sol site with a superficial layer of alluvium resting on a more steep material. | | |
| S1 | site composed of or containing a clayey layer more than 10 cm thick. | S4 | very loose site |
| S2 | liquefiable soil site of sensitive clay or other soil not mentioned previously. | | |

One can note that the RPA classification is not accurate. More categories of sites must be added for a better identification of instable or liquefiable soils.

## Design Methods

During strong motions, the forces and displacements induced by seismic excitations can exceed the elasticity limit of structural elements causing, thus, nonlinearities which may lead to collapse. In the classical method, known as force-based (FB) or acceleration-based (AB) method, these nonlinearities are taken into account by a reduction of the forces derived from an elastic analysis procedure while the displacements are approximately checked at the end (Pinho et. al., 2007).

The Algerian seismic code (R.P.A.), amongst others, is based on the conventional (FB or AB) method which uses the acceleration spectra (Algerian Ministry of Inhabitants, 2003). After the terrible Northridge 1994 earthquake and similar further earthquakes (Kobe 1995, Kocaeli 1999 and Boumerdes 2003), this classical approach proved to be unsuccessful in the prevention of earthquake consequences. The use of more perfect approaches that clearly takes into account the nonlinearities of structures became necessary (Pinho et. al., 2007). In this perspective, the "Performance Based Seismic Design" was recently developed and is more and more used for three reasons:

It seems to be more realistic and accurate than the conventional method as it takes directly into account the displacement and permits the evaluation of the behavior expected on each structural element. It is more economical as it provides a structure that meets the requirements for the several limit states. It may be a good alternative to the nonlinear time-history (exact) method which is practically complex as it is governed by difficult conditions and tools.

This procedure consists to compare the capacity of a structure with a target displacement derived from a pushover analysis. The nonlinearities of materials are taken into account by a combination of the nonlinear static (pushover) analysis and the response spectrum approach. The applications of such an approach are: the capacity spectrum method of ATC 40 (ATC, 1996), the nonlinear static procedure of FEMA 356 (American Society of Civil Engineers, 2000) and the N2 method (Fajfar, 1999) implemented in the Eurocode8 (Code, 2005). In these methods, the pushover analysis of a multi-degree-of-freedom (MDF) model is combined with the response spectrum analysis of an equivalent single-degree-of-freedom (SDF) system.

The most important steps of a simplified method are given in (Berra et. al. 2019). This new design concept uses the displacement as a key parameter in damage control on the basis of performance objectives which associate security with economy. This procedures is very effective for application to seismic rehabilitation of structures and is gradually extended to the design of new constructions. So, it is very relevant to the evaluation of the Algerian housing stock which consists mainly of Reinforced Concrete (RC) self-steady frames. A large part of this stock may not satisfy the limits imposed to such constructions by the "RPA 2003" code as they have been constructed before its advent. This new procedure must be incorporated in the RPA which does not refer to it.

**Response Spectrum**

In the RPA, the response spectrum called "normalized acceleration spectrum" Sa/g isgiven by the following equations:

$$\frac{S_a}{g} = \begin{cases} 1.25 A\left[1+\frac{T}{T_1}\left(2.5\eta\frac{Q}{R}-1\right)\right] & if \quad 0 \le T \le T_1 & \text{(1a)} \\ 3.125\eta\, A\,\frac{Q}{R} & if \quad T_1 \le T \le T_2 & \text{(1b)} \\ 3.125\eta\, A\left(\frac{Q}{R}\right)\left(\frac{T_2}{T}\right)^{\frac{2}{3}} & if \quad T_2 \le T \le 3.0\,s & \text{(1c)} \\ 3.125\eta\, A\left(\frac{Q}{R}\right)\left(\frac{T_2}{3}\right)^{\frac{2}{3}}\left(\frac{3}{T}\right)^{\frac{5}{3}} & if \quad T \ge 3.0\,s & \text{(1d)} \end{cases}$$

where: A, T, T1, T2, Q, R and η represent, respectively, the acceleration coefficient of zone, the fundamental period, the characteristic periods, the quality factor, the behavior factor and the damping correction factor given in terms of the damping ratio ξ, by Eq. 2:

$$\eta = \sqrt{7/(2+\xi)} \ge 0.7 \quad (2)$$

First of all, one can note that the four overloaded equations (Eqs. 1a, 1b, 1c and 1d) of the RPA are very complex compared with the three simple equations (Eqs. 3a, 3b and 3c) of the UBC 94 (Chopra, 1995) and the two equations (Eqs. 4a and 4b) of the NBCC 95 (Chopra, 1995) for example. The acceleration spectra A/g of UBC 94 (for soil profile S1) and NBCC 95 (for zonal velocity ratio υ = 0.4) are given, respectively, by the following:

$$\frac{A}{g} = \begin{cases} Z + T_n & if \quad 0 \le T_n \le 0.15\,s & \text{(3a)} \\ 1 & if \quad 0.15 \le T_n \le 0.39\,s & \text{(3b)} \\ \frac{0.39}{T_n} & if \quad T_n \succ 0.39\,s & \text{(3c)} \end{cases}$$

$$\frac{A}{g} = \begin{cases} 1.2 & if \quad 0.03 \le T_n \le 0.427\,s & (4a) \\ \frac{0.512}{T_n} & if \quad T_n \succ 0.427\,s & (4b) \end{cases}$$

Where Z is the seismic zone factor and Tn the natural period of an SDF system (Chopra, 1995). On top of that, the present formulas of the RPA usually lead to a negative slope of the first branch (i.e. range of short periods) while it must be a positive one as it is the case in either seismic design spectra or computed ones (Fig. 1). This anomaly has been already highlighted by Berra and Boulaouad (Berra et. al. 2019).

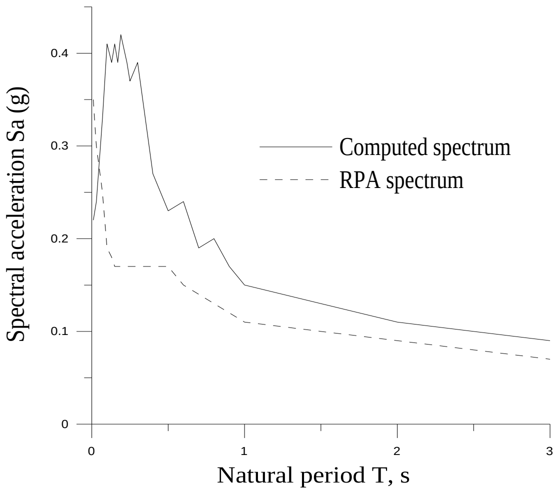


Figure 1. (a) RPA spectrum and Computed one

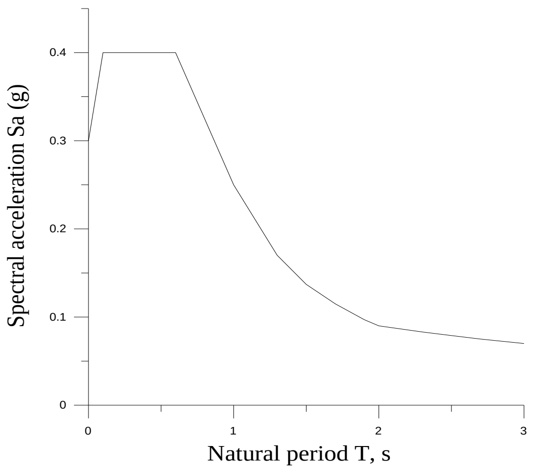


Figure 1. (b) EC8 Type I spectrum

The third and last defect which may be observed is the fact that the RPA code gives one and only design spectrum for all regions of Algeria whereas it must give specific spectra for particular regions such as the district of Algiers the capital which is often subjected to strong motions and groups most people of the state.

**Ductility Concept**

The Eurocode 8 gives 3 classes of structures corresponding to 3 levels of ductility: low, medium and high (Code, 2005). The RPA comments about ductility are general and vague without any specification of levels or classes. But, according to the requirements imposed to the construction, only one level is considered corresponding, likely, to the third class of the EC8 (high level). On top of that, the RPA gives one and only value of ductility for a multistory structure, not taking into account the reduction of ductility in elevation.

**Behavior Factor**

In order to account for the inelastic behavior of the structure, the seismic codes have introduced the well known behavior factor, noted R (or q in the Eurocode 8). This factor is also called reduction factor too as it is used to reduce the earthquake load. The values attributed to this parameter are subject to the following comments: They are given arbitrarily without any scientific basis. They depend only on the Lateral Loading Resisting System (LLRS) type of the building. They are often higher than those given by other codes. In the case of frame structure with masonry for example, the value given in the EC8 is 1.5 while it is 3.5 in the RPA. Consequently, they seem to be overestimated as shown in Figure 2 where a comparison is made between the values given by the RPA, the ATC 40, the FEMA 356 and the time history (TH) methods (Fig. 2). This fact has been confirmed by the damage observed on this type of structure after the 2003 Boumerdes earthquake and lately by the works of Berra and Boulaouad (Berra et. al. 2019). Last but not least, they do not take into account the particularity of some regions of high sensibility to earthquakes, such as Algiers, where the life-safety criterion takes precedence over the economical one. In such a case, the incursion in the plastic domain must be strictly limited and consequently R must be reduced.

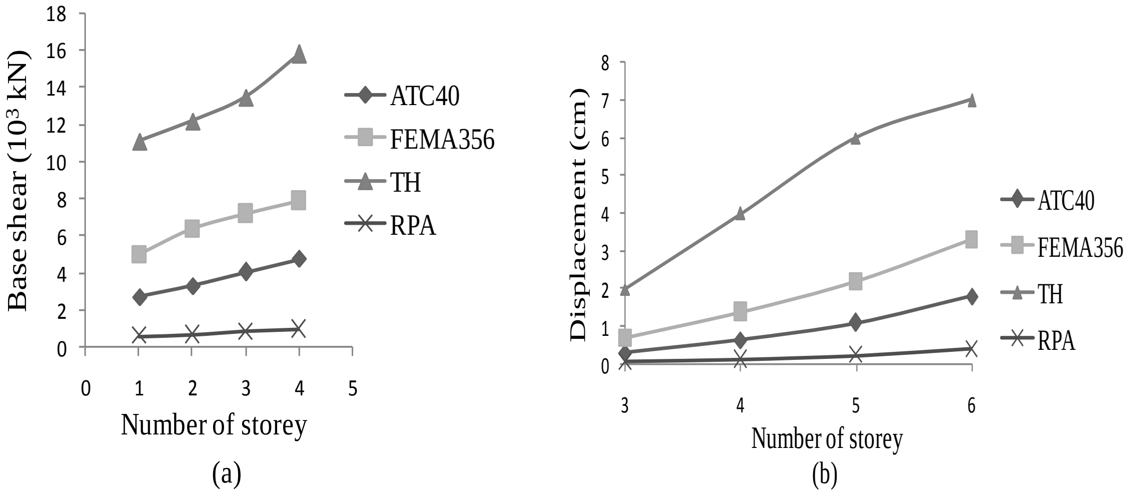


Figure 2. RPA, ATC, FEMA and exact methods: (a) base shear and (b) displacement

**Self-Steady Structure**

During the Boumerdes 2003 earthquake, a large proportion of the self-steady structures collapsed or were severely damaged (Figure 3). The lesson learned from this relevant information is that the Algerian seismic regulation must be revised so that the use of such structures must be prohibited in zone of very high seismicity (zone 3) and their number of stories restricted to 3 or 4 in the other zones. The type of structure recommended instead of the self-steady frame is the combined system (wall and frame).

Figure 3. Shear collapse due to the interaction between masonry and frame in Boumerdes town.

**Dual System (Frame and Wall)**

The RPA does not give any indication concerning the proportion of the different elements. Attention must be focused on the proportion of walls to insure a minimum of stiffness.

## Conclusion

In order to improve the Algerian seismic code (RPA) which presents many deficiencies, seven points have been selected and treated on the basis of two main parameters: the damage observed after the 2003 Boumerdes earthquake and the comparison with other codes. Relevant observations have been made and beneficial suggestions have been given. Other items can be pointed and treated in the same manner.

## Acknowledgements

The authors would like to thank technical staff of the civil engineering departement, faculty of Technology, Med Boudiaf University, Algeria. for the help given to accomplish the present research work

## Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

## References

Algerian Ministry of Inhabitants (2003). Règles Parasismiques Algériennes, C.G.S, Algeria.

Code, P. (2005). Eurocode 8: Design of structures for earthquake resistance-part 1: general rules, seismic actions and rules for buildings. *Brussels: European Committee for Standardization*. Brussels, Belgium.

Pinho, R. (2007). Nonlinear dynamic analysis of structures subjected to seismic action. In *Advanced earthquake engineering analysis*. Springer.

Applied Technology Council (ATC) (1996). Seismic evaluation and retrofit of concrete buildings. *Report No. SSC 96-01: ATC-40, 1*.

American Society of Civil Engineers. Prestandard and commentary for the seismic rehabilitation of buildings (FEMA356). *Washington, DC: Federal Emergency Management Agency*, *7*(2).

Fajfar, P. (1999). Capacity spectrum method based on inelastic demand spectra. *Earthquake Engineering & Structural Dynamics*, *28*(9), 979-993.

Berra, I., & Boulaouad, A. (2019). Algerian seismic code improvement by proposition of a specific design spectrum for Algiers City. *Asian Journal of Civil Engineering*, *20*(7), 925-932.

Chopra, A. K. (1995). *Dynamics of Structures: Theory and Applications to Earthquake Engineering*. Prentice Hall.

## Author Information

**Boulaouad ABDERRACHID**
Department of Civil Engineering, Faculty of Technology,
Mohamed Boudiaf University of M'sila**,** M'sila, 28 000, Algeria

**Belagraa LARBI**
Department of Civil Engineering, Faculty of Technology,
Mohamed Boudiaf University of M'sila
M'sila, 28 000, Algeria

**Bouglada Mohammed SALAH**
Department of Civil Engineering, Faculty of Technology,
Batna2 University, Batna, 05000, Algeria
Contact e-mail:m.bouglada@univ-batna2.dz

**To cite this article:**

Abderrachid, B., Larbi, B., & Salah, B.M. (2021). The review of Algerian building seismic code(RPA) in seven points compared to American and European codes. *The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 13*, 45-50.