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ALGERIAN SEISMIC BUILDING CODE: MAIN FEATURES OF THE NEW DRAFT RPA 2015

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Abstract

Algeria is an earthquake prone area and is periodically stricken by seismic events that could trigger important human and material Losses such as the "21st May, 2003 Boumerdes Earthquake (Mw 6.8)" which resulted in more than 2300 dead and 10 000 injured people and more than 3 billions US Dollars of damage. To reduce the earthquake damage, one of the main countermeasures is, of course, the strict application of the requirements of the seismic code and other building regulations. The Algerian experience in the field of seismic risk reduction has begun after the major earthquake of EL Asnam (Mw 7.2) of 10th of October 1980 which resulted in the death of 3000 people and about 3 billions of US Dollars of damage. Immediately after this dramatic event, the government has enacted the first national seismic code entitled “Règles parasismiques algeriennes RPA 81”. Since then, this code has been periodically updated, taking into account the continuous progress of earthquake engineering research at national and international levels and the specific experience of Algerian professionals (academia and practitioners). In this framework, a new draft of the seismic building code (RPA 2015) is in way to be finalized by an ad-hoc working group, after more than five years of efforts. In the present paper, the main features and contents of this draft document are presented.

Keywords: Algerian seismic code, earthquake resistant regulations, Seismic risk reduction

1. Introduction

The Algerian experience in the field of Seismic Risk Reduction has begun after the major earthquake of El Asnam of 10th of October 1980 (3000 dead people and near 3 billion of US Dollars of damage).

During the last 35 years, our country, its population and its economy have greatly suffered from adverse consequences of ten earthquakes (M_w over 5.3) and among them two very damaging ones:
- El-Asnam (Oct. 10, 1980, M_w = 7.2)
- Boumerdes-Alger (May 21, 2003, M_w= 6.8)

Having acquired a very valuable experience, particularly after the strong earthquake which has stricken the area of El Asnam in October 10th , 1980, the Algerian Government has adopted since May 19, 1985, a national plan of prevention and management of seismic risk and other natural and technological disasters.

This plan has been updated and reinforced in July 2003 after the lessons learned from different earthquakes and other disasters occurred since that period and particularly the huge floods of Bab El Oued / Algiers in November 10th, 2001 (900 dead people) and the dramatic Boumerdes earthquake of 21 May, 2003 (2300 dead people and more than 3 billions of US Dollars of damage) .

Knowing that the main way to reduce the seismic risk is the seismic design and construction, and immediately after the dramatic El Asnam earthquake, the government has enacted the first national seismic code entitled “Règles parasismiques algeriennes RPA 81” [1]. Since then, this code has been periodically updated, taking into account the continuous progress of earthquake engineering research at national and international levels and the specific experience of Algerian professionals (academia and practitioners) [1].

In this framework, a new draft of the seismic building code (RPA 2015) [2] is in way to be finalized by an ad-hoc working group, after more than five years of efforts. In the present paper, the main features and contents of this draft document will be presented.

2. Historical evolution of the Algerian seismic code

A draft code for earthquake resistant design of new buildings was developed in June 1978 with the assistance of Stanford University; it was based on the American codes (UBC 73 and 76) [3], [4]. The seismic design forces are obtained with equivalent static approach analysis; seismological data provided seismic hazard assessment and seismic zoning map. Seismic design of the building was required after the El Asnam earthquake of 10 October1980 (M 7,2) with the enforcement of the code in 1981 (RPA 81) followed by a slight revision in 1983 (RPA 83) dealing mainly with detailing of structural components.

A second revision of the code has been undertaken in 1988 (RPA 88) with some improvements as a small informative appendix for guidance in Modal Spectral Analysis (if needed), new requirements for RC short columns and lintels in dual systems, detailing of RC beam-column joints etc…

The third revision in 1999 resulted in a more complete and understandable document organized in ten (10) chapters (instead of 4, formerly) including three specific material chapters (dealing with detailing and additional requirements for reinforced concrete, steel and tied masonry structures) and one chapter dealing with foundations, retaining walls and geotechnical hazards. The document comprises also a modification and an improvement of the equivalent static approach and a larger introduction of the dynamic approach (modal analysis) with design response spectra (4 spectra instead of 2 formerly) similar to those of the Eurocode 8 (EC 8) [5]. Some improvements inspired from UBC 97 [6], as new empirical period formula, were also included in this new version.

The Fourth revision took place after the Boumerdes-Zemmouri earthquake of 21 may, 2003 (M 6,8). In the resulting document called RPA 1999/2003, there is an extension of the seismic zone III of high seismicity to a larger zone along the coast in the northern part of the country and the inception of an intermediate seismic zone (the zone IIb) between the former zones III and II (henceforth called IIa).The “RC moment resisting frames with masonry infill walls” were limited to buildings with two stories maximum in the seismic zone III and with five stories in the low seismic zone I, and the use of shear walls is strongly recommended. There are also new and more restrictive requirements dealing with soft stories (see fig. 6).

3. Presentation of the new draft "RPA 2015"

3.1 Objectives

The present regulations, that are essentially applicable to current buildings and constructions, aim at giving an acceptable protection for human lives and constructions against the adverse effects of seismic actions through an appropriate design and detailing.

For current constructions, the aimed objectives are to provide the structure with a sufficient strength and stiffness in order to limit the non-structural damages and to avoid the structural ones through an essentially elastic behavior of the structure while facing a relatively frequent moderate seismic event.

An adequate ductility and capacity of energy dissipation is required to allow the structure to undergo inelastic displacements with limited damages and no collapse or loss of stability while facing one rare major seismic event.

For certain important constructions, the aimed protection is even more severe since the construction should stay in operation immediately after a major seismic event.

3.2 Global Contents

The present regulations, that are essentially applicable to current buildings and constructions, aim at giving an acceptable protection for human lives and constructions against the adverse effects of seismic actions through an appropriate design and detailing.

The document is structured in eleven (11) chapters and four (4) annexes, which are:

Chapter I : General
Chapter II : General rules for conception
Chapter III : Classification Criteria
Chapter IV : Analysis Methods
Chapter V : Security Verification
Chapter VI : Additional requirements and non-structural components
Chapter VII : Reinforced Concrete Structures
Chapter VIII : Steel Structures
Chapter IX : Buildings with bearing tied (confined) masonry
Chapter X : Timber Buildings
Chapter XI : Soil and Foundations
Annex 1 : Seismic Zoning of different communes of National Territory
Annex 2 : Recommendations for geotechnical investigations
Annex 3 : Seismic Isolation
Annex 4 : List of main seismic events (since 1365)

The six (6) first chapters deal with general recommendations and requirements for seismic design, dimensioning and verification of resistant and secondary structures.

The four (4) following chapters VII, VIII, IX and X, deal with detailing and complementary requirements to ensure that the different building systems and material used can provide necessary ductility and resistance as assumed in seismic design using a reduction factor (or a behavior coefficient) R. The last chapter (XI) deals with foundations design, slope stability, liquefaction, and retaining walls.

3.3 Design Methods of RPA Draft Document

In the document, are described and developed essentially the 2 allowed or recommended design methods that are the equivalent static method and the modal response spectrum analysis method.

3.3.1 Equivalent Static Design Method

In this method a global base shear force V_{base} is computed with the previously given formula (Eq.1) and linearly distributed through different levels of stories (generally concentrated on the floors - see Eq. 2 and fig.1). For buildings where the fundamental period is more than 0.7 sec, a conventional force Ft is added at their top to account for high modes influence.

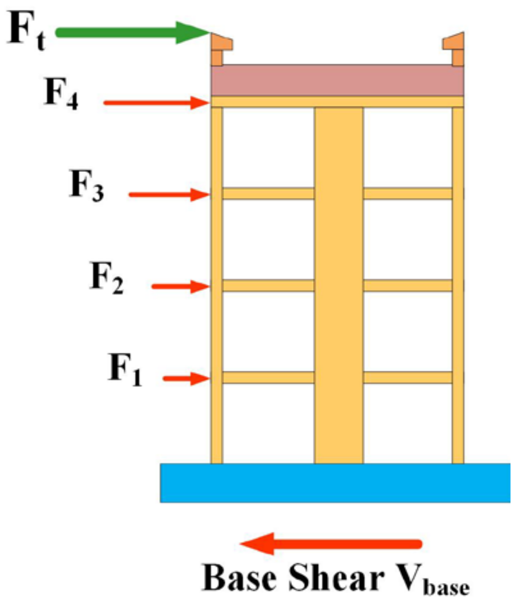

Fig. 1 – Distribution of seismic forces

$$V = 0.8.\frac{A.S.I.D.Q}{R}W \qquad (1)$$

With: R / Q ≥ 1.5 and V ≥ 0.1 A I W

$$F_i = \frac{(V_{base} - F_t)Wh_i}{\sum_{j=1}^{n} W_j h_j}$$
$$F_t = 0.07TV(T \succ 0.7\,\mathrm{sec}) \qquad (2)$$
$$F_t = 0(T \prec 0.7\,\mathrm{sec})$$

The different components of (Eq.1) are defined hereafter:

- A : Coefficient of zone acceleration
- S : Site coefficient
- I : Coefficient of importance
- D: Average dynamic amplification factor given in consideration of site category, damping correction factor (η) and the fundamental period of the structure (T).
- R : Global behavior coefficient of the structure
- Q : Quality factor
- W Total Weight of the structure (W = ∑Wi , with Wi = $WG_i + \beta WQ_i$)

- A: Coefficient of zone acceleration

This coefficient is given in fraction of the gravity acceleration and results from the seismic hazard map of 500 years return period (see hereafter in Fig.2 the updated map of isoseismals, based on historical seismicity catalog and the results of regional seismic hazard investigations performed since 1984). For current buildings of importance group 2 (as residential or office buildings), the basic design acceleration for a given site is theoritically the nearest isoseismal of 500 years return period. However, for more convenience the communes of the national territory are distributed in four (4) seismic zones (see Fig.3 and Table 1 below) to which a mean acceleration coefficient is attributed for current buildings (Group of importance 2). For higher or lesser importance groups of usage the coefficient is multiplied by the coefficient of importance I (see Table 2).

This new zoning map (fig. 3) of the seismic code has been established accounting for, besides the updated historical seismicity catalogue, the results of different regional seismic hazard assessments that have been performed since 1984, in the northern part of the country based on all necessary data including seismotectonics and strong motion records of the last important events, including the 21, May 2003 Boumerdes earthquake.

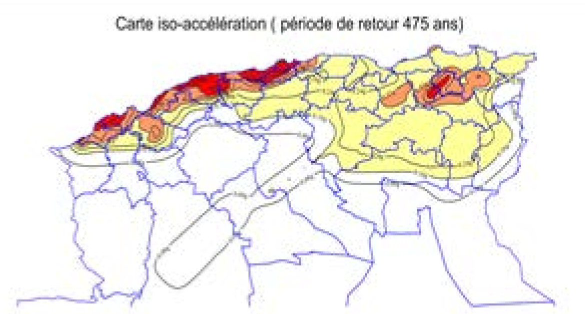

Fig. 2 – 500 years return period seismicity map

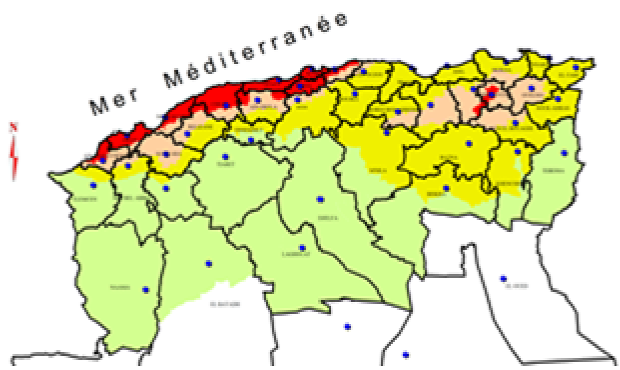

Fig. 3 – New Macrozoning map of Algeria

The coefficient of zone acceleration A is given in Table 1 in consideration of seismic zone

Table 1– Coefficient of zone acceleration A

Zone	**I**	**IIa**	**IIb**	**III**
A	0.10	0.15	0.25	0.35

- I : Coefficient of importance : it is given in Table 2 following the importance group

Table 2 – Values of coefficient of importance I

Importance Group	**1A**	**1B**	**2**	**3**
I	1.40	1.20	1	0.80

- S: Site Coefficient: It varies from 1 to 1.3 following the site category (see Table 3)

Table 3– Values of site coefficient

Site	S1	S2	S3	S4
S	1.00	1.10	1.20	1.30

- D: Average dynamic amplification factor

$$D = \begin{cases} 2.5\eta & 0 \le T \le T_2 \\ 2.5\eta\left(\frac{T_2}{T}\right) & T_2 \le T \le T_3 \\ 2.5\eta\left(\frac{T_2 T_3}{T^2}\right) & T \ge T_3 \end{cases} \quad (3)$$

$$\eta = \sqrt{7/(2+\xi)} \ge 0.7 \quad (4)$$

ξ (%) : Critical damping ratio

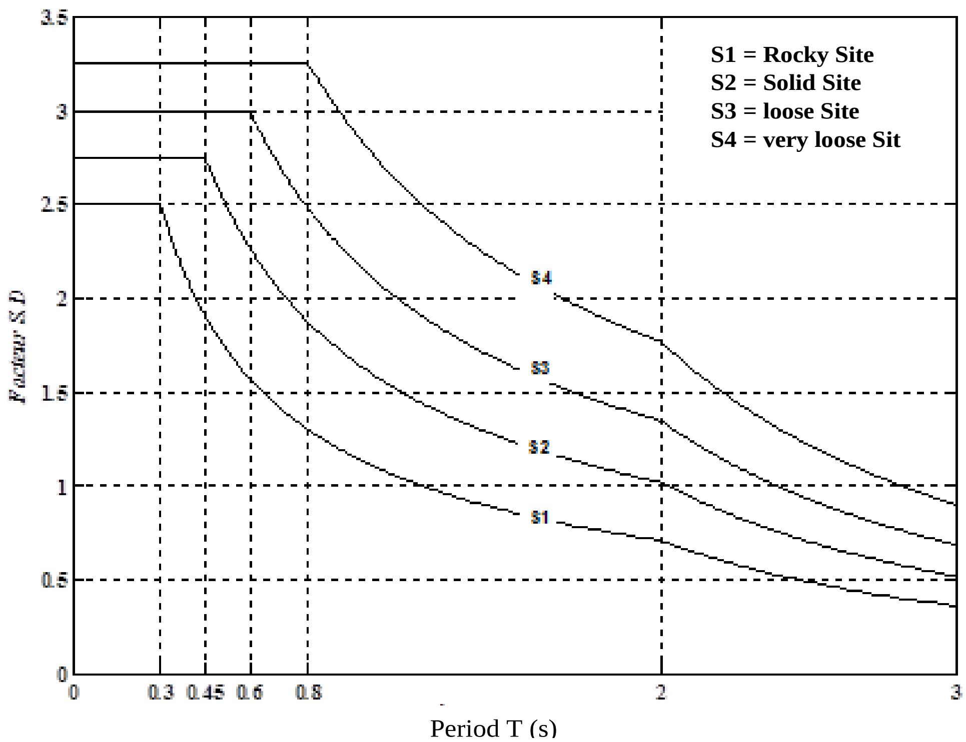

Fig. 4 – Average Dynamic Amplification Factor D = f (T) (factored with S; with ξ = 5%)

- Global behaviour coefficient of the structure R:

In the draft code are listed 27 lateral force resisting systems for which the value of R is given going from R=2 for the less ductile and/or reliable systems to R=6 for the ones with very good expected performance. (see Table 5 for R values for RC systems).

- Quality factor Q

This quality factor varying from Q=1 to Q=1.4 account for quality aspects as symmetry, redundancy, hyperstaticity and regularity. It supplements R by giving penalties to less reliable systems. The real (or effective) behavior factor is then R/Q.

This quality factor has been introduced for the first time by Professors H. Shah and Tsutty (from Stanford University) in the first Algerian seismic draft code that has been enacted as “RPA 81” [7].

The same idea to modulate the value of “R” in accounting for respecting or not the previously mentioned quality criteria has been also formulated by some other seismic codes as “Eurocode 8” (Paragraph 5.2.2.2. Behaviour factors for lateral seismic actions) [5].

The value of Q is given by:

$$Q = 1 + \sum_{q=1}^{4} P_q \tag{5}$$

P_q is the penalty (equal to 0.1) given when the concerned quality criteria is not respected (cf. Table 4).

The quality criteria to be verified are:

1-Minimum conditions of lateral resisting files

- For frames or mixed frame/shear walls systems: at all levels it must be at minimum 3 spans And the ratio between the lengths of 2 neighbouring spans do not exceed 1.5
- For walls systems, each file of walls must have at least one pier with ratio height/span not being more than 0.67 or must have 2 piers with the same ratio not more than 1.

2-Redundancy in plan: Each story must have at least 4 files of frames or mixed frame/walls in the direction of lateral forces considered. These lateral resisting files must be placed as symmetrically as possible with a ratio between maximum and minimum space between them not more than 1.5.

3-Regularity in plan: The structure has to be classified as regular in plan (as defined in the code)

4-Regularity in elevation: The structure has to be classified as regular in elevation (as defined in the code)

Table 4 – Values of penalties P_q

Criteria «q»	Pq	
	Observed	**Not observed**
1-Minimum conditions of lateral resisting files	0	0.10
2-Redundancy in plan	0	0.10
3-Regularity in plan	0	0.10
4-Regularity in elevation	0	0.10

3.3.2 Modal response spectrum analysis method.

$$V = \sum_{i=1}^{n} \left(\frac{S_a}{g} \right) . \alpha_i . W_r \tag{6}$$

(Sa /g) : Design response spectrum
a : Modal participation factor

W_T : Total Weight of the structure

$$\frac{S_{ad}}{g}=\begin{cases} AIS\left(1+\frac{T}{T_1}\left(\frac{2.5\eta Q}{R}-1\right)\right) & 0 \prec T \leq T_1 \\ \frac{2.5\eta AISQ}{R} & T_1 \prec T \leq T_2 \\ \frac{2.5\eta AISQ}{R}\left(\frac{T_2}{T}\right) & T_2 \prec T \leq T_3 \\ \frac{2.5\eta AISQ}{R}\left(\frac{T_2 T_3}{T^2}\right) & T \succ T_3 \end{cases} \qquad (7)$$

4. Evolution of the seismic code (2003 vs. 2015)

In addition to making the different requirements more understandable and clear, some legitimate or reasonable goals are targeted and performed (at least, partially) in the process of this new revision (2015), as:

- Harmonization of security levels between the different lateral force resisting systems (see in Table 5, the proposal that is made to change values of R for RC resisting systems, for instance)
- More penalties for beam-columns frames which showed their evident brittle behavior in many cases due to the bad quality of execution, the under dimensioning of RC columns and, over all, the very bad concrete recast in critical sections (see fig. 5) [8].. The privileged systems are systems with shear walls and especially the mixed frame/shear walls system that present a double line of defense mobilizing the rigidity and resistance of walls, at first stage, and then, on second line, the frame ductility and resistance of the frame for dissipating the remaining energy of the event..
- Changes in zoning map considering the recent results of regional seismic hazard assessment studies in northeast and north-west regions of Algeria.
- Introduction of a new chapter dealing with timber frames and one appendix for seismic isolation
- Introduction of an Appendix for guidance in geotechnical investigations to better identify the right design site spectrum to be used.

Table 5 – Values of the behavior factors R

Categ.	**Structural Lateral Load Resisting Systems**	**Current values Of R (RPA2003)**	**Proposed Values Of R (RPA2015)**
	Reinforced Concrete		
1a	Moment Resisting Frames without infill masonry panels	5	4,5
1b	Moment Resisting Frames with infill masonry panels	3,5	3,5
2	Load bearing Shear Wall	3,5	4
3	Core	3,5	3,5
4a	Mixed frames/shear wall with interaction	5	5,5
4b	Frames with lateral load resisting shear wall	4	4
5	vertical cantilever with distributed masses	2	3
6	Inverted pendulum	2	2,5

Fig. 5 – Bad concrete recast And execution (Boumerdes 2003 Earthquake)

Fig. 6 – Soft story and bad execution (Boumerdes 2003 earthquake)

5. Conclusions

The Algerian community of earthquake engineering is really very proud of this essential tool of seismic reduction that is the seismic code RPA, and specifically the last version RPA 1999/2003.

This tool is now very largely used and mastered by our practitioners..

The new version "RPA 2015" will probably be the more satisfactorily version of Algerian Seismic Regulations for new buildings, as it is expected from it to integrate the experience feedback of the national professionals and academia for more than 3 decades.

To improve seismic design code in the future, we need also to undertake experimental tests of the main lateral force resisting systems that are used in our country; in this context, the National Earthquake Engineering Centre (CGS) has planned and begun to undertake some experimental research projects in the new structural dynamic laboratory (operational since 2013); this laboratory include a 6 DOF 6m X 6m shake table, a reaction wall 15 m high, and a strong floor of 32 m X 13 m.

5. References

[1] Règles Parasismiques Algériennes RPA (Versions 1981, 1983, 1988, 1999, 2003, Ministry of Housing, and CGS, Algiers)

[2] RPA 2015 Draft document (internal report, CGS 2015)

[3] Unified Building Code (UBC 73)

[4] Unified Building Code (UBC 76)

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