Implication Of The Seismic Code
On The Seismic Design Of Bridges In Algeria

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SUMMARY

Infrastructures such as bridges, tunnels, dams etc, are of paramount importance for the country and need to be well designed to resist earthquake ground motion. Post-seismic reports show that these structures may endure severe damage during strong seismic events. Therefore, many countries in the world which are in seismic prone regions developed their own seismic codes for these types of structures. Yet, earthquake hazard mitigation has noticeably improved because of the application of the seismic codes.
In Algeria, a new seismic code called RPOA has been recently issued by the ministry of public works to replace the conventional method based on static seismic force equal to percentage of the weight of the structure. The aim of this work is first to present the code and to evaluate it through a seismic study of two kind of typical bridges using simple static and dynamic methods as specified by the RPOA. Nonlinear static and dynamic analyses were carried out to investigate the post-elastic behavior of the bridge. Implications of the use of the new seismic code were also addressed by comparing the results of the two methods.

Keywords: Seismic code, Earthquake hazard mitigation, Method, Typical bridges, Algeria.

1. INTRODUCTION

The experience of old and recent earthquakes highlights the main causes of the collapses and disorders suffered by bridges, which result in relative displacements deck and support, and the brittle failure of some elements due to lack of ductility or confinement of concrete.

It shows the importance of taking into account seismic risk in project development the major civil engineering structure.

A most countries that are located in seismically active areas have developed their own codes to specific seismic structures.

To date, the calculation of the earthquake engineering structures in Algeria is governed by a standard method simplified. Recently proposed rules seismic structures RPOA was developed to be applied in Algeria.

Like other codes, this seismic regulation offers designers two major possibilities for design support:

• Design supports with elastic behavior
• Design supports with inelastic behavior

2. LINEAR ANALYSIS OF A GIRDER BRIDGE

2.1. MODEL OF BRIDGE ANALYSED

The analyzed structure is a girder bridge classified according to the RPOA in the category of major bridges, located in medium seismicity.

Our choice fell on a girder bridge that carried the type of bridge is the most common in Algeria.

2.2. MODELING OF THE BRIDGE

A computer code SAP2000 was used for the analysis of bridge, as shown in figure 1.1 with a dimension of 65 m in length and 9.40 m in width.

Figure 2.1. 3D view of Girder Bridge

2.3. MODAL ANALYSIS

According to the RPOA all modes that have an important contribution to the total structural response must be taken into account.

Table 2.1. Modal Participation Factors

Modes	Période (sec)	Ux %	Uy %	ΣUx %	ΣUy %
1	0.847	80.27	16.06	80.27	16.06
2	0.842	0.44	1.15	80.71	17.21
3	0.840	15.51	78.88	96.22	96.10

2.4. Response spectrum analysis

According to the RPOA parameters of the elastic spectrum (Sae) are:

- T1= 0.15 sec, T2 = 0.4 sec. (Soil S2)
- S = 1.1: Coefficient of site
- A = 0.25: Coefficient of acceleration zone.
- H = 1: Correction factor damping [ξ = 5%].

2.5. Parametric study

With an aim of quantifying the implication of the use rules seismic structures RPOA on the design and dimensioning of this type of bridge (Girder bridge), One compares the variation of the ratio « shear force/weight of the structure» (V/W) with that used by the conventional method based on static seismic force equal to percentage of the weight of the structure taken equal to 0.1.
The results obtained are illustrated in a graph 1 showing the variation of V/W according to the category of the soil (S1,S2,S3,S4) and zone of seismicity (Z1, Za, Z2b, ZIII).

Table 2.2. Variation of V/W

	V/W			
Site	Z1	Z2a	Z2b	ZIII
S1	0.10	0.16	0.20	0.26
S2	0.15	0.24	0.29	0.39
S3	0.20	0.33	0.40	0.53
S4	0.30	0.50	0.60	0.80

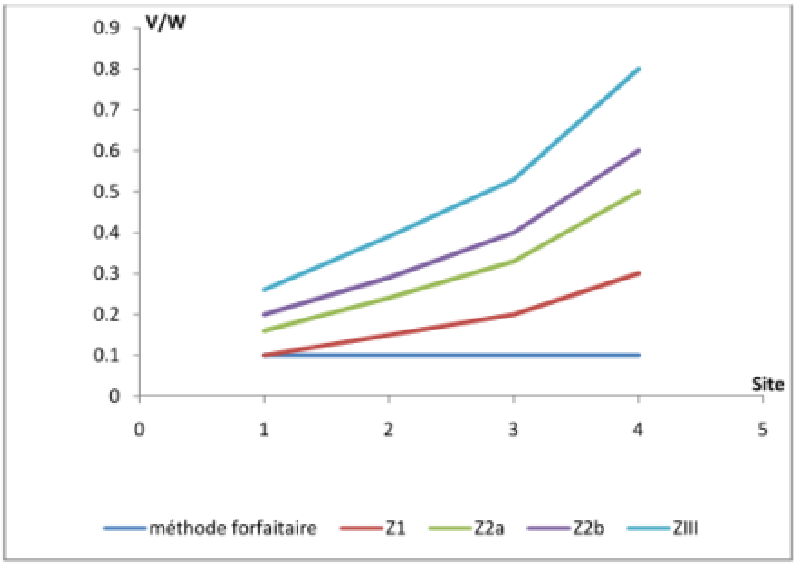

Figure 2.2. Variation of V/W according to the category of the soil (S1, S2, S3, S4) and zone of seismicity (Z1, Za, Z2b, ZIII).

The results obtained show an increasing variation of the varying coefficient V/W from 0.1 to 0.8 which represents a ratio relatively high. The efforts generated in the structure obtained by method RPOA will be thus sedentary compared to those of the conventional method. Thus it is noted that the latter covers only the cases of the bridges in zone 1 on the site S1.

It should be noted that these results are specific to a case of one fundamental period bridge located in the interval ($T2 \leq T < 3s$) of a category of soil S2.

To generalize this conclusion, one studies the variations of the ratios of the spectral values (S4/S3, S4/S2, and S4/S1) and one plot the corresponding curves according to the period.

It is noticed that these ratios are close (< 1.3) for the short periods ($0s \leq T \leq 0{,}5s$) and increases linearly in the interval ($0{,}5s \leq T \leq 0{,}8s$), to reach the threshold of 3 for ratio S4/S1 in the averages at long periods (T>1s).

These results show that the effect of the soil becomes very significant for the bridges at periods higher than 1s where spectral accelerations of calculation of a bridge established on a soil S4 is 1,5 those of a soil S3, twice those of a soil S2 and three times those of a soil S1.

3. NONLINEAR ANALYSES OF CANTILEVER BRIDGE

One studies the structural behavior under seismic stress of a cantilever bridge, by using dimensioning in capacity design in accordance with RPOA , with the design of ductile supports which results in the formation of the plastic hinge which must be confirmed by calculation by using the two methods of analyses " push-over " and " nonlinear dynamic analysis ".

3.1. MODEL OF BRIDGE ANALYSED

The analyzed structure is a girder bridge classified according to the RPOA in the category of major bridges, located in medium seismicity.
Our choice fell on a cantilever bridge that carried the type of bridge is the most common in Algeria.

3.2. MODELING OF THE BRIDGE

A computer code SAP2000 was used for the analysis of bridge, as shown in figure 3.1 with a dimension of 510 m in length and 13.50 m in width.

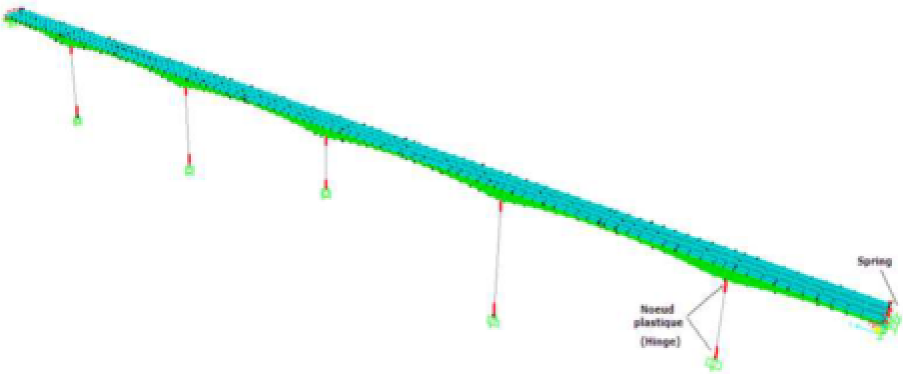

Figure 3.1. 3D view of Cantilever Bridge

3.3. MODAL ANALYSIS

According to the RPOA all modes that have an important contribution to the total structural response must be taken into account.

Table 3.1. Modal Participation Factors

Modes	Période (sec)	Ux %	Uy %	ΣUx %	ΣUy %
1	1.94	50.26	0.00	50.00	0.00
2	1.82	0.00	7.89	50.00	8.00
3	1.66	8.07	0.00	58.00	8.00

3.4. PUSHOVER ANALYSE

The results of the analysis push-over are shown in a graph which expresses the variation of the shear force at the base of the structure according to displacement at the top according to two directions (x-x) and (y-y).

x-x y-y

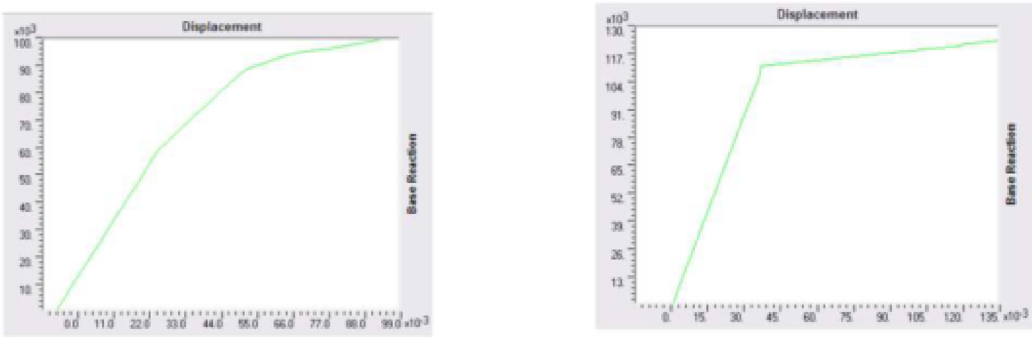

Figure 3.2. Variation shear force/displacement

- (x-x): the progressive passage towards the plastic range indicates a succession in the formation of the plastic hinge.
- (y-y): the curve is characterized by an abrupt passage of the elastic range to the plastic range what indicates the formation simultaneous several plastic hinge.

3.4.1. LEVEL OF PERFORMANCE

x-x y-y

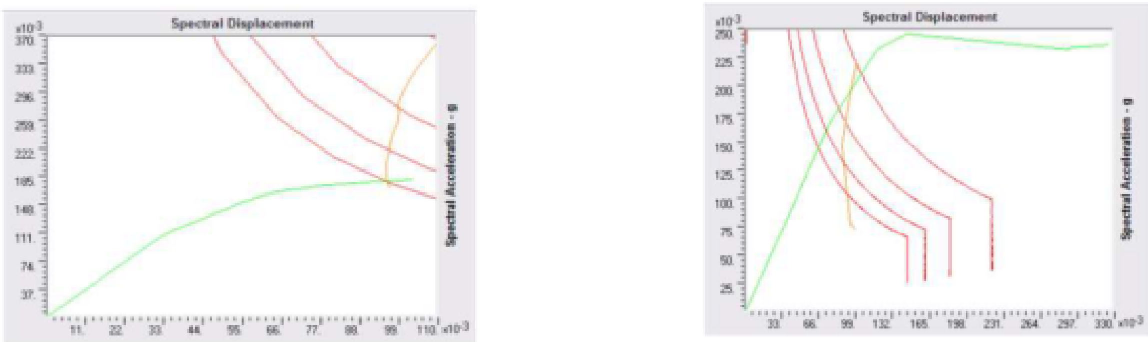

Figure 3.3. Level Performance

The analysis according to the two directions (x-x) and (y-y) one notes that the structure is in a level of performance Collapse Prevention " CP " in the first direction, and Immediate Occupancy "IO" according to second direction's.

3.5. NONLINEAR DYNAMIC ANALYSE

3.5.1. PLASTIC HINGE

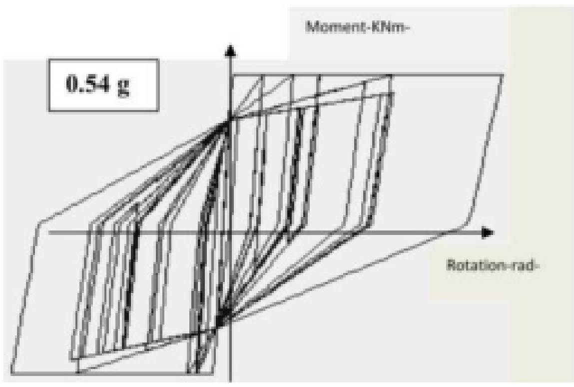

Figure 3.4. Curve (M-Ø) with PGA=0.54g

3.5.2. LONGITUDINAL AND TRANSVERSAL DISPLACEMENT

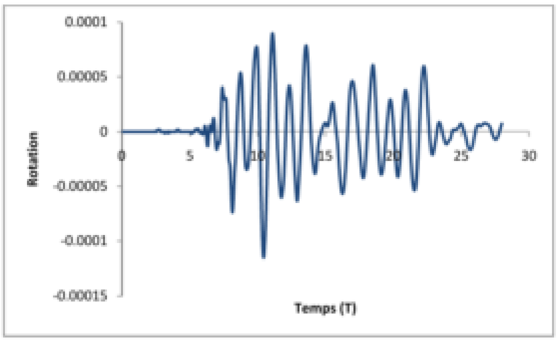

Figure 3.5. Transversal Displacement

3.5.3. CURVES OF ENERGIES

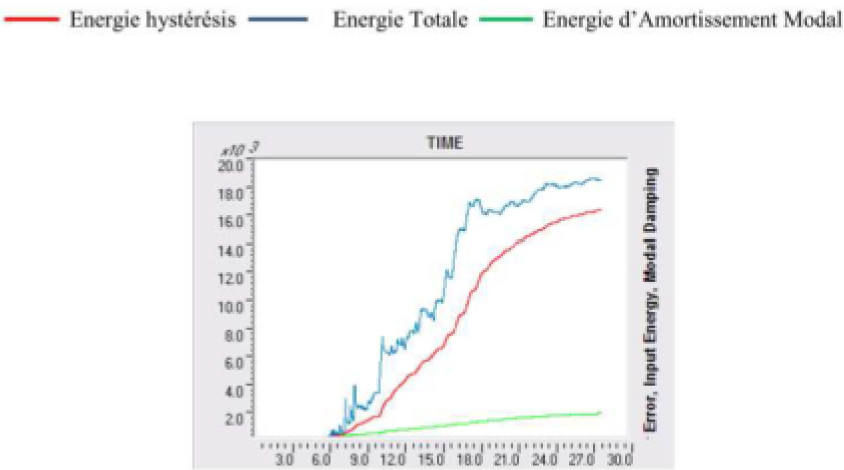

Figure 3.6. Curves of Energies

3.5.6. INCREMENTAL STUDY

An incremental study was carried out with an aim of evaluating the performance of the structure to increasing intensities. The accélérogramme is balanced by multiplicative coefficients in order to obtain maximum thresholds of acceleration (PGA) varying 0.05g with 1.2g which make it possible to sweep the elastic range and post-elastic band of the bridge.

One then obtains the curves (IDA) by tracing the maximum values of the shear force at the base and corresponding displacements for the two transverse and longitudinal directions of the bridge as shows it the following figures:

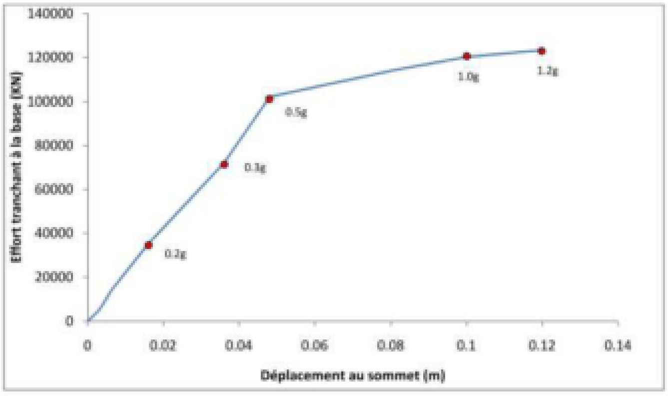

Figure 3.7. IDA curve according to the transverse direction of the bridge

From share the shape of the curves obtained one clearly distinguishes the two phases by which the structure passes, namely the first elastic phase which is characterized by a straight line until an acceleration of 0,5g or the curve more or less horizontally continues what means that the structure passes in the post-elastic band field.
Lastly, a comparison between the results of the analysis push-over and those of the nonlinear dynamic analysis prove to be judicious and allows us confirmed results. One then superimposes the IDA curves of the two analyses as presented by the following figures:

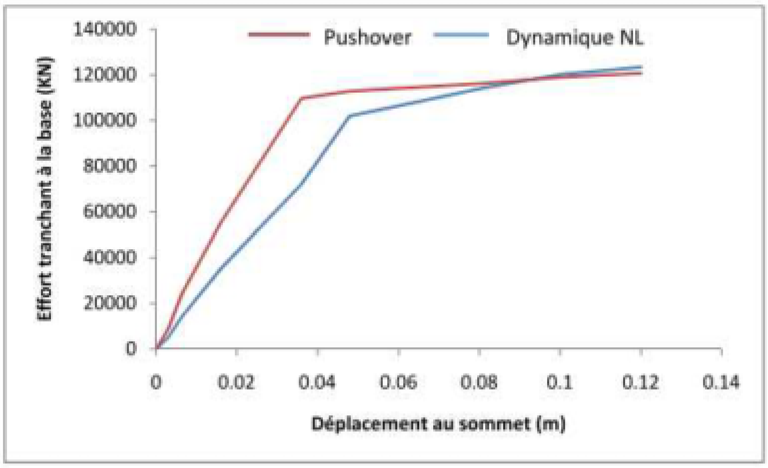

Figure 3.9. Comparison of the results of the nonlinear dynamic analysis and Static nonlinear analysis – transverse Direction of the bridge

4. CONCLUSION

By comparing the results obtained by the two analyses, one noted a good agreement with light differences which can be allotted to the effect of reversibility of the dynamic load which leads the structure to return in its state of balance.

The results of the nonlinear dynamic study showed that the bridge which was designed in accordance with the RPOA good seismic performance characterized by a capacity of appreciable dissipation of energy and an elastic reserve in the bearing of sufficient ductility to minimize the residual deformations.

The nonlinear dynamic analysis enabled us to follow the development of the efforts in the structural elements and to note the degradation and the deterioration of their rigidity and of resistance, and informed us about the capacity of the structure to dissipate energy by effect of hysteresis.

REFERENCES

L.Guizani, « Isolation sismique et technologies parasismiques pour les ponts», ALG Groupe Conseil Inc, 2006.
Kazuhiko Kawashima, «Seismic Design and Retrofit of Bridges», 2000.
Roberts.J.E, « Optimizing Post Earthquake Lifeline System Reliability Seismic Design Details for Bridges », Taipei, Taiwan, R.O.C, 1999.
Buckle,I.A, « Overview of Seismic Design Methods for Bridges in Different Countries and Future Directions», Paper No.2113, 11WCEE, Acapulco, Mexico,1996.
Priestley, M.J.N, Seible.F and Calvi, « Seismic Design and Retrofit of Bridges », John Wiley and Sons, New York, USA, 1996.
L.Guizani, «Rapport Sommaire Préliminaire sur l'isolation sismique des ponts », Madrid, Août 2005.
American Association of State Highway and Transportation Officials (AASHTO), «Guide Specifications for Seismic Isolation Design », 1998.
Canadian Highway Bridges Design Code (CAN-CSA-S6-00), Décembre 2000.
CNRC 2003, « Revue Canadienne de Génie Civil», Volume 30, Avril 2003.
Housner,G.W, «The Continuing Challenge-The Northridge Earthquake of January 17,1994 », Sacramento, California, 1994.
Denis Mitchell, Michel Bruneau, « Performance of Bridges in the 1994 Northridge Eathquake ».