Seismic Vulnerabilitv Index Method For Steel Structures

O. AMELLAL
Dept. of Civil Engineering, Saad Dahlab University, Blida, Algeria

M. BENSAIBI & K. GRINE
Dept. of Civil Engineering, Saad Dahlab University, Blida, Algeria

SUMMARY:
Steel frame structures are getting widely used in Algeria especially for industrial buildings due to their flexibility in use and despite the fact that they can be vulnerable to seismic hazard.
The present paper deals with a development of a vulnerability index method based upon the determination of numbers of structural and non structural parameters having an influence on the seismic behaviour of steel constructions.
This method was developed in order to be used by engineers, to establish a good classification and to allow better description of the "Seismic Quality" of these kinds of constructions. A technical data sheet in association with a developed calculating computer program named, Vulnerability Index Program (VIP) using "Delphi", have been used and validated to get the structural and non structural parameters as well as the vulnerability index and to establish a classification of the structure (safe, unsafe or intermediate situation).
The results show that the established classifications confirm what has been observed in situ.

Keywords: Seismic vulnerability, Steel structures, Vulnerability Index, Algeria.

1. INTRODDCTION

The North of Algeria is an area prone to seismicity. Most of the buildings and the industrial constructions located in this area are made of steel frame. Despite this fact, no studies have been curried out until know to show the vulnerability of such structure to seismic event. Thus it is important to quantify the seismic vulnerability of these constructions in order to prevent heavy damages.

Recently, Steel frame as a mode of construction is becoming frequently adopted in industrial construction. This is mainly due to the gain in realisation time and the ease that the material itself offers to realise longer span. However, in the literature it has been reported that the crucial point which can affect steel frame structure is the fact that they can undergo a significant damage during earthquake making them vulnerable to seismic hazard.

There are several tools to estimate the seismic vulnerability function, it depends mainly of the constituent material of the structure, the purpose of their uses and the typology. To provide these functions several methods do exist.

For steel frame, two main methods considering vulnerability functions are found. The first one is a global approach method such as HAZUS, RISK-UE, and RADIUS, considered not very accurate. The second, with more specific approach like the Push-over and the Time History Analysis requesting skilled persons.

However an intermediate method can be considered and be used by engineers to give a realistic estimation of the seismic quality of steel frame structures. This method has been considered in this present work. It is called "Vulnerability Index Method".

2. VULNERABILITY INDEX METHODE

This approach considers numbers of structural and non structural parameters. These parameters have an influence on the seismic vulnerability of steel frame structures. These parameters are determined by post-seismic observations and seismic experience feedbacks. The parameters taken into account are as follow:

1- Ductility
2- Bearing capacity
3- Assemblage
4- General maintenance conditions
5- Type of soils
6- Floor
7- Buckling
8- Plan regularity
9- Modifications
10- Elevation regularity
11- Pounding effect
12- Ground conditions
13- Roof
14- Details

Among these parameters, Ductility, Bearing capacity and Buckling need calculation, the other parameters are related to the in situ observation. In this paper, only Ductility is presented because it is the most important and complex parameter.

2.1. Ductility

Under a strong earthquake, the steel frame structures undergo plastic deformations, due to their faculty of dissipation of energy. Indeed, they have the ability to resist greater strain than the design one.

To take into account these plastic deformations, the seismic codes consider a reducing factor called "Behavior Factor" defined by the coefficient 'R' according to the Algerian seismic code (RPA 99 version 2003). The R values are given in table 1.

Table2. 1. Ductility according the behavior factor for steel frame structures

Ductility level	Value of "R"
High Ductility Class A	[6 – 4 [
Average Ductility Class B	[4 - 2 [
Low Ductility Class C	≤ 2

3. QUANTIFICATION OF EACH PARAMETER

Weighting factors for each parameter are proposed on table 3.2. These factors are determined on a basis of a statistical data containing more than 300 constructions damaged by different earthquakes. The considered parameter can take only one factor. Three classes are defined for each parameter. Each considered parameter can belong to one of the three defined classes A, B, and C. These classes are declined as follows:

Class A expresses a parameter inducing a good behaviour of the structure during an earthquake,
Class C, expresses a parameter inducing a bad behaviour of the structure during an earthquake,
Class B expresses an intermediate behaviour of the structure during an earthquake.

Table 3.2. Weighting factor "Ki"

No	Parameters	Classes/Ki		
		Class A	Class B	Class C
1	Ductility	0.00	1.5	2.5
2	Bearing capacity	0.25	1.25	2.00
3	Assemblage	0.25	1.5	2.5
4	General maintenance conditions	0.25	1.00	1.5
5	Type of soil	0.50	0.75	1.00
6	Floor	0.50	0.75	1.00
7	Buckling	0.50	1.00	1.5
8	Plan regularity	0.50	0.75	1.00
9	Modifications	0.50	0.75	1.00
10	Elevation regularity	0.50	0.75	1.00
11	Pounding effect	0.50	0.75	1.00
12	Ground conditions	0.50	0.75	1.00
13	Roof	0.50	0.75	1.00
14	Details	0.50	0.75	1.00

The vulnerability index, VI, of a construction is expressed according to the formula (1):

$$VI = \sum_{i=1}^{14} k_i$$

(3.1)

According to the value obtained for the vulnerability index, three vulnerability classes Green, Orange and Red are proposed, table 3.3:

Table 3.3. Vulnerability index classes

Class	Green	Orange	Red
VI	[5.75 – 9.5]	[9.5 – 19]	[16 – 19]

The first class associated to the green colour classifies the construction as resistant with no requirement to any repairs.
The second class associated to the orange colour classifies the construction as moderately resistant requiring reinforcement.
The third class associated to the red colour classifies the construction to be a construction with low resistance requiring demolition.

4. ELABORATED CHART

In situ observations on structures are important information required to assess the vulnerability of steel frame structures. An investigation chart for a survey was elaborated. The chart contains:

1. General data
2. Geometric characteristics
3. Information on the structural system
4. Information on the ground
5. Details on the non structural elements
6. General maintenance conditions

5. DEVELOPED PROGRAM

A program called Vulnerability Index Program "VIP using Delphi was elaborated providing the vulnerability index values for steel frame structures. It uses the elaborated chart in order to estimate the coefficient of the different parameters and classify the structures. The front page of the program is given on figure 1.

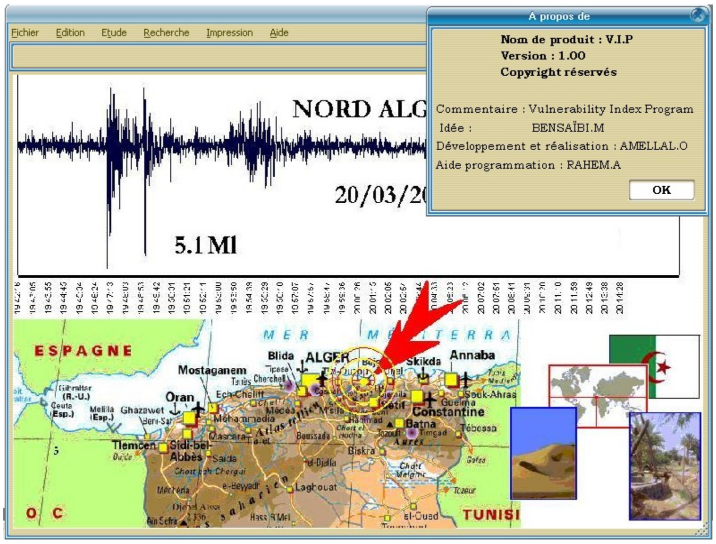

Figure 1. Front page of the VIP

6. APPLICATION

Several examples have been treated by the developed program. Here in, are two case studies presented as an example.

6.1. Case study one

It is a Zinc production manufacture built in 1949 and located in the West part of Algeria. The following figures show the damage undergone by this structure.

Figure 2. Damage in the bracing system

Figure 3. Corrosion of columns

Figure 4. Damage in the assembly system

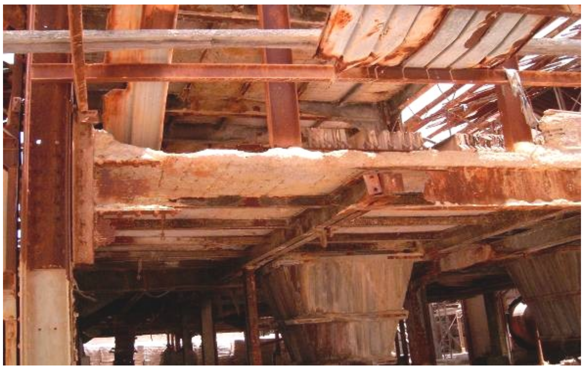

Figure 5. Damage in beams and floors

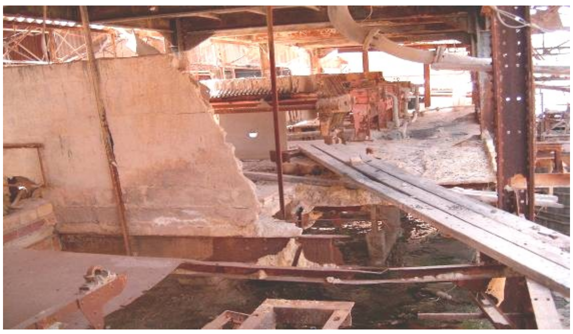

Figure 6. Collapse of a floor

The results given by the program are as follow (table 6.4)

Table 6.4. Manufacture parameters vulnerability

Nº	Parameters	Class	Coefficient Ki
1	Ductility	**B**	**1.5**
2	Bearing capacity	**C**	**2.00**
3	Assemblage	**C**	**2.5**
4	General maintenance conditions	**C**	**1.5**
5	Type of soil	**B**	**0.75**
6	Floor	**C**	**1**
7	Buckling	**C**	**1.5**
8	Plan regularity	**C**	**1**
9	Modifications	**A**	**0.5**
10	Elevation regularity	**C**	**1**
11	Pounding effect	**B**	**0.75**
12	Ground conditions	**A**	**0.5**
13	Roof	**B**	**0.75**
14	Details	**C**	**1**

A vulnerability index of 16.25 was found, this indicates that the structure belong to the red class.
The conclusions provided by the Structural Engineering Control (CTC: official organization in charge of control in Algeria) suggest the demolition and the rebuilt of the manufacture according the latest standards.

So, the two conclusions are in adequacy.

6.2. Case study two

The second structure is an industrial complex of "the National Company of Industrial Vehicles SNVI" built in 1978.

Figure 7. Instability of the bracing system

Figure 8. Hole in the joints

Figure 9. Landslide

Figure 10. Cracks in the walls

Figure 11. Cracks in the pavements

The VIP gives the following results (table 6.5):

Table 6.5. SNVI parameters vulnerability

Nº	Parameters	Classe	Coefficient Ki
1	Ductility	**C**	**2.5**
2	Bearing capacity	**A**	**0.25**
3	Assemblage	**A**	**0.25**
4	General maintenance conditions	**B**	**1**
5	Type of soil	**B**	**0.75**
6	Floor	**A**	**0.5**
7	Buckling	**A**	**0.5**
8	Plan regularity	**C**	**1**
9	Modifications	**C**	**0.5**
10	Elevation regularity	**C**	**1**
11	Pounding effect	**C**	**1**
12	Ground conditions	**C**	**1**
13	Roof	**A**	**0.5**
14	Details	**A**	**0.5**

The program gives VI=11.25, so the structure is classified Orange.

7. CONCLUSION

A vulnerability index method for steel structure has been developed and presented in this study. Even though the method is an intermediate one, it gives reasonable results regarding the influence of the different parameters such as Ductility, Bearing capacity and Buckling on the seismic behaviour of steel structure.

A classification has been established according to the damage undergone by the structure. The results from this classification are in accordance with the one done in situ. As a result, this classification can be used by engineers to reduce seismic risk and casualties in case of an earthquake.

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REFERENCES

Zacek, M. (1996). Construire parasismique, Publisher Parenthèses. Marseille, France.
Davidovici, V. (1999). Construction en Zone Sismique., Publisher the Moniteur. Paris, France.
Jacques, B.M. and Doury, J.L. (2002), Construire parasismique, Technique de l'Ingénieur, France.
Boukri, M. (2003). Détermination vulnerability index of masonry construction, thesis of master, University Saad Dahleb de Blida, Algérie.
Belheouane, F.I.(2006). Détermination vulnerability index of concrete construction, thiese of master, Université Saad Dahleb de Blida, Algérie.
Ecole Polytechnique Fédérale de Lausanne. (2001). Charpente Métallique Conception et Dimensionnement des halles et bâtiments, Lausanne, Swiss.
Helmut, C.S, and Werner, S. and Habermann, K. J. (2003). Construire en acier, Publisher Détail, Lausanne, Swiss.
AFPS. (2004). Guide la Conception Parasismique des Bâtiments, Publisher Eyrolles, Paris, Frances.
Walfgang, J. (2003). Règles de construction parasismique PS 92, Publisher Eyrolles, Paris, France 2003
AFPS.(2005). Vulnérabilité Sismique du Bâtis Existant. **cahier technique: 25**. France.
Nollet, M.J. (2004). Evaluation de la Vulnérabilité Sismique des Bâtiments Existant, cahier technique de l'ETS, Ecole de Technologie Supérieure Université du Québec, Montréal, Canada.
Akkase, M.N. (2006).Thaughts on Concepts of Seismic Hazards, Vulnérability and seismic Risk, *9th European confer on Earthequake engineering* **Vol X**.
Règles parasismiques Algériennes RPA 99 modifiées en 2003, Algérie.
Giancu, V.and Mazzoalani, M.(2002). Ductility of Seismic Resistant Steel, publisher Span Press, London and New york,.
Lang, K.(2002). Seismic Vulnerability of Exesting Building, thesis of doctorate, Swiss Federal institute of technology, Zurich, Swiss.
Bourahla, M.B. (2002) Comportement dynamique non-linéaire des systèmes de contreventement des ossatures métalliques thesis of master, University Saad Dahleb de Blida, Algérie.

Plumier, A. and oushaba, B. B.(1988). Relation entre la ductilité Local et le facteur de comportement sismique des structures en acier, *Construction métallique*, **Vol :2**.
Séminary(1997) . Comportement ductile des structures métalliques, GECOTEC Groupement Alger 17 et 18 juin.
Règles de Conception et de Calcul des Structures en acier CCM 97. (1997). Algérie.
Morel, J.(1995). Conception et calcul des structures métalliques, Publisher Eyrolles, paris, France.
Bensaibi, M., Djaalali, F., Belheouane, F. I., Amellal, O., Yousfi, N., March, 2011 « Seismic vulnerability index method: Algerian case studies», *8th International Conference on Urban Earthquake Engineering,* Tokyo Institute of Technology, Tokyo, Japan, 7-8.
Amellal, O. Bensaibi, M. Grine Khaled., septembre 2011 « indice de vulnérabilité pour les structures en charpente metallique » 8eme colloque de l'association française du génie parasismique, Paris, France.