Seismic vulnerability classification of roads

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Abstract

Experience from past earthquakes all over the world showed that the road network could undergo heavy damages. To prevent these damages, vulnerability studies must be carried out. The purpose of this study is to develop a seismic vulnerability assessment method for roads. The methodology is based on determination of a numerical indicator called Vulnerability Index (VI). To achieve this, the main parameters that influence the seismic behaviour of roads are identified on the basis of the worldwide seismic feedback experience and data from past Algerian earthquakes. Furthermore, the Analytical Hierarchy Process (AHP) is used to quantify the identified parameters and define an analytical expression of the ‘VI’. A classification of the seismic vulnerability of road sections is proposed, according to the obtained Vulnerability Index (VI) value.

To exhibit the efficiency of the developed method, several road sections are studied and the obtained results are in good adequacy with in-situ observations. Moreover, in order to assess the seismic vulnerability of an urban city road network, the developed model is combined to a GIS (Geographical Information System) to perform several earthquake scenarios and the results of Tipaza city are presented.

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Keywords: Earthquake; roads; vulnerability index (VI); Analytical Hierarchy Process (AHP); seismic scenarios; classification

1. Introduction

Among lifelines, road network plays an important role in the daily life. It assures services such as transportation...
and socio-economic exchanges. Moreover, during major disasters such as earthquakes, it allows emergency response, repair operations and recovery activities. Nevertheless, the road network may as well as other structures suffer heavy damages due to seismic event. As a result, these damages induce delay in the rescue operations and extensive socio-economic losses.

In order to reduce road seismic vulnerability, several studies have been carried out [1,2,3,4,5]. Methods for performing seismic scenario have been developed taking into consideration road networks [6,7,8,9,10,11]. Among vulnerability assessment methods, the vulnerability index method is used for different lifelines [12]. It consists in determining a value resulting from an analytical expression that contains several parameters. These parameters are either qualitative or quantitative which differentially affect the system vulnerability. Furthermore, the expression of the VI generally contains weighting coefficients. These weights may be calculated by applying MCDM (Multi Criterion Decision Making) methods. These could take into account many parameters with different nature and unequal importance [13].

Among the MCDM methods, the Analytical Hierarchy Process (AHP) is commonly used. It was developed by Saaty [14] and was used in different fields. Recently, many researchers have applied this method to assess seismic vulnerability of tunnels [15], bridges [16], buildings [17], buildings construction site [18], lifelines [19] and urban areas [20].

In this study, the vulnerability index method is applied to assess the seismic vulnerability of roads. Based on feedback from past earthquakes over the world [21,22,23,24,25,26], and Algerian observations from AinTemouchent and Zemmouri earthquakes [27,28], most important parameters that have an influence on seismic behavior of road network are identified. Moreover, to take into consideration their relative importance, the AHP method is used to derive weighting coefficient for each identified parameter.

### Nomenclature

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
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<tbody>
<tr>
<td>Cijkl</td>
<td>Score of category</td>
</tr>
<tr>
<td>LP</td>
<td>Liquefaction Potential</td>
</tr>
<tr>
<td>MMI</td>
<td>Mercalli Modified Intensity</td>
</tr>
<tr>
<td>RSVI</td>
<td>Road Seismic Vulnerability Index program</td>
</tr>
<tr>
<td>VI</td>
<td>Vulnerability Index</td>
</tr>
<tr>
<td>VR</td>
<td>Vulnerability Range</td>
</tr>
<tr>
<td>Ws</td>
<td>weighting coefficient of structural or hazard parameters</td>
</tr>
<tr>
<td>Wj</td>
<td>weighting coefficient of items</td>
</tr>
<tr>
<td>Wijk</td>
<td>weighting coefficient of factors</td>
</tr>
</tbody>
</table>

### 2. Background of the proposed method

The developed methodology is based on the use of; firstly the vulnerability index method to identify the main parameters affecting the seismic behavior of road structures and then the AHP method which allows determining the weights of every identified parameter. The methodology consists in four basic steps. The description of each step is given hereafter.

#### 2.1. Identification of vulnerability parameters

Roads vulnerability depends on their geometric and structural characteristics as well as geotechnical and seismic properties of the location site. Factors that affect the seismic behaviour of the road are defined on the basis of seismic experience of past earthquakes all over the world and in Algeria, thus, two types of parameters are identified: Structural and Hazard ones. These parameters are divided into items. In turn, the identified items are divided into factors and factors are subdivided in categories, as given in Table 1 (Appendix. A).
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