IMPROVEMENTS OF DOMINICAN GUIDELINE FOR POST-EARTHQUAKE EVALUATION OF BUILDINGS

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ABSTRACT

Due to the recent disasters worldwide particularly in the neighboring country of Haiti in 2010, the institutions that deal with disaster management policies have launched the National Plan of seismic Risk Reductions in 2011. According to the plan the methodology of evaluation of damages should review and validate in a period not exceeding one year. To meet this goal, the Dominican Guideline for post-earthquake seismic evaluation has been reviewed in this research. In order to know how the current Dominican Guideline should be improved, relevant active guidelines and recommendations were reviewed. Knowing the weaknesses of Rapid Evaluation, the Detailed Evaluation and Engineering Evaluation, the improvements were proposed. The Rapid Evaluation and the Detailed Evaluation were improved by adopting a quantitative procedure and for the Engineering Evaluation by the proposal based on the concept of damage class, deterioration of seismic capacity and deterioration factor.

Keywords: Post-earthquake Evaluation, Rapid Evaluation, Detailed evaluation, Engineering Evaluation, Buildings.

1. INTRODUCTION

Dominican Republic is situated in the eastern part of Hispaniola Island, which is located between the North America and the Caribbean Plates. There is a fault system composed by several failures , due to this fault system, the country has been affected by several earthquakes over the years and due to the last three disasters caused by these earthquakes, the seismic engineering has been advanced in the country. In 2010, an earthquake of magnitude 7.0 hit Haiti and it caused a big disaster. Due to this earthquake, several measures were taken for the seismic risk reduction in Dominican Republic, and the Ministry of Economic Planning and Development launched the National Plan of Seismic Risk Reduction in 2011, which involves all the institutions that deal with the theme to work on disaster management policies in terms of earthquakes with a period of work for the first stage up ten years. In this plan the National Office of Seismic Evaluation and Vulnerability of Infrastructures and Buildings is responsible to have the damage evaluation methodology validated within a period not greater than one year, as well as the criteria for training a voluntaries team for post-earthquakes evaluations.

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2. PURPOSE AND SCOPE

The purpose of this study is to establish the detailed damage evaluation method for structures of reinforced concrete (RC) and reinforced masonry concrete blocks (RMCB), and to improve the Dominican Guidelines of post-earthquake evaluations.

The scope is to evaluate the safety conditions of buildings affected by earthquakes, to provide a method to standardize a seismic evaluation after earthquake, as well as the method of the deterioration of seismic capacity after event to be applied in reinforced concrete buildings and reinforced masonry buildings fundamentally.

3. METHODOLOGY

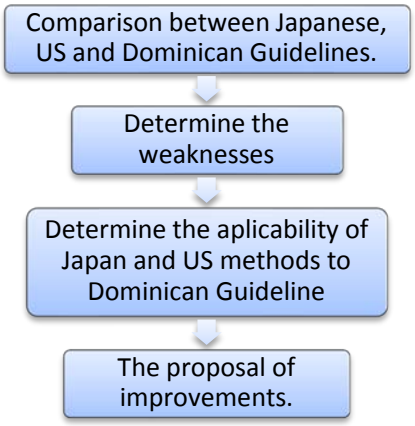


Figure 1. Methodology flow chart

The improvements of Dominican guideline were proposed following the procedure shown in Figure 1. The Dominican guideline was compared with Japanese and Us guidelines, because they have similar methodology flow chart of the post-earthquake evaluations, they have similar structure types as RC buildings and reinforced masonry concrete blocks, and Japan and US have a very similar concept for engineering evaluation. After the comparison the weaknesses can be determine and the applicability of Japanese and US methods to the Dominican guideline.

After these steps the improvement can be proposed, based on the applicability determined.

4. WEAKNESSES OF DOMINICAN GUIDELINE

In the post-earthquake evaluation three procedures are defined and the weaknesses of these procedures are detailed as fallow:

- In the "Rapid evaluation" and the "Detailed evaluation", the parameters which judge the safety of buildings are not clearly defined.
- In the "Rapid evaluation" and the "Detailed evaluation", the judgment of the safety of buildings is made in subjective ways because the judgment is totally according to the experience and criteria of evaluators.
- The guide for the "Engineering evaluation" is practically not provided.

5. IMPROVEMENTS ON DOMINICAN GUIDELINE

5.1. Improvements on Rapid Evaluation

In the emergency stage, the rapid evaluation of damaged buildings should start as fast as possible. The main objectives of this evaluation are to determinate whether the building is safe or not for use, and in that sense to avoid a secondary disaster due to the aftershock, therefore the field book was made compact and the parameters to judge about the posting were defined.

5.2. Improvements on Detailed Evaluation

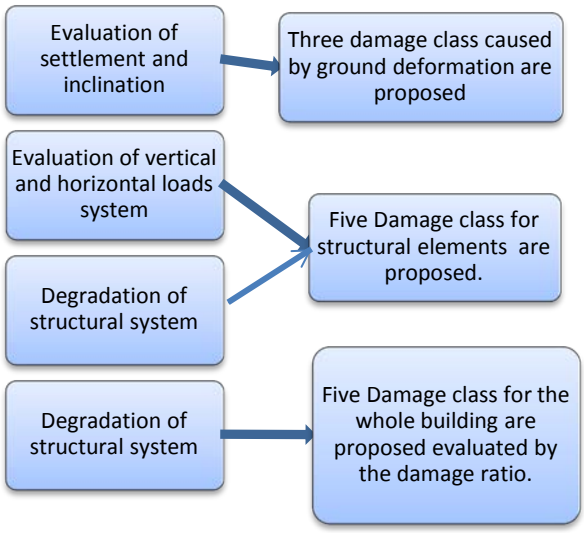


Figure 2. Improvements on Detailed evaluation.

After the rapid evaluation procedure the buildings with unsafe or limited entry classification need a detailed evaluation of structural elements, this evaluation must be done to judge the building continuity in use and the necessity of a restoration work. The improvements provides a quantitative and qualitative procedures through which different teams of evaluators can reach the same conclusions when assessing the structural safety of the same building, and thus they can assess whether the construction is ready to be occupied or not through the procedure. The items improved in this procedure are the evaluation of settlement and inclination, evaluation of vertical and horizontal loads system, the degradation of the structural system and the evaluation of global damage.

Damage Class

The Damage classification proposed is based on the load carrying capacity of structural members, when cracks appears on loading bearing members means that seismic capacity of structural members have been reduced. The proposed damage classification of the structural elements will be taken into account the damages in RC members and reinforced masonry concrete blocks (RMCB). This damage classification will be divided into five levels defined as follows:

Minor: when the damage does not significantly affect structural properties of elements.
Slight: when the structural members properties are slightly affected.
Moderate: Damage has an intermediate effect on structural properties.
Severe: Damage has a major effect on structural properties.
Extreme: Damage has reduced structural performance to unreliable levels.

Damage Level of Structure

For the evaluation of the damage level of structures, the concept of damage ratio D of JBDPA (1991) is proposed by using Eq. (1) (JBDPA); this equation represents the percentage of damaged members (RC and RMCB) according to the each damage class D_i and the percentage of the damage of the inspected level$\sum D_i$, considering the floor showing the largest concentration of damage.

$$D = D_1 + D_2 + D_3 + D_4 + D_5 \quad (1)$$

Where:

$$D_1 = \left\{\frac{10B_1}{A}; D_2 = \left\{\frac{26B_2}{A}; \; D_3 \left\{\frac{60B_3}{A} \; ; \; D_4 = \left\{\frac{100B_4}{A} \;\; and \; D_5 = \left\{\frac{1000B_4}{7A}\right.\right.\right.\right.$$

Where:

B_i: The number of elements or length of walls classified as the same damage level.
A: The total number of elements or total length of walls investigated.

Table 1. Damage level according to the R index

Minor damage	$R \geq 95$ (%)
Slight damage	$95 > R \geq 80$ (%)
Moderate damage	$80 > R \geq 60$ (%)
Severe damage	$60 > R$(%)
Collapse	$R \approx 0$

For structures based on reinforced masonry concrete blocks, the structure must be analyzed in both directions separately and take the most unfavorable result as a damage ratio of the evaluation. The damage level of an entire building will be evaluated based on Eq. (2)(Maeda 2000), to evaluate the deterioration of seismic capacity of the building. The damage level of the building will be classified into five levels according to the R index as shown in Table 1.

$$R = 1 - \frac{D}{100} \tag{2}$$

5.3. Proposal of Engineering Evaluation

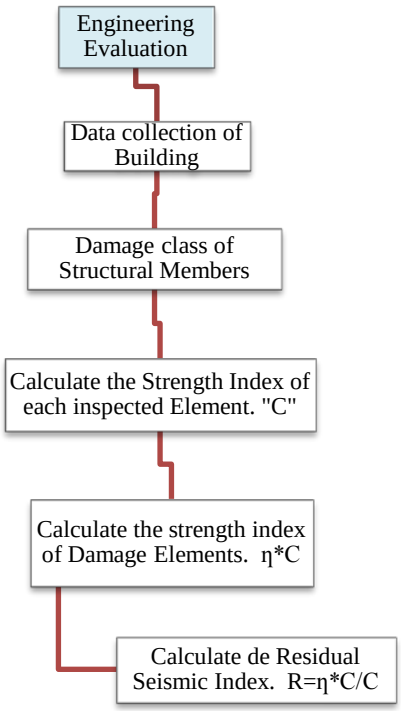


Figure 3. Full procedure of engineering evaluation

In Dominican Republic, most of the buildings do not have drawings of any information about design specification, and due to the nature of these buildings a diagnosis is needed in a short time. So, the proposed procedure has been made based on the 1st level screening method JBDPA standard. In this method the seismic capacity of the structure is evaluated base on the basic seismic index E_0 as a function of level shear modification factor ϕ, strength index C and ductility index F are shown in Eq. (3)(JBDPA). It is used in the proposal to evaluate the seismic capacity of many buildings, mainly due of two reasons. One is that the evaluation must be achieved in short time because of large numbers of buildings. Second is that structural drawings are not available for many buildings, therefore, the evaluation must be achieved without structural drawings.

$$E_0 = \emptyset * C * F \tag{3}$$

In the simplified method of JBDPA (2001), a normalized strength index $\bar{C}$ for each typical member section of Japanese buildings is used, and to obtain the damage stage of the building a deterioration factor η according to the damage level is considered.), then considering the typical sections of elements shown in Table 2, and the deterioration factor proposed on Table 3. As the residual seismic capacity ratio R is defined as the ratio of seismic capacity of the structure after and before damage, this R index is found by the equation Eq. (4)(JBDPA). The full procedure proposed for engineering evaluation is shown in Figure 3.

$$R = \frac{\sum \eta * C}{\sum C} \tag{4}$$

In order of to apply this concept to Dominican Republic, as the $\bar{C}$ index is already determined for RC members, to find this index for the typical sections of elements of RMCB is needed. In the lecture note of Masonry Structure II (2) by S. Sugano, the Eq. (5), and Eq. (6) are explained as a modified JBDPA evaluation method with the variation for masonry concrete blocks, which can be used in Dominican Republic, and this variation is used for to obtain the strength index for masonry concrete blocks for in-plane walls and out-of-plane walls.

$$C_1 = \frac{A_w * \tau_1}{W} \tag{5}$$

$$C_3 = \frac{2 * \tau_2}{(3 * \gamma * l)} \tag{6}$$

Table 2. Proposed values of strength index $\bar{C}$ for RMCB

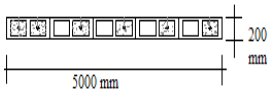
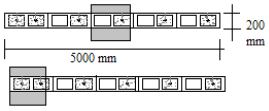
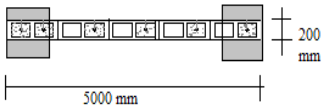
	Wall without Boundary Columns	Columns with wing wall (s)	Wall with Boundary Columns.
Section			
$\bar{C}$	0.45	1.45	4.60

Table 2, shows the proposed values of strength index for RMCB, for the typical section with RC columns and without columns, these values were proposed by using the strength index for masonry concrete blocks for in-plane walls. To calculate the seismic capacity after the damage, a deterioration factor according to the damage level and behavior of the damaged element is needed. As in the Dominican Republic there are no laboratories to test structural elements according to the Dominican construction practices, the deterioration factors of U.S. and Japan will be taken as references. The values of Table 3 were adopted from the Japanese guideline for Columns and RC walls, from Dr. Nakano for RC frames with RMCB infill and from ATC-43 for RMCB. These factors are the starting point of deterioration factors to be used in Dominican Republic; those factors will be reviewed through future researches with laboratory tests on elements with the features of construction of Dominican buildings.

Table 3 Proposed Deterioration factors

Damage Class	Flexural members (columns)	Shear members (columns/ RC walls)	RC frame infilled by RMCB	RMCB Shear Behavior	RMCB Flexural Behavior
Minor	0.95	0.95	0.90	1	1
Slight	0.75	0.6	0.60	0.8	0.9
Moderate	0.5	0.3	0.30	0.5	0.8
Severe	0.1	0	0	0	0
Collapse	0	0	0	0	0

6. CONCLUSIONS

To know how the current Dominican Guideline should be improved, relevant active guidelines and recommendations (Japanese guidelines, JBDPA/AIJ and US guidelines, ATC-20/ATC-43) were reviewed. It was found that the Japanese guideline is based on the quantitative criteria in the whole procedure and the US guideline has the qualitative procedures in ATC-20 and the quantitative procedures in ATC-43. Five levels of damage are defined in both guidelines. To determine the deterioration of seismic capacity, Japan and US have the same concept but different approach; this concept is the ratio of the seismic capacity after and before earthquake by applying a deterioration factor.

Through the revision, in the current Dominican Guideline, several weaknesses were found. In order to improve the current Dominican guideline, the proposal was made based on the weaknesses and is summarized as below:

Improvement of Rapid Evaluation:

The field book which had too many check items were made compact so that the discrepancy between the guideline and the field book may be eliminated.

Improvement of Detailed Evaluation:

The quantitative procedure based on the damage class of elements and the damage level of a whole structure was adopted.

New proposal of Engineering Evaluation:

The concept of the damage class based on the crack width, failure type and damage ratio is adopted.
The deterioration of the seismic capacity of members and a whole structure caused by earthquakes (deterioration factor) are evaluated.
The deterioration factors are proposed referring to relevant guidelines.

7. RECOMMENDATIONS

In the Dominican Republic, it is necessary that the relevant organizations initiate investigations regarding to the post-earthquake evaluations. It is also necessary to form a group of volunteer, so in case of a major earthquake they are trained and able to apply the guideline for post-earthquake evaluations of buildings. Post-earthquakes evaluations are essential to prevent secondary disasters and reduce economic losses; therefore the tools and procedures for evaluation after event should be ready, because these events do not warn.

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