Evaluation of potential seismic damage in the Great Soviet Panel precast system

Evaluación de daños sísmicos potenciales en el sistema prefabricado Gran Panel Soviético

DOI: http://doi.org/10.17981/ingecuc.18.2.2022.17

Artículo de Investigación Científica. Fecha de Recepción: 25/09/2021. Fecha de Aceptación: 10/08/2021.

Yamila Concepción Socarrás Cordobí
Universidad de Oriente. Santiago de Cuba (Cuba)
ysocarrascordovi@gmail.com

To cite this paper
Y. Socarrás Cordobí, "Evaluation of potential seismic damage in the Great So-viet Panel precast system", *INGE CUC*, vol. 18, no. 2, pp. 209–222. DOI: http://doi.org/10.17981/ingecuc.18.2.2022.17

Resumen

Introducción— Las investigaciones recientes han demostrado la probabilidad de cambios desfavorables en el comportamiento sísmico de algunas edificaciones construidas en Santiago de Cuba, con el sistema prefabricado Gran Panel Soviético. A causa, de los daños patológicos en elementos y juntas estructurales, seguidos de las transformaciones de pesos y de rigidez. Por lo tanto, es conveniente realizar una evaluación de los daños sísmicos potenciales, de forma rápida, en la mayor cantidad de edificaciones, sin tener que realizar obligadamente la modelación estructural. Sin embargo, las diferentes metodologías para evaluar la vulnerabilidad sísmica, que se han consultado, no integran una detallada y precisa evaluación de daños patológicos como punto de partida de la evaluación de los daños sísmicos potenciales.

Objetivo— Se concreta elaborar un procedimiento que permita evaluar los daños sísmicos potenciales en el sistema prefabricado Gran Panel Soviético que se sustenta en un conjunto de variables, indicadores y subindicadores.

Metodología— La validación del procedimiento se realiza a través del método Delphi.

Resultados— Este procedimiento tiene como punto de partida en una primera etapa, la evaluación de los daños patológicos, de acuerdo a su incidencia en el comportamiento estructural, el cual se articula en una segunda etapa, con otros aspectos causantes de vulnerabilidad sísmica.

Conclusiones— El procedimiento diseñado es un instrumento para el soporte de decisiones en materia de la rehabilitación sismorresistente del sistema Gran Panel Soviético. Se puede aplicar de forma rápida, en un análisis primario, en todas las edificaciones existentes en la ciudad de Santiago de Cuba.

Palabras clave— Daños sísmicos potenciales; daños patológicos; gran panel soviético; hormigón prefabricado; evaluación

Abstract

Introduction— Recent research has shown the probability of unfavorable changes in the seismic behavior of some buildings built in Santiago de Cuba, with the prefabricated Great Panel Soviet system. Due to pathological damage to structural elements and joints, followed by weight and stiffness transformations. Therefore, it is convenient to carry out an evaluation of the potential seismic damages, quickly, in the largest number of buildings, without having to carry out structural modeling. However, the different methodologies for evaluating seismic vulnerability, which have been consulted, do not integrate a detailed and precise evaluation of pathological damages as a starting point for the evaluation of potential seismic damages.

Objective— It is specified to elaborate a procedure that allows evaluating the potential seismic damages in the prefabricated Soviet Great Panel system based on a set of variables, indicators and sub-indicators.

Methodology— The validation of the procedure is carried out through the Delphi method.

Results— This procedure has as a starting point in a first stage, the evaluation of the pathological damages, according to their incidence in the structural behavior, that is articulated in a second stage, with other aspects that cause seismic vulnerability.

Conclusions— The designed procedure is an instrument for decision support regarding the earthquake-resistant rehabilitation of the Soviet Grand Panel system. It can be applied quickly, in a primary analysis, in all existing buildings in the city of Santiago de Cuba.

Keywords— Potential seismic damage; pathological damage; great soviet panel; precast concrete; evaluation

I. Introduction

In Santiago the Cuba, the area of greatest seismic danger in the country, 665 buildings were built with the prefabricated I-464 system, popularly known as the Great Soviet Panel. This prefabricated system due to its own structural conception and the type of both horizontal and vertical joints between the precast elements, which are of the wet type, has shown adequate behavior in the event of high intensity earthquakes in Chile and Armenia (ex-Soviet republic) [1]-[2].

In Chile, it is considered that these buildings of a social nature have shown good earthquake-resistant behavior under adequate maintenance conditions, which is why it is recommended that their construction be resumed [3]. In the former Union of Soviet Socialist Republics, the situation is different, after so many years of implementation of the prefabricated system, many buildings have poor construction quality, inadequate maintenance and, in general, lack of comfort [4]. The replacement of many of these buildings began in the 1990s.

In Santiago de Cuba, these buildings, with more than 50 years of operation, without a systematic conservation and maintenance policy, present several aspects that can lead to potential seismic damage. Among them, we can mention the pathological damages in levels of affectation that compromise its structural response to strong earthquakes, as well as structural modifications due to the violations of the inhabitants [5]. For this reason, the community of specialists in the territory has been concerned about these buildings for some time.

To carry out more in-depth studies, research has been carried out so far, ranging from the characterization of the materials in the current operating conditions to the prediction of the seismic behavior of some buildings built with the prefabricated GPS system. The investigations have found that in elements with pathological deterioration, poor concrete quality and compressive strength decreases by 25.78% with respect to that prescribed in the original project [6]-[7]. Equally, evaluate the impact of some structural transformations [8].

On the other hand, they also conclude that, in three instrumented buildings, the values of the periods as a function of ambient vibrations correspond to periods in the range of those expected before the design seismic action, due to the deterioration of the stiffness [9]. Other studies validate these results, through the analytical path, using structural modeling [10]. They suggest that pathological damage to structural elements and joints, followed by weight and rigidity transformations, are the main aspects that affect the change in seismic behavior of said buildings, estimating potential seismic damage to them. Likewise, assess the seismic behavior in relation to soil factors and the possibility of overturning is appreciated [11].

Based on the above, it is necessary to define the probable structural performance of the entire sample of diagnosed buildings, through an evaluation of potential seismic damage. At the same time, it is convenient to carry out this evaluation quickly in the largest number of buildings, without having to carry out structural modeling.

At the international level there are various methodologies used to assess seismic vulnerability that could serve these purposes. Some revisions compare some of them, in terms of descriptions of pathological damage, the modifiers based on them, among other aspects. Concluding that they do not integrate a detailed and precise evaluation of pathological damages as a starting point for the evaluation of potential seismic damages, therefore, they do not fit the intended purpose [12].

These aspects are the basis for the proposal for a procedure for evaluating potential seismic damage in buildings built with the Great Soviet Panel prefabricated system. Which has as a starting point, in a first stage, the evaluation of pathological damage, according to its incidence in structural behavior; that is articulated in a second stage, with other aspects that cause seismic vulnerability. Likewise, the evaluation of pathological damage, in a detailed analysis, is embedded in the analysis of structural behavior.

II. Methodology

To propose the variables, indicators and sub-indicators that support the evaluation procedure of potential seismic damages in buildings built with the Great Soviet Panel prefabricated system, the primary analysis must be:

1. Define the pathological damages and their levels of affectation in the buildings.
2. Specify the aspects causing potential seismic damage in buildings.
3. Delimit the tasks that a detailed analysis must contemplate, with the aim of defining the incidence of aspects leading to potential seismic damage on the behavior and resistance of buildings.

In defining the pathological damages that affect precast concrete structures, there are different theories [13]-[15]. Among these authors there is consensus regarding the damages that affect cast-in-situ concrete structures, which are common to precast concrete structures, which are common to precast concrete structures because they are subject to the same requirements of structural mechanics and exposure to the environment.

There are pathological damages that in its initial stages can compromise SLS, such as humidity and organisms, however, when these are in an advanced stage, they can compromise ULS. For example, the appearance of organisms only affects the aesthetics and functionality of the structure in the initial stages of appearance, but in advanced stages they can affect its strength and rigidity, causing cracks to disintegration of the concrete.

Other damages, such as deformations, will always compromise the ULS, since residual displacements or slides, buckling or deflection, and possible distortions are the imminent cause of structural collapse. At the same time, if the structure already shows evidence of pathological damage such as corrosion or cracking, in its different levels of affectation, both its resistance and its rigidity will be affected to resist seismic action, therefore, they will to be damages that always compromise the ULS.

For the definition of the levels of affectation of pathological damages, various contributions were also evaluated [15]-[21], such as the methods for the evaluation of post-earthquake structures, as well as the damage indices [22]-[25].

It is considered in this research that, as a result of humidity, the level of affectation I, is manifested by humidity spots and small cracks with a width of less than 0.1 mm. The level of affectation II is when cracks with width between 0.1 mm-1 mm and efflorescence can appear, already in the level of affectation III the phenomenon of corrosion and mechanisms of disintegration of the concrete begins.

In the case of dirt and organisms, it is thought that they will have a level of affectation I, when they affect only the paint, with a change in color of the surface and accumulation of dust and soot. If mold and fungus are seen, the level of affectation is already II. When plant species appear that generate cracks and disintegration of the concrete, and even the corrosion of the steel can be generated, the level of affectation is III. But if these damages that are part of the SLS are in a level of affectation II or III, they already have manifestations that must be evaluated as damages that compromise the ULS, because the concrete begins to decrease its resistance.

As in the methods of evaluating post-earthquake structures, whenever deformations and inclinations, buckling of walls or columns, inclination of the floor system are observed, the damages are valued as severe; the deformations will always be evaluated for a level of affectation III, because as long as this damage exists, the structure may be close to collapse.

The cracks produced by the action of the loads, are characteristics of the concrete in the hardened state, being important the determination of the causes that cause them to define the suitable therapy. Likewise, there are hydraulic shrinkage and setting cracks, which appear in the plastic stage of concrete, just hours, days or weeks after the casting of the elements. But taking into account the exploitation time of these structures, it is considered that these cracks in such case, if they had their appearance, are no longer at a primary level of affectation. So for any type of cracks regardless of the origin, when assessing the damage, the same levels of damage are considered.

On the other hand, all the processes of deterioration of the reinforced concrete, independently if they cause alterations in the concrete (attacks of sulfates, attacks of acids, alkali-aggregates among others) or in the steel (corrosion by carbonation and diffusion of chlorides), give as a result, the decrease in the cross section of the steels, loss of mass, decrease in the mechanical resistance of steel and concrete, among others. Likewise, the manifestations of damage due to the disintegration mechanisms of concrete and corrosion of steel will be the same, since the evidences of these processes in advanced stages of damage are cracking of concrete, delamination of steel, disintegration of concrete. and decreased adhesion between concrete and steel. It is considered for a level of affectation I, the change of coloration, erosion of the surface, crisscross and small fissures with width less than 0.1 mm and rust spots. At level II, there is evidence of exposure of aggregates and cracks with a width of up to 1 mm and at level III, cracks with a width greater than 1 mm, detachment or bending of the concrete, delamination of the steel, loss of adhesion of the concrete with the steel bars.

The definition of the aspects that condition seismic vulnerability or potential seismic damage is based on taking into consideration the adjustments to large panel structures [26]-[30]. These factors are organized into two groups: soil conditions and pre-existing conditions. Soil conditions are evaluated through indicators such as: susceptibility to induced physical-geological phenomena (landslide and liquefaction), soil type and possibility of resonance. Within the pre-existing conditions, pathological damage to structural elements and structural joints, the quality of the elements and the execution, the type of structuring, the type of joints (form of realization, structural work and continuity), geometric configuration is contemplated, transformation in weight and stiffness, transformation in stiffness, transformation in weight and knocking effect. For the classification of potential seismic damage, the post-earthquake damage evaluation methods were taken into consideration [22], [25], [31]-[32].

In this way, there is the theoretical support, of the primary analysis, to assess the repercussion of the pathological damages and other aspects that lead to potential seismic damages, present in the buildings built with the Great Soviet Panel prefabricated system, in the structural response to an earthquake of great intensity. Likewise, in the diagnosis made by UNAICC (Cuba) to a sample of 200 buildings, it was evidenced that the pathological damages previously addressed appear, generating the same consequences [5]. Among the remaining aspects that condition potential seismic damage is those related to weight and rigidity transformations due to: panel and slab openings; elimination of panels, addition of dividing walls, water tanks and cisterns in mezzanines, also water tanks attached to the facades, filling of the latticework of façade panels, among others.

To validate the proposed procedure, the Delphi method was applied, with the participation of 15 specialists. All are civil engineers, 6 hold the scientific degree of doctors of science (40%), 6 have a master's degree in science (40%) and 2 have degrees in Earthquake Engineering (13.33%). Table 1 shows the distribution by institution and country.

Table 1.
Distribution of experts by institution and country.

Institution	Country	Quantity
Faculty of Civil Engineering of the Technological University of Havana	Cuba	1
Center for Seismological Research of Cuba (CENAIS)	Cuba	2
Project Company # 15 of Santiago de Cuba (EMPROY-15)	Cuba	2
Matanzas Projects Company (EMPAI)	Cuba	1
Faculty of Constructions. University of Oriente	Cuba	4
National Applied Research Company (ENIA)	Cuba	1
Associated Consultants CONAS	Cuba	1
Berkeley University	USA	1
Cruceiro University. Do Sur.	Brazil	1
REM+E INGENIERÍA WTC.	Mexico City	1

Source: Authors.

To delimit the tasks that a detailed analysis must contemplate, the Rapid Assessment by Dynamic Analysis methodology is taken into account [33]. It is concluded that the key aspects that distinguish the detailed analysis are:

- The calibration of the structural model considering the fundamental periods according to the environmental vibrations.
- Use of flexural stiffness modifiers according to regulations FEMA 273 [26] and code ACI 318-19 [34].
- The check of the joints between the structural elements.
- Reduction of the resistance of concrete and steel in elements with pathological damage.

III. Results

The bibliographic study and the validation with the experts, facilitated to achieve a procedure for the evaluation of potential seismic damages for the Great Soviet Panel prefabricated system where several aspects leading to potential seismic damages in the prefabricated structures are involved, including pathological damages in the joints and in the elements. structural. These pathological damages are evaluated according to the importance of the damaged joint or element, in the structural response of the building. Thus, even without performing a detailed analysis applying structural modeling, it is possible to obtain an evaluation that reflects the probable structural performance of the building.

The procedure consists of two stages. Stage I is the evaluation of pathological damage. Stage II is developed for two levels of analysis, primary and detailed, as shown in Fig. 1.

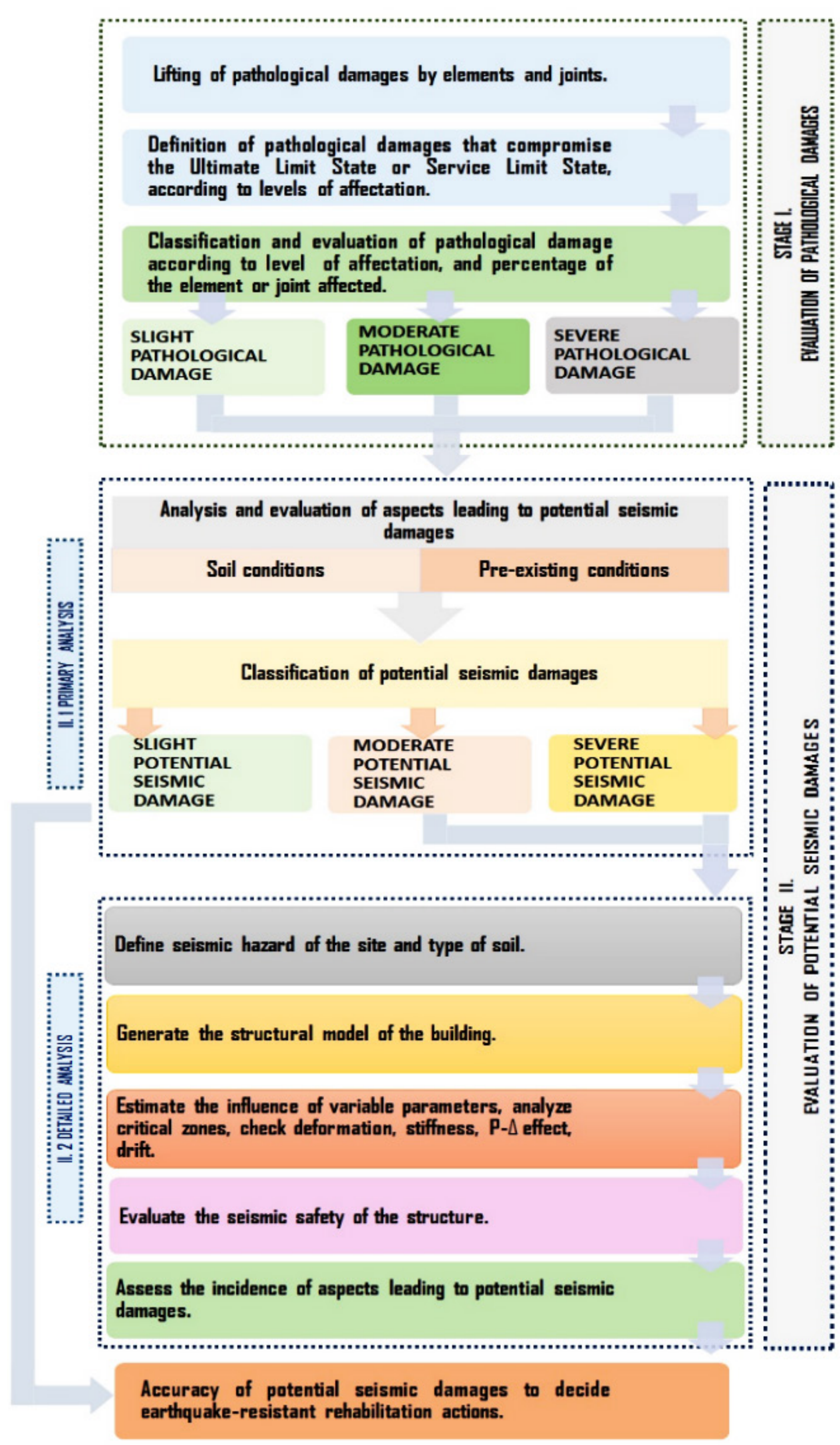

Fig. 1. Procedure for the evaluation of potential seismic damages for the earthquake-resistant rehabilitation of the Great Soviet Panel prefabricated system.
Source: [35].

The development of each stage is explained below.

A. *Stage I: Evaluation of the pathological damage in the building.*

It starts from the evaluation, by means of a score, of the pathological damages that each one of the structural components present. This score takes into account the percentage weight according to the importance of the structural components in the earthquake-resistant behavior. The structural components, their percentage weight and the maximum score that they can receive depending on the classification of the pathological damage they present, are detailed in Table 2.

Table 2.
Scores assigned by element or board.

Structural Component	Weighting coefficient	Classification of pathological damage		
		Slight	Moderate	Severe
		Assigned scores		
Panels and baseboards	20 %	7	14	20
Mezzanine* and/or deck slabs	17 %	6	11	17
Horizontal joints	23 %	8	15	23
Vertical joints	23 %	8	15	23
Foundation	17 %	6	11	17
Maximum score per classification		35	66	100

* The ± 0.00 level slab is also structural.
Source: Authors

Once the scores assigned independently for each of the structural elements and structural joints have been defined, these points are added to carry out the evaluation of the pathological damage in accordance with the provisions of Table 3.

Table 3.
Evaluation of pathological damage.

Assessment of Pathological Damage	
Structural elements	Score obtained
Slight	≤ 19
Moderate	20 - 36
Severe	> 36
Structural joints	Score obtained
Slight	≤ 16
Moderate	17 - 30
Severe	> 30
Building	Score obtained
Slight	≤ 35
Moderate	36 - 66
Severe	> 66

Source: Authors.

1) *General indications for the evaluation of pathological damage*

1. Thoroughly examine each component of the superstructure at all structural levels and define pathological damage to them.

   Table 4 shows a categorization of pathological damage to the superstructure, according to its impact on SLS and ULS, as well as the levels of structural involvement. In Fig. 2 some of them are observed.

Table 4.
Pathological damage to the superstructure and levels of involvement..

Pathological Damage		Levels of affectation		
		I	II	III
SLS	a) Moisture*	Moisture stains, small cracks with width less than 0.10 mm.	Cracks with width between 0.10 mm - 1 mm Efflorescence.	See e) or f)
	b) Dirt and organisms	Change in color of the surface, accumulation of dust and grime.	Mold and fungi.	Plant species.
ULS	c) Deformations* (arrows, buckling, warping and/or collapses)			Fissures or cracking mainly due to cutting, crushing or flaking, distortions up to buckling or fracture of longitudinal and / or transverse reinforcement, residual displacements and slides.
	d) Cracks or fissures*	Fissures with width up to 0.10 mm.	Fissures with width between 0.10 mm - 1 mm.	Fissures with width greater than 1 mm, detachment or bending of concrete, delamination of steel, loss of adhesion of concrete with steel bars. Exposure of the longitudinal reinforcement with or without buckling of it, crushing of the concrete.
	e) Mechanisms of concrete decomposition f) Corrosion of armor	Color change, surface erosion, criss-cross and / or small fissures less than 0.10 mm wide, rust spots.	Exposure of aggregates and cracks with width up to 1 mm.	Cracks with width greater than 1 mm. Detachment or buckling of concrete, delamination of steel, loss of adhesion of concrete to steel bars.

* They can also appear in the components of the superstructure due to problems in the foundations (See indication 5 of stage I).
Source: Authors.

a) Moisture(Level II) c) Cracks or fissures (Level III)
b) Dirt and organisms (Level III) d) Mechanisms of concrete decomposition and Corrosion of armor (Level III)

Fig. 2. Examples of pathological damage and levels of involvement.
Source: Authors.

2. The damages that compromise the ULS are those that will be taken into account in the classification, the rest define the therapeutic measures from the diagnosis stage. Unless these damages are in levels II and III or affect more than 50% of the elements, and are taken into account in the classification.
3. As the buildings are multilevel, it is recommended to define and quantify the pathological damage in each component of the superstructure for each level. When pathological damages appear with a level of affectation III, the entire area of the element or joint length, respectively, is taken as the affected surface or length. Then it is quantified throughout the building in order to define the classification of pathological damage for each type of component.

If several types of damage converge in one type of superstructure component, the classification is made according to representative damage. To define representative damage, the one with the highest level of damage or the one that affects the highest percentage of the component must be analyzed, taking the highest score. In the event that damages coincide with the same levels of affectation and percentage of the affected component, these will affect in the same way, and any of them may be representative.

4. The classification of pathological damage in the components of the superstructure is made according to the level of affectation and the percentage of affected surface of the element or percentage of the affected length of the joint.

- *Slight pathological damage*: A good condition predominates, the damages have a level of affectation I up to 50% and damage with a level of affectation II can occasionally appear in less than 20% of the area of the element or joint length.
- *Moderate pathological damage*: There are damages with a level of affectation I in more than 50% of the elements or joints; a level of affectation II between 20% - 50% of the element or joint; damage with an impact level III in less than 20% of the element area or joint length.
- *Severe pathological damage*: Damage with a level of affectation II predominates in more than 50% of the element area or joint length; Level III damage in more than 20% of the element area or joint length.

5. The classification of pathological damage to the foundation is carried out according to the damage observed in the superstructure (in case it is proven to be the cause), because many times the damage to the foundation is not directly appreciated.

- *Slight pathological damage*: If punctual damp spots appear on 1st level panels, due to ascending capillarity.
- *Moderate pathological damage*: In the event of occasional settlements, vertical cracks in the panels and in the vertical joints. Generalized wet spots.
- *Severe pathological damage*: Collapse and horizontal cracks in the panels. Water penetration.

When pathological damage corresponding to three or two classifications occurs, their assessment will be determined by the higher classifications.

6. If the building does not show any pathological damage to the structural components, it goes directly to stage II. If pathological damage appears in the superstructure, which regardless of its extension creates instability and there are generalized settlements in the foundation, the classification of pathological damage in the structural components should be taken as severe.
7. If the exterior transverse panels of the 1st and 2nd structural levels and the vertical joints between them, present pathological damages that compromise the ULS, the classification of the pathological damage in the panels and the vertical joints will be determined for a category higher than that obtained when applying the procedure.

B. *Stage II: Evaluation of the potential seismic damage of the building*

1) *Primary analysis*

It starts with the evaluation by means of scoring the different aspects that lead to potential seismic damages, which are broken down into indicators and sub-indicators. This score takes into account the percentage weight according to its incidence in seismic vulnerability. The maximum score that they can receive is detailed in Table 5. Once each one has been evaluated, these points are added to carry out the classification of potential seismic damage in the building, in accordance with the provisions of Table 6.

Table 5.
Scores assigned by indicators and / or sub-indicators.

Variables (aspects that generate potential seismic damage)	Indicators and sub-indicators		Assigned scores
Soil conditions	Susceptibility to induced physical - geological phenomena (landslide and liquefaction)	Insignificant	0
		Medium	3
		High	6
		Very high	10
	Soil type	"Soils A and B" (competent rock)	0
		"Soils C and D" (soft rock)	7
		"Soils E" (soft clays)	14
		"F soils" (liquefiable soils)	20
	Possibility of resonance	Te ≠ Ts *	0
		Te ≈ Ts *	10
Pre-existing conditions	Pathological damage to structural joints	Severe damage	15
		Moderate damage	10
		Slight damage	5
		No harm	0
	Pathological damage to structural elements	Severe damage	10
		Moderate damage	6
		Slight damage	3
		No harm	0
	Quality of elements and workmanship	Bad	7
		Regular	4
		Good	0
	Structure type	Crossed	1
		Transversal	2
		Longitudinal	3
	Joint form	Seca	3
		Damp	2
	Joint structural work	Articulated	3
		Recessed	2
	Position of continuous joints	Vertical or horizontal	2
		Horizontal and vertical	1
	Geometric configuration	Asymmetry in plan	2
		Elevation asymmetry	3
		Symmetry in plan and elevation	0
	Transformation in weight and stiffness	Insignificant	0
		Medium	1
		High	2
		Very high	3
	Transformation in stiffness	Insignificant	0
		Medium	2
		High	3
		Very high	4
	Transformation in weight	Insignificant	0
		Medium	1
		High	2
		Very high	3
	Tapping possibilities		2
Maximum score			100

* The term Te is the fundamental period of the building and the term Ts is the period of the ground. To the extent that the two periods equal their values and their relationship approaches unity, the building enters into resonance. With only a few thousandths of a second difference, the possibility of the occurrence of the phenomenon must be assessed. Source: Authors.

Table 6.
Classification of potential seismic damage.

Structuring of Large Panels	
Classification of potential seismic damage	Score Obtained
Slight	≤ 25
Moderate	26 - 45
Severe	46 - 100

Source: Authors.

2) *General guidelines for evaluating potential seismic damage*

1. Inspect the entire building and verify if it presents structural modifications as detailed below:

- Weight transformations (addition of water tanks, addition of masonry dividing walls in the multipurpose area, among others).

  Insignificant: Weight increase up to 95 kN.

  Medium: Weight increase between 96 kN - 190 kN.

  High: Weight increase between 191 kN - 285 kN.

  Very high: Weight increase of more than 285 kN. Also when the location of the elements that generate weight increase have asymmetry in plan and elevation, as well as concentrations of weight in upper floors.

- Stiffness transformations (elimination and opening of panels and slabs). The panel openings that are considered are those made for door openings and those of the slabs to place interior stairs.

  Insignificant: No panel or slab opening or removal.

  Medium: Interior cross panel openings and slab openings.

  High: Longitudinal panel openings.

  Very high: Exterior cross panel openings. Elimination of panels and slabs.

- Weight and stiffness transformations (closing of lattices and doors with masonry or concrete).

  Insignificant: In less than 12% of the apartments.

  Medium: When between 13% - 50% of the apartments.

  High: When between 51% - 75% of the apartments.

  Very high: between 76% - 100% of the apartments.

2. When pathological damage to elements or joints causes collapse or is close to it, the maximum score for potential seismic damage will be 100.
   According to the classification of potential seismic damages, its evaluation is carried out:

- *Slight potential seismic damage*: The structure substantially maintains the original strength and stiffness. There are no permanent drifts. Fine cracking in walls < 1.0 mm wide. Coupling beams experience cracking < 3.0mm wide. Cracks < 1.0 mm wide in the joints between walls. Cracking less than 1.0 mm along joints between slabs. Small settlements (≤ 10 cm) and negligible slopes (< 1º).

- *Moderate potential seismic damage*: The structure retains residual stiffness and strength at all levels. Permanent drifts and slippage appear at the joints between slabs, with local crushing and spalling at the joints. Cracks < 2.00 mm around openings. Crushing and cracking < 2.00 mm in panels. Coupling beams with extensive (< 6.00 mm) bending and shear cracking and / or crushing, although concrete generally remains in place. Total settlements between 10 and 20 cm. Inclinations between 1st - 2nd. Extensive cracking of the slabs (< 6.00 mm wide), with local crushing and spalling. Building repair can be financially difficult.

- *Potential severe seismic damage*: The structure has low residual strength and stiffness. Permanent drifts. Cracks > 2. 00 mm due to bending and shear. Extensive crushing and buckling of the reinforcement of the panels and coupling beams. Slippage and failure in joints. Crushing in joints between slabs. Cracks > 2.00 mm around openings. Large settlements (> 20 cm) and slopes greater than 2º. The building is close to collapse.

3) *Detailed analysis*

You can decide to develop this analysis directly on a particular building or depending on the results of the classification of potential seismic damage (moderate or severe) in the primary analysis. It is mandatory to have developed stage I, which would provide a detailed survey of pathological damage in the building. The structural model is generated with any computer software and different linear analysis procedures can be used to calculate the seismic force. The possibility of using non-linear analysis procedures in particular cases is not ruled out.

The tasks that make up this detailed analysis are:

B.1. *Definition of the seismic danger and characteristics of the soil.*

B.2. *Generation of the building variant, evaluating the modifications to the construction system.*

The project data relative to the geometry (modulations in plan, number of floors, props) must be known; permanent loads and temporary loads. It is necessary to include in the model, all the structural elements or not, that provide rigidity and mass. Likewise, the characteristics of the construction materials must be specified. The modulus of elasticity of precast concrete can be calculated by the expression recommended by the code ACI 318-19 [34], but with a reduction greater than 40%, for buildings made of precast panels [36], on the other hand, it can increase by 20% as the seismic action is of short duration. The shear modulus G is obtained from the modulus of elasticity E, assuming a Poisson's coefficient = 0.17 for concrete.

When a non-linear analysis procedure is used, it is essential to characterize the materials, through a destructive and non-destructive testing plan, of the concrete and steel. If a linear analysis is performed, material properties predefined by historical data or information available in the original drawings can be used. Likewise, the rigidity of the structural elements must be reduced, taking into account the cracking of the sections during the initial stage of the seismic force action [26], [34].

The assessment of the modifications to the construction system, which may be related to weight transformations and rigidity transformations, as well as the pathological damages detected, allow defining a set of parameters, whose variations will influence the dynamic behavior of the variant of edifice. For the inclusion of pathological damage, several routes can be used, assessed in each particular case:

- Apply stiffness reductions to damaged elements iteratively and assume cracked sections.
- Elements with moderate or severe pathological damage must be decoupled from the structural model.
- Release of degrees of freedom in the elements that have pathological damage in levels of affectation III in the areas of the joints.
- Redefine the geometry of the damaged sections.
- To be able to reproduce the damages that the structure presents through specialized software.

Calibration can be done through iterative or non-iterative methods, manual or computerized. In the model calibration process, in a building with pathological damage and transformations in weight and rigidity, it must be obtained that the period of the generated model (T generated model) in relation to the period according to environmental vibrations (T environmental vibration) is:

T generated model ≈ (1.02 ~ 1.15) T environmental vibration, as it is a building of large prefabricated panels [37]-[38].

B.3. *Influence of the selected variable parameters on the dynamic behavior of the building variant.* Global control parameters such as:

- Building weight.
- Basal shear and seismic coefficient, corresponding to the two main directions of seismic action.
- Reactions at the base of the structure.

B.4. *Analysis of the critical areas of the structure, by checking the normal and tangential stresses and checking the structural joints.*

B.5. *Check for deformation and stiffness.*

B.6. *Evaluation of seismic safety.*

B.7. *Assessment of the incidence of aspects leading to potential seismic damage on behavior and resistance.*

IV. Conclusions

From all the analysis carried out, it can be concluded that:

- The set of variables, indicators and sub-indicators contemplated by the procedure in the primary analysis; classifications of pathological damage to the superstructure; the weighting factors by structural component to evaluate the pathological damage, as well as the aspects that condition potential seismic damage; they were validated through the Delphi Method.
- The designed procedure is an instrument for decision support regarding the earthquake-resistant rehabilitation of the Great Soviet Panel prefabricated system. The inclusion of a first stage focused on the evaluation of pathological damage in structural elements and joints is an essential feature that distinguishes it from conventional approaches to assess potential seismic damage. In the evaluation of pathological damage, the importance of the element or joint affected in the seismic response of the building is taken into account.
- The checking of the structural joints and the calibration of the models considering the fundamental periods according to the environmental vibrations, are cardinal aspects to assess the incidence of the aspects conducive to potential seismic damages, on the resistance or rigidity of the structure.
- The adaptation of the procedure for the evaluation of potential seismic damages in other prefabricated systems based on large panels can be considered. The modification should focus fundamentally on redefining the weighting factors according to the importance of the structural component in the seismic response of the structure.

Acknowledgements

We thank all the specialists who made up the panel of experts and who contributed their opinions to validate this procedure. Likewise, Lic. Cecilia María Halley González for the reading and perfection of the manuscript.

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Yamila Concepción Socarras Cordobí. Graduated from Civil Engineering. Master of Science. Doctor of Technical Sciences, all of them from the University of Oriente (Cuba). From 1992 to 2001 he worked in the Company of Various Works Projects, initially attached to the State Committee for Economic Collaboration and later to the Ministry of Construction. From 2001 to date she is a professor at the Universidad de Oriente. Currently belongs to the Faculty of Construction. His research interests include: precast, earthquake resistant structures, and construction pathology. https://orcid.org/0000-0002-3198-3543