HOSPITAL SYSTEM VULNERABILITY TO A MODERATE EARTHQUAKE

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ABSTRACT:

This research aims at proposing to the technical manager of a hospital, a method for assessing the vulnerability of the hospital system in the case of a moderate earthquake. A primary case study on a Hospital Centre has allowed us to define the methodological basis. Also, it concludes to the need for a systematic method due to the complexity of hospital system and the specific involved knowledge. This method exits: "Screening method" but it is applicable to the context of a major earthquake, where the main objective is to save life, while ours is to guarantee the continuity of hospital services. Other aims are to adapt this method in order to introduce the concept of a moderate earthquake, to take into account the environmental interactions of the hospital system and to improve the knowledge base. Subsequently, a software tool was developed to facilitate the implementation for the technical manager.

KEYWORDS: Vulnerability, moderate earthquake, method, lifelines, hospital system.

1. INTRODUCTION

During the earthquake of 1994 Northridge in California, several major hospitals had to be evacuated, not because of structural damages, but because of the failure of emergency generators, air regulators and the fall of ceilings fixtures. In Canada, the 1988 earthquake in Saguenay, the strongest earthquake in eastern North America recorded during the last 50 years, has caused little structural damages. The vast majority of injuries, damage and financial loss had been caused by the failure of operational and functional building components [1].

The percentage of the cost of non-structural elements at a total cost of construction is much higher in hospitals than in other buildings. Indeed, the non-structural elements represent about 60% of the value of residential housing, whereas for hospitals values range are from 85% to 90%, mainly due to the cost of medical equipment [2].

The seismic risk management requires a multidisciplinary process [3], in particular engineering, and it exhibits a multi-steps cycle in which the vulnerability assessment is a very important one [4].

The overall objective is to find relevant information to assess hospital performances in seismic zones in order to detect the actions needed to reduce the vulnerability for a moderate earthquake. While in countries where seismicity is low or moderate, the collapse of hospitals has not been occurred, these establishments had suffered significant non-structural damages that have put hospitals out of service.

Our research is directed towards understanding the hospital system, including hospital services, in order to enable the hospital technical manager to better prevent potential functional danger in case of a moderate earthquake. Based on a case study, realized on a Hospital Center, we define the methodological requirements which are influenced by two key parameters: the cost and the competence.

This document successively presents the methodological approach for the case study and the main conclusions, sums up the characteristics of an existing method, very close to our problematic, and exposes the evolution of this one to adapt it to the vulnerability assessment of the hospital system in the case of a moderate earthquake.

2. STATE OF THE ART

Most existing methods and approaches of vulnerability assessment focus on the structural part:

1- Probabilistic approach using Damage Probabilistic Matrix [5],

2- Deterministic approach using vulnerability or fragility curves[6],

3- Classification of structure vulnerability using vulnerability indices, the most representative [7]: Wind cross (Cv), quality of materials (Mq), Irregularity in elevation (Ie), Irregularity in plane (IP), Quality of execution (Eq), Intervention on buildings (Is), Short column (Cs), soil conditions (Sc)…). The vulnerability index (V) for each structure is equal to the sum of products at all levels of assessment of vulnerabilities on their weights.

In return, the vulnerability of non-structural elements or functional ones is briefly developed, aside fault, causes and events trees.

3. NOTION OF MODERATE EARTHQUAKE

The structures are designed and built against the major earthquake (Statutory), but through the whole structure's life this major earthquake has a little probability to occur. On the other hand, a moderate earthquake has a high probability to occur, and even several times during the building's life. In this context we can distinguish a moderate earthquake of the major one in relation to the responsibility of the State and the technical manager.

1- State's responsibility: usually the State takes care of major natural disasters (against property) or humanities (against persons); otherwise, it is responsible of large scale disasters that exceed individuals' or society capacity (floods, fires, earthquakes…).

2- Technical hospital manager's responsibility: The technical hospital manger is a person liable when the earthquake doesn't reach the regulatory level, when it puts down necessary services provided by his establishment. Effectively, the hospital manager is responsible for providing services, at least, of which critical ones after a non-major earthquake.

Furthermore, after a major or catastrophic earthquake, injuries will be transported to the nearest region that have suffered less damages, i.e. which have suffered a moderate earthquake.

4. VULNERABILITY ASSESSMENT PROCESS

The approach that has been used for hospital vulnerability assessment, developed in our case study, is organized as follows [figure 1]

4.1. Characterize Hospital System

A hospital is a very particular building, in its structure as well as in its organization involving a very complex industrial process. This stage aims at defining to an exhaustive way the hospital's organization, i.e. the medical hospital corps and all attached services [8].

Generally, components constituting a hospital are classified as follows:

- Structural system (frames, beams, colons, floors…)
- Functional hospital system (patients' flow, units' care, sterilization's ones…)
- Technical hospital system (lighting, heating, air conditioning, elevators…)
- Biomedical system (diagnostic equipments, therapeutic equipments…).

4.2. Identify Critical Systems

After the earthquake, the technical hospital manager is responsible for ensuring the continuity of services, and then the question is: how much hospital systems, required for emergency services, are critical? Several visits to the studied Hospital Centre, in cooperation with its technical staff have allowed us to characterize these critical services such as the lifelines (water, electricity, oxygen and void…).

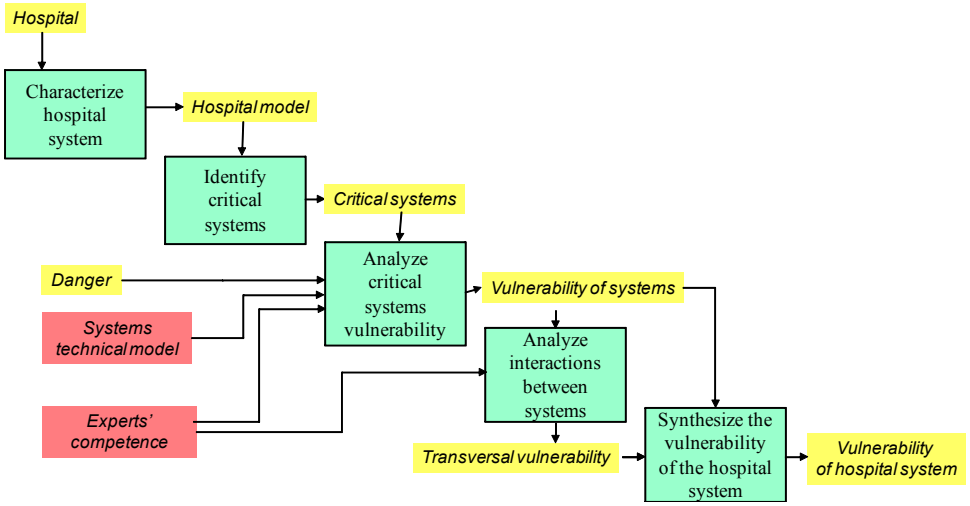

Figure 1. Process of hospital system vulnerability analysis

4.3. Analyze Critical Systems Vulnerability

The analysis at a primary level is based on visual remarks, favorable or unfavorable, in relation to the seismic response of each component of every critical system. This analysis is similar to "walk-down" one [9].

Eventually, scoring the vulnerability of a system essentially depends on our skill.

Analyze interactions between systems (transversal vulnerability)

Considering that often networks and pipelines are grouped in cages or under the ceiling, falling or damaged one can be affect the other networks. These interactions are, first of all, analyzed in a visual way. Secondly, the interactions guessed dangerous are subject to a deeper analysis.

Synthesize the vulnerability of the hospital system

The judgment of the vulnerability of vital networks, and consequently the vulnerability of the hospital system are done by the analyzer, based on points favorable compared to those unfavorable. The judgment remains, at the limit, subjective, meaning it may be different from an analyzer to other one.

Vulnerability Analyses – Case Study

Results of approach proposed

At the end of this diagnostic vulnerability analysis, we find, as experts, that constructive dispositions against the effects of moderate earthquake are incoherent, insufficient and inadequate [figure 2]. Without describing in detail the result of this experiment, let us resume the main conclusion:

- This judgment is very subjective: two experts could produce quite different results.
- Without a specific organization this diagnosis could be very long.
- It requires expert knowledge, usually not available in the technical services of the hospital
- More detailed are the results, more complex is the analysis.
- The cost: To have recourse to a specialist (office) it is expensive.

In conclusion, the need for assistance methodological is very real because

Figure 2. Transformer on rolling support and bottles of air without strap

Advantageously, this methodological basis previously is already existent: "Screening Method"[10].

Screening Method Description

This is a method developed by the Multidisciplinary Center for Earthquake Engineering Research (MCEER) during a program to reduce earthquake losses [11], defined as follow:

"This method recapitulates several years of research to develop a detailed methodology to evaluate and improve the reliability of systems equipment functional after the earthquake. It is envisaged that this method be used by engineers, asset manager, owners, technicians and others interested in evaluating and improving the functional capacity of systems and equipment. The approach is quite simple as it is described below:

1- Systems Definition: Requires input from appropriate facility operators and engineers to identify which systems are required fore life-safety purposes and which systems are required for normal operations. For each system, graphically sketch system process in a logic diagram, identifying critical components, system dependencies, and redundancies.

2- Evaluation of Individual Components: perform a rapid visual screening inspection of each of system components.

3- Systems Evaluations: Develop the scores for each subsystem and system in conjunction with the logic diagram using the scores for the individual components. The logic diagrams will help to identify weak links in the system.

The scoring methodology for an individual component uses the following logic:

1- Each component is assigned a basic score that is a function of the performance history of that type of equipment, and the seismicity of the site.

2- The basic scores are modified by Performance Modification Factors (PMFs) which indicate the decrease of reliability due to specific configurations or details that may be present in an equipment installation.

3- The evaluation and checklist are completed such that the basic score and all applicable PMFs are identified.

4- The equipment item is assigned a score equal to its basic minus the largest (worst case) applicable PMF."

Advantages and Drawbacks of Screening Method

Screening Method allows a rapid assessment of the seismic reliability, neither very strict nor very detailed, is intended to industrial and nuclear fields. However, it can be extended to urban areas (buildings) because in some types of buildings are found in equipment, systems (networks) more or less similar to those in factories. For example hospitals include systems is quite complex, biomedical (network oxygen, avoid…) or technical (water, electricity, air conditioning…).

The Seismicity Site

In the method, the seismicity of the site is divided into four zones, corresponding to several intensity of a major earthquake.

The Localization of Component

The method divides the building into three thirds (lower, middle, upper), whatever the height of the building (the number of floors),

Dependency of PMFs

PMFs are considered as independents, but it seems that this is not necessarily the case. For example, if the anchor is defined as inadequate and the component is timeworn, it is obvious that the damages are augmentatives.

Evolution of this Method

We propose to adapt this method to our problematic, into two directions :

1. The knowledge base

Corresponding with our main hypothesis named a moderate earthquake, we consider only one seismic zone. This hypothesis leads to simplify the generic form of each critical component.

We propose a specific approach to enrich the data base of component, especially when there is a lack of disaster data. In order to systemizing the analyses the behavior of a component in case of earthquake, an guide based on its main characteristics (geometry, mass, materials, type of anchorage, functionality, …) allow to defined the score of this generic component.

2. The method itself

Specific adaptation of the method are added to take into account :

- The ageing of the component.
- Cumulative effect of PMF
- The importance of moderate earthquake is considered at the project level likewise the site effect.
- The weight of the location of a component in the building depends on its height.
- Capacity of defining generic model of a system, in order to accelerate the application.

5. CONCLUSION

The objective methods that treat the vulnerability functional of buildings are rare relatively to those that focus on the structural vulnerability. Even when a methodological support exists, another difficulty appears for the achievement of the method, it is the insufficiency of knowledge (shortcoming of data). Beside, the data available are often come from a major earthquake more than a moderate one.

This method is dedicated to the technical staff of a hospital, giving them the ability to draw up a rough analysis of the vulnerability of the system. This short cut allows them to gain time and money, and then they will have recourse to specialist only for specific and critical analysis.

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