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# SEISMIC VULNERABILITY OF NONSTRUCTURAL COMPONENTS OF HOSPITALS

**Mohammad HOSSAIN NAZER[1], Fariborze NATEGHI ELAHI[2]**

## SUMMARY

1971 San Fernando and 1972 Managua earthquakes indicated that seismic design of nonstructural elements must be considered. Some researches signify that in future earthquakes at least 50% of losses are due to nonstructural elements loss. One of the most important buildings that must be safe and operational during and after earthquakes, are hospitals and heath care facilities. Although from 1970's and particularly after 1985 Mexico earthquake, seismic resistant design of structures have considered carefully but nonstructural components in buildings specially in hospitals have suffered serious damages during resent earthquakes.

This research is about vulnerability of nonstructural components in hospitals and health care facilities. Case study was performed and results were obtained. It is based on 1994 and 1997 NEHRP provisions and with visual inspection procedure of ATC 3-06. The hospital used for this particular study has 1000 beds and contains the most advanced medical instruments and it's construction is ended in 2001. It has improved and advanced emergency water and power supply reservoirs. This research indicates that most of the nonstructural components of the hospital namely, architectural, mechanical, electrical and medical gas systems have not been designed accordingly and are therefore, vulnerable.

## INTRODUCTION

Lessons learned from past earthquakes indicate that hospitals and health care facilities are of the most important facilities that must remain safe and operational after earthquakes. If the structures of hospitals remain useable after earthquakes but damages to nonstructural elements and equipments be so sever that make them inoperable, practically the whole hospital could not be operable and so it is unusable when it is most needed.

In 1999 ChiChi Taiwan earthquake , damages to the structure of Shiu-Tuwan hospital was not so sever but because of damages to nonstructural equipments and making them inoperable , the whole hospital was closed . It was constructed only two years before the earthquake.

[1] Research Engineer ,International Institute of Earthquake Engineering and Seismology,Tehran, Iran.Email: mhnazer@iiees.ac.ir

[2] Professor, International Institute of Earthquake Engineering and Seismology, Tehren, Iran. Email: nateghi@iiees.ac.ir

In new hospitals and healthcare facilities about 80 percent of the cost is for nonstructural elements and equipments of them FEMA150 [1].

This paper is about seismic vulnerability of nonstructural components and equipments of hospitals. This research is based on 1994[2] and 1997 NEHRP [3] provisions and with visual inspection procedure of ATC 3-06[4]. The case study of the research is a 1000 beds hospital, and it is on of the most equipped hospitals of Iran.

## STRUCTURES AND NONSTRUCTURES OF HOSPITALES

Health care facilities have different kind of architectures and structures. Although it could be divided in five types: urban medical centers, large general hospitals, community hospitals, special hospitals and convalescent homes.

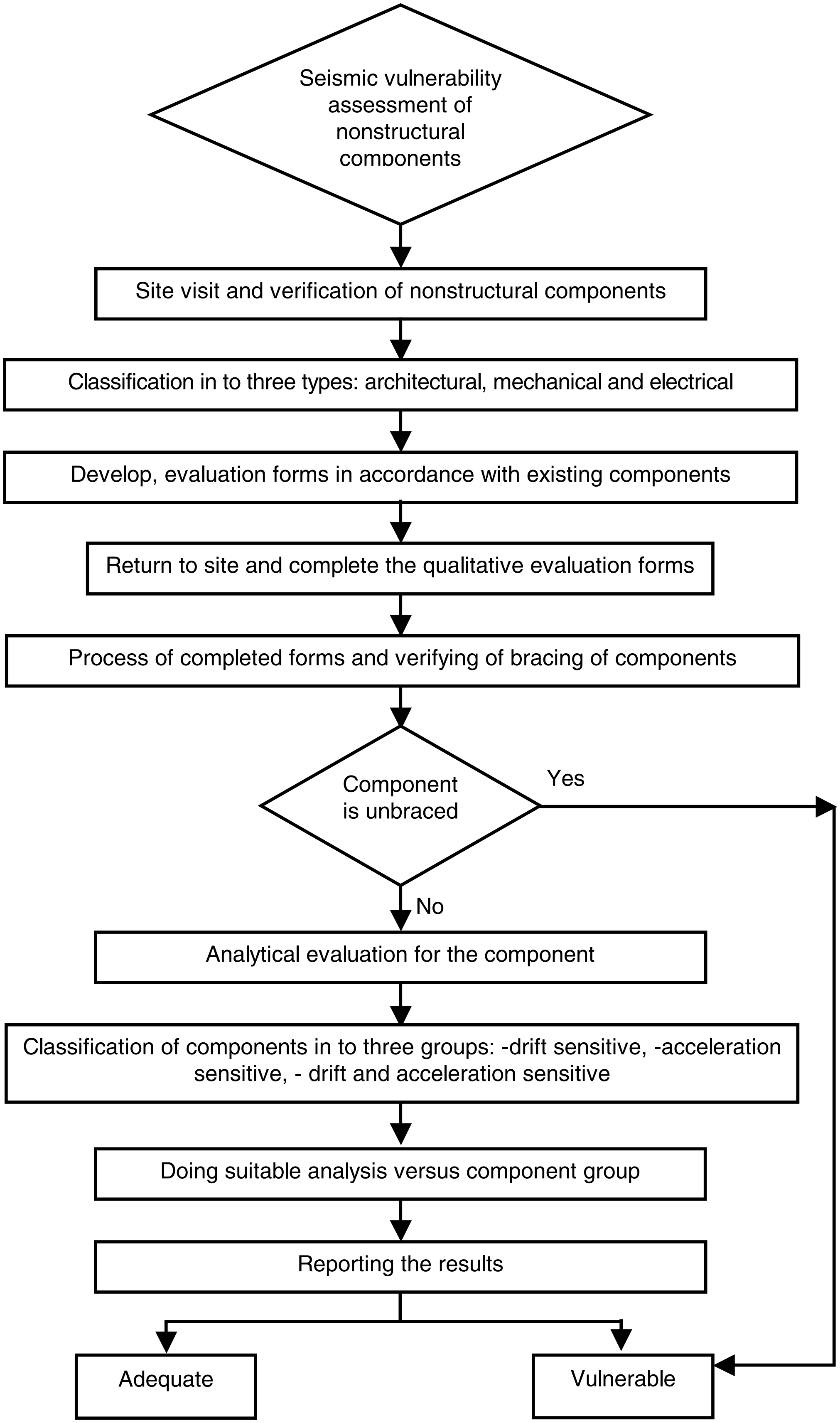
Each type of hospitals has different types of difficulties related to earthquakes. They are constructed in years and so have different ages. Even hospitals and health care facilities that have been constructed after 70's and regarding new provisions, during earthquakes like Mexico 1985, have suffered very hard damages. The basic problems affecting the seismic performance of health care facilities areFEMA150[1]:-building form irregularities, -discontinuities in stiffness of structures, -inadequate diaphragms, -structural connections and nonstructural attachments, -effect of nonstructural components on structures: even in structures that are designed with regularity in stifness, location and design of nonstructural components may change the stiffness of the structure .For example the location of an element like a nonductile core of a staircase or elevator in a building or infill walls , between ductile columns; makes the ductile elements behave as nonductile elements.-Damage to nonstructural components and equipments in health care facilities makes them inoperable. Although structures of hospitals may have minor damages, but damages to nonstructures could be sever.

In 1987 Whittier Narrows earthquake in Los Angeles, from 116 hospitals more than 20 of them had sever damages to nonstructural elements. Damages to nonstructural components and elements in 400 beds Shiu-Tuwan hospital in 1999 ChiChi Taiwan earthquake, was so hard that it was closed and unusable.

Vulnerability of equipments in hospitals depends on: lateral forces and drifts, main periods of electrical and mechanical equipments, supports of equipments, emergency reservoirs, and mechanical and electrical equipments lines crossed over expansion joints of structures, and site interaction. In health care facilities egress ways are most important and must remain open and safe after earthquakes.

## PROCEDURE OF THE WORK

Defining of seismic vulnerability of equipments and nonstructural elements in hospitals in this paper is based on 1994 and 1997NEHRP provisions. The procedure of the work is as shown in the following diagram:


Seismic vulnerability assessment of nonstructural components
Site visit and verification of nonstructural components
Classification in to three types: architectural, mechanical and electrical
Develop, evaluation forms in accordance with existing components
Return to site and complete the qualitative evaluation forms
Process of completed forms and verifying of bracing of components
Component is unbraced
Yes
No
Analytical evaluation for the component
Classification of components in to three groups: -drift sensitive, -acceleration sensitive, - drift and acceleration sensitive
Doing suitable analysis versus component group
Reporting the results
Adequate
Vulnerable

## THE CASE STUDY

The hospital that has been studied is 1000 beds and is beside a medical university. It has been constructed during thirty years.

The structure of main buildings is braced steel structure. The height of almost all flours is 4 meters, except the middle flour that is 2.5 meter high. This will cause a stiffness irregularity in height of the structures. Part of the departments of the hospital in plan, is with U and T forms and their plan is re-entrant corner plan forms.

## MECHANICAL ROOM AND EMERGENCY RESOURCES

The mechanical equipments room of the hospital is braced steel structure and without any flameproofs cover and in case of fire is vulnerable. Water of the hospital is supplied by city water resources, but as emergency water supply, there are three underground water concrete tanks. The usage fuel of the system is natural gas, and related equipments are constructed in an open site. The structure of the emergency power station is a single story concrete structure.

## NONSTRUCTURAL ELEMENTS OF THE HOSPITAL

Depending on 1994 and 1997 NEHRP, the nonstructural elements of the hospital are divided in architectural, mechanical and electrical components. But because of the importance of medical equipments and accessories, it is classified in a separate type of components.

## VULNERABILITY OF ARCHITECTURAL COMPNENTS

In this case study, in architectural type nonstructures, vulnerability of exterior walls and facades, glass windows, canopies, storage cabinets, suspended ceilings and interior nonstructural walls and partitions have been studied. The main exterior facing of the hospital is made from preconstructed concrete panels. It is connected to the main structure by preinstalled plates that are welded to plates that are installed in the structure concrete. These panels are not designed for drifts of the structure and so they are vulnerable. Figure 1 shows a sample of the panel:

Figure 1: Preconstructed concrete exterior panels

## MECHANICAL AND ELECTRICAL COMPNENTS

In this study vulnerability of mechanical and electrical equipments of the hospital, like steel storage tanks in upper stories, HVAC systems and duct works, cold water producing units and piping, piping, fire detectors and extinguishers, boilers, absorbing chiller units, high temperature shriller washing machines, uninterruptible power supplies (UPS) systems, emergency power generators and substations, and elevators have been studied.

### Boilers

Boilers of the hospital are installed in the mechanical equipments room and on the ground flour. They produce 400 centigrade degrees steam water for air conditioning chillers. Although they are well constructed for working in high temperature, but they are not bolted to their foundations and are vulnerable. Figures 2 and 3 show one of the boilers of the hospital and its basement:

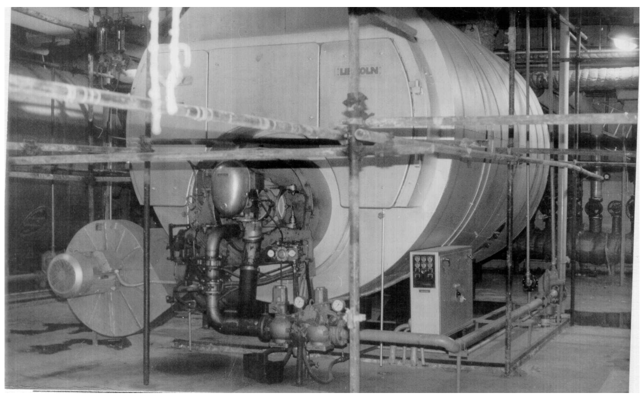


**Figure 2: One of the boilers**

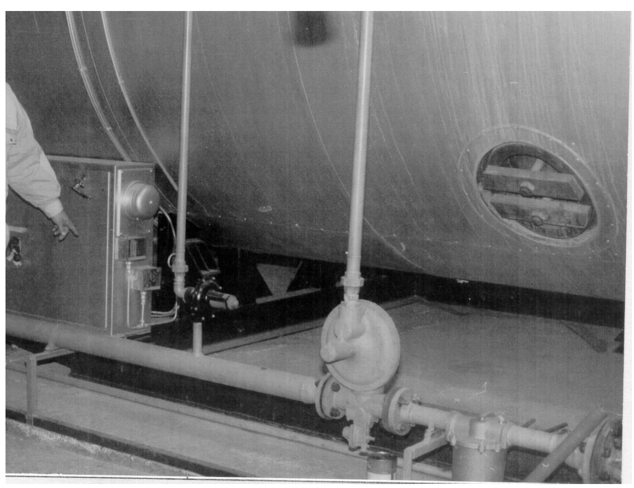


**Figure 3: Attachment of the boiler**

### On ground steel storage tanks

In the hospital on the ground flour in the mechanical equipments room there is a separated room for medical gas tanks. As seen in figure 4 these tanks are not bolted to the ground a so during an earthquake it could topple and slide, so they are vulnerable:

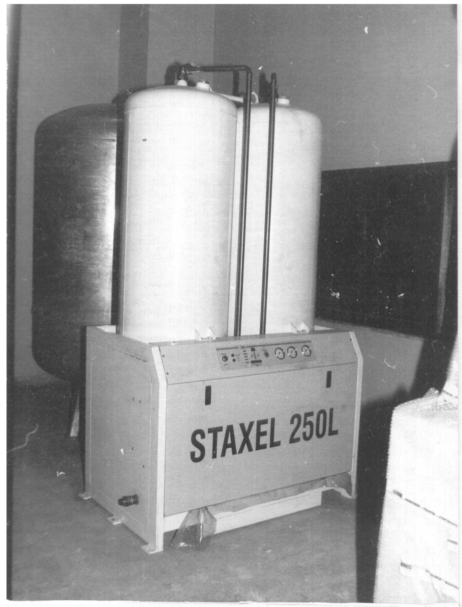



**Figure 4: Medical gas tanks**

**Power generators**
Because of the importance of the hospital and uninterrupted working, emergency power for using in all departments has been supplied. The power generators room is on the single story building and beside the hospital. Each one of the power generators engine and its generator is installed on one single foundation; this prevents unbalanced settlements of the different parts of the generator, figure 5. For fuel supply of the generators, manual pumps have been installed, so the fuel can be supplied even if the electrical fuel pump is damaged during and earthquake, figure 6. Power generators are well installed on vibration isolators, but no seismic clamps have been installed and so they may slide during an earthquake and this may cause damage to the pipes and stacks and make damages to the power generators figure 7.

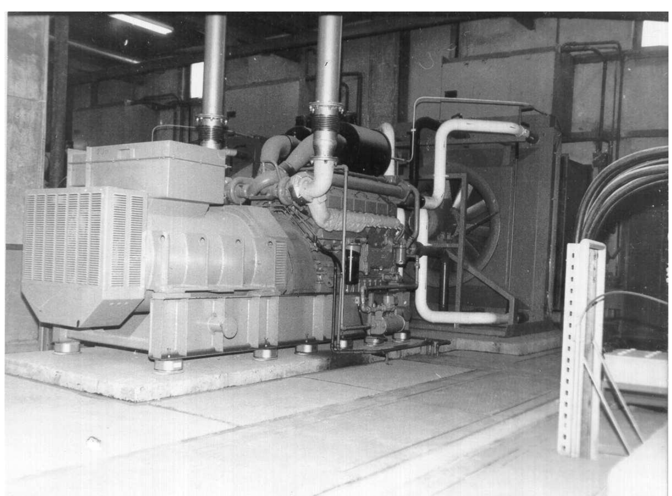


**Figure 5: Power generator on single foundation**

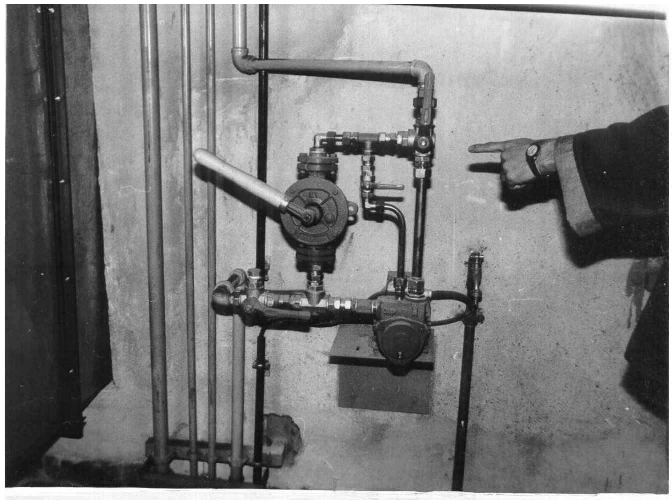


**Figure 5: Power generator manual fuel pump**

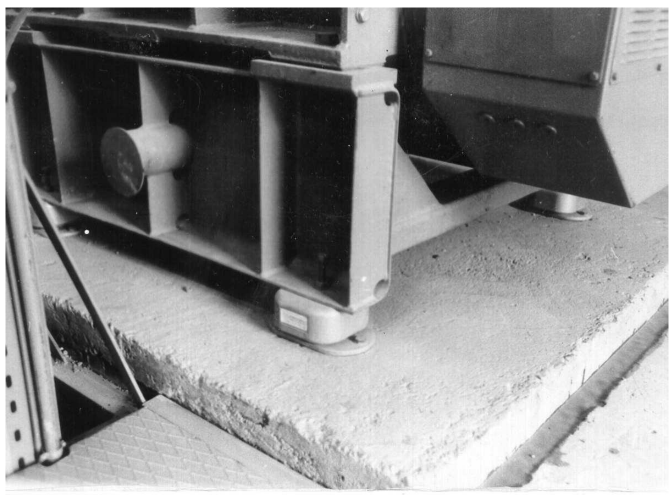


**Figure 7: Power generator vibration isolators**

## MEDICAL EQUIPMENTS

Medical equipments are of the most important accessories of the hospital, accessories like CT scan, radiology instruments and MRI scan equipment and related control panels.

The CT scan of the hospital is in the 7th floor and is placed on the floor without and bracing or bolts. Because of the heavy mass of the instrument, during an earthquake it may slide and this cause damages to it and the supporting floor, and so it is vulnerable, figure 8. The control panel of the CT scan is on four wheels and without any slid lock and its large displacement during earthquake cause damage to it and its connections, figure 9.

**Figure 8: CT scan of the hospital**

**Figure 9: The control panel of the CT scan**

To maintain the medical gas for surgery rooms and different departments of the hospital, high pressure pipes have been used. These pipes reach medical gas to special panels in surgery rooms, figure 10. As it is seen in the figure the panel can move and round and has no any kind of bracing to avoid large displacement during earthquakes and so it is very vulnerable.

**Figure 10: The medical gas panel in surgery room**

## CONCLUSIONS AND RECOMENDATIONS

Architectural nonstructural elements of the hospital have not been designed and constructed for lateral forces drifts and displacements and so they are vulnerable. Suspended ceilings especially in main entrance of the hospital is without and bracing and could collapse and close the egress of the hospital.

Emergency power generators and substation control panels are installed very well and so they have minor damages during an earthquake. Emergency water supplies and tanks are enough for many days even if the city water pipes are broken.

Medical instruments and accessories are without any bracing or connection bolts so they are vulnerable.

Mechanical and electrical components supports and attachments of the hospital are not designed for lateral forces, and are vulnerable. Also nonstructural elements sensitive to displacements and drift are not designed and constructed regarding to these displacements.

As a recomendation it can be insisted that nonstructural elements and equipments of the hospitals and health care facilities, which are the most important for operating of these centers must be designed and installed for lateral forces causing by earthquakes.

## REFERENCES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