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Criteria of seismic strengthening of equipment of a hospital in Italy

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ABSTRACT: Hospitals are essential facilities which should survive seismic events remaining functional to provide the necessary support in the early phases of the earthquake emergency. Often, in Italy, hospitals are ancient buildings not seismically designed and heavily modified in the time after the construction so that important works are necessary to reduce the vulnerability of the structures. The kind of interventions and related technologies are today widely known and accepted. A similar attention should be paid to equipment which is essential for the functionality of critical facilities. In the paper some criteria for the seismic strengthening of these devices are proposed. Such criteria are based on the experience gained in the evaluation of seismic margins of existing Nuclear Power Plants.

1 INTRODUCTION

This paper presents the first results of a collaboration activity between ENEA (Comity for Innovation, Energy and Ambient) and Regione Emilia-Romagna regarding the seismic review and the definition of the improvement measures on the equipment of an old hospital.

The situation, typical in such cases, is the following:
- The hospital is a very old building and has been built since 1860 in successive steps and blocs until 1950-60. Now it appears as a set of block joined side by side with different type and different materials also in the same block.
- It is located in a seismic zone;
- The Italian seismic code regards only civil structures. No requirements there are on the equipment;
- It is in final stage the design of the retrofit and improvement measures of the oldest civil structures. In few years a new block will be built in which all the essential components will be located.
- The cost of the strengthening actions shall respect a limited total budget.
- The requirements of the medical authorities are wholly general because this is the first study of this kind in Italy.

This work is divided in two parts: the first regards the criteria and the second the method used to define the improvement actions.

2 DESCRIPTION OF THE HOSPITAL

The hospital is located in Castelnovo ne' Monti, a little town in the Appennines in Emilia-Romagna region. It is the most important sanitary structure in an area about 30 Km in radius comprising several other towns. During the summer holidays the number of potential users reaches about 70.000 people. The various portion of the hospital shown in fig. 1 where built in different times and materials. A synthesis of the history, the type of construction and of the services is in the following table.

The main sanitary systems are:
- Sanitary gas distribution plant Four lines (oxygen, compressed air, suction and nitrogen) made up by copper pipes 20 to 42 mm in diameter jointed by butt welds. The main branches have been renewed four years ago and are completely accessible, while the final lines

Table 1.

block ident.	n. of floors	type of construction	date of constr.	main services housed
1	3	stone masonry	1867	sister's rooms, warehouse
2	3	stone masonry (1&2fl) concr.block (3rd fl.)	1922÷ 1931*	first aid, orthopedics
3	5	stone masonry(ext.walls) R.C.M.R.F.+(inner struct)	1955	physiotherapy, surgery
4	4	masonry bearing walls and clay brick walls	1934- 1950	Day hospital, medicine
5	4	R.C.M.R.F.+	1973	UTIC,nursery
6	3	masonry	-	kitchen
7	4	R.C.M.R.F.+	1971	surgery room, analysis lab.
B	1	stone masonry	-	maintenance ser central heating emerg. gener.
F	3	R.C.M.R.F.+	1990	new emerg.gener

* 3rd floor rebuilt after World war II
\+ Reinforced Concrete Moment Resisting Frame

are old and often embedded into the walls.

- Gas plant

It is limited to the kitchen and to a small pipe for the analysis laboratory.

- Electric plant

The power center is almost completely new but it is not seismically qualified and is not fixed at the structures; the internal net is old but for the switch boards 70 % of which have been rebuilt 4 years ago.

At present the hospital has an emergency diesel generator (100 KVA) which can sustain only some safety features; in the next future a 500 KVA generator will be installed in building 'F' providing emergency power for all the relevant features.

The surgery room is equipped with a dedicated emergency system (Batteries and inverter).

- Sanitary devices (X-ray, analysis laboratory, reanimation and so on).

The hospital is also equipped with a recently renewed fire protection.

3 CRITERIA

The hospital is a socially important plant since it is house of patients having less than the capacity of normally health persons to protect themselves, but its function become more important after a ruinous event as an earthquake. It should be capable of continuously providing services to the public. Therefore its equipment, necessary to the functionality, should remain active and the integrity of other not essential systems and components should be maintained if their failure can produce an increase of damage caused by the earthquake or consequent accidents as flooding, fires and explosions.

In order to satisfy this requirement, not only the load bearing structures, but also non structural elements should remain not damaged or at least should not be, by themselves, cause of damage of essential components (for instance a partitioning wall that falls down on an equipment).

Generally speaking, in defining the improvement criteria, we should be aware that a plant that has been designed without any antiseismic measure can't be improved to a resistance level of a new plant. Therefore, a great difficulty in the investigations on an old hospital, as that one in Castelnuovo ne'Monti, has been the arrangement of rooms necessary to cure patients (as delivery, surgery and reanimation rooms) that have been developed without any criteria of post-disaster emergency. .

A real retrofit is not possible for the following reasons:

- At present a national code regarding the retrofit of plant seismic design does not exist.
- Only one part of the building is retrofitted while the rest is 'improved', that is strengthened as best as possible.
- It is not available or does not exist any data on the fragility of hospital equipment.

So it has been decided to ' improve ' the equipment, that is to make changes that, as possible, improve the seismic response compatibly with

time and economic resources.
Consistently it is not strictly possible to speak of a design or retrofit earthquake, however it is necessary to define a reference earthquake. In fact reference figures, as acceleration or differential displacement levels, are necessary to the actions of improvement and should be defined.
A deterministic approach is used to choose the reference earthquake and the maximum historical event has been considered. That is the ' Garfagnana ' earthquake that struck the town in September 7th 1920 and was felt as a VII-VIII degree of Mercalli scale. A 0.12 g maximum acceleration and 3 cm maximum ground displacement has been assessed as reference values compatible with an earthquake of above mentioned intensity and with the site characteristics.
Two logical phases are present during the work, but not really separate:
- Review phase in order to know the status of the plant and to identify the essential system and components.
- Definition of the actions phase that take into account also the medical requirements and the civil work aspect.

The review analyses require :
- Analysis of drawings and design documentation (when available) and information meeting with technicians of the hospital
-Walkdown surveys in order to identify critical structures and components and to ensure that all the safety systems are properly installed and to suggest early repairs and modifications.
Both surveys and office studies are undertaken by an expert team including hospital personnel with a wide knowledge of the layout and functions of the equipment. This requires personnel covering at least mechanical, electrical, civil engineering and medical disciplines.
We operated on base of:
- Professional judgement
- Experience gained from post-earthquake surveys.
- Analysis that has been done on other fields (nuclear for instance) (Duff 1984, Murray 1986).

4 METHODOLOGY

The definition of the essential functions that should keep safe during an earthquake takes into account the following scenario:
- The "future" earthquake has an intensity less or equal to the September 7th 1920 Garfagnana earthquake.
-No civil structure collapses (otherwise it is impossible to assure the functionality of the essential systems).
- During the earthquake the electrical and hydraulic supply through the national distribution systems are interrupt.
- The fire protection system is available after the earthquake.
The logical scheme in order to define the improvement measures, is the following:
a) Identify the functions that are essential to the operations of the hospital after the earthquake. In this phase it is necessary to take into account the injured people flowing from the region served by the hospital.
b) Identify the principal and/or auxiliary systems necessary to perform the a) functions.
c) Locate the component that assure the functionality of b)
The above points, other than logical sequences, are also working phases that involve both analyses at office and in site investigations and meetings with operators that know the functions and the importance of the hospital systems.

In the following scheme the essential services and consequent systems, identified for the Castelnuovo ne'Monti hospital, are listed.

In almost every case, the corrections, repairs, fixing or modifications suggested were generally inexpensive. Simple and logical actions that can certainly produce an increase of safety also without a preliminary analysis, are:
- replacement or addition of new and stronger supports.
- relocate some component in such a way they couldn't fall down (for instance locating on the ground emergency batteries).
- Fixing massive structures in order to reduce the differential displacements of electrical or mechanical connections.
- Fixing on the wall or on the ground cabinets or racks that can overturn.

Table 2.

Services	Systems
1) Essential services to bedridden (to be continuously assured) departments: reanimation, surgery radiology, essential analysis lab., dialysis	heating, medical gas electric supply lighting hydraulic supply essential equipment
2) Internal and external communic. (to be continuously assured) departments: exchange, radio link	Telephone lines radio link, intercom electric supply lighting
3) Reception of injured people (1-2 hours after the earthquake) departments: casualty ward	Accessibility personnel prepared to emergency electric supply intercom.
4) Transfer of injured people to other departments (2-3 hours after the earthquake) departments: surgery, reanimation, admission	Communication ways elevators corridors, stairs intercom.

- Fixing electrical lines and piping were certainly will not suffer support differential displacements and vice versa release them were differential displacements are possible or provide them with sliding supports.
- Guarantee free way between the critical facilities.

Specific actions identified after the completion of the rewiew and analysis phases have been the following:

- Substitute or duplicate some particularly critical electrical or mechanical equipment.
- Provide emergency oxigen cylinders near the surgery rooms, the first aid and the reanimation.
- Substitute an elevator that is on a critical way near the casualty ward.
- Add three new tanks for emergency water to the surgery, radiology and dialysis rooms.
- Substitute every electrical, hydraulic and gas-medical line where deep civil works are necessary.
- Provide emergency communication systems either between the blocks of the hospital or between the hospital and the external emergency management institutions.

Other than the previously mentioned measures the most important suggestion is to provide the hospital with an operative manual and an emergency plan and take as soon as possible the action of personnel training. The training should involve, other than medical personnel, also technicians that could be able to intervene as soon as possible to reduce the possible damages on critical components (BICEPP, 1987).

CONCLUSIONS

There is a lack of specific guides or codes regarding hospital equipment design and review. A criterion that can be used is to take all the measures that improve, as possible, the seismic response compatibly with time and economic resources. The actions are based on personal judgment, experience gained in post-earthquake surveys and on analogies with other fields (i.e. nuclear). The review work requires long detailed examinations of design drawings and several walkdown surveys, but a lot of measures can be taken in early phase. We suggest indeed to proceed step by step introducing as soon as possible practical and logical measures, as that ones previously described, that anyway produce an increase of seismic safety level.

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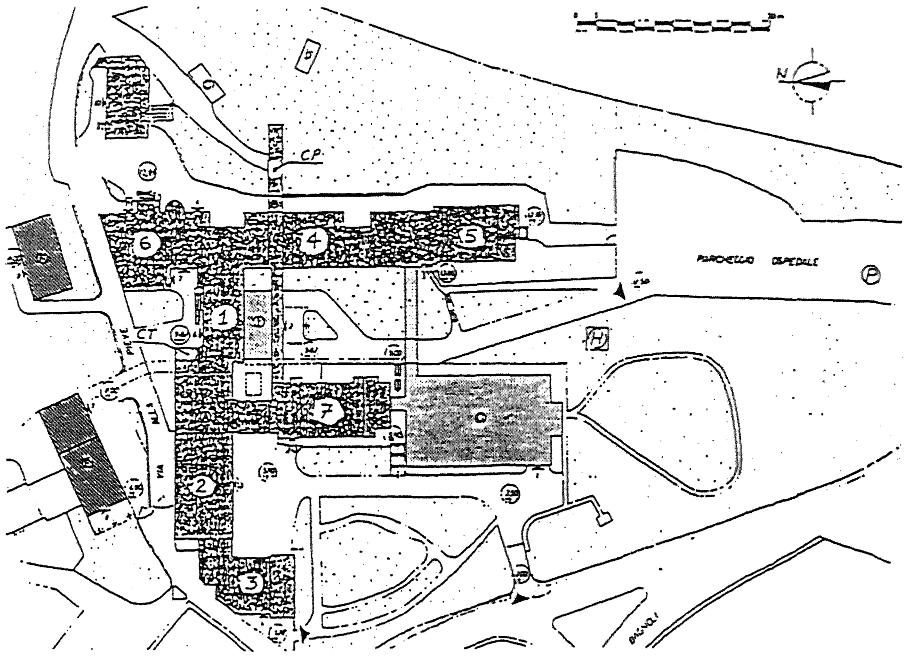

Figure 1. Plan view of the hospital.

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