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Seismic vulnerability of the healthcare system in El Salvador and recovery after the 2001 earthquakes

Ruben L. Boroschek*
World Health Organizatio/Pan-American Health Organization Collaborating Centre for Disaster Mitigation in Health Facilities
University of Chile, Blanco Encalada 2120, Piso 4, Santiago, Chile

ABSTRACT

During the January and February 2001 earthquakes, the national healthcare system in El Salvador suffered infrastructure damage that caused loss of functionality and the evacuation of the main hospitals in the country. These evacuations produced a strong effect on the capacity to care for the wounded and to continue offering the normal daily health assistance. The loss of functionality was due to damage in nonstructural elements, limited damage in engineered structural elements, and loss of confidence of the staff and patients in the safety of hospital buildings. Many hospitals had to operate totally or partially outside their premises with temporary shelters for two years after the events. A review of the hospital infrastructure indicates that the seismic design objective used, if any, only intended to protect the main structural elements. Only limited seismic design was made to protect nonstructural components and the functionality or the hospitals' investment. Additionally, construction practices contributed to the damage observed. Due to massive damage to the health infrastructure, a recovery strategy is needed in which new standards and performance objectives are considered. However, they are limited by economic resources and the need for a fast and massive reconstruction. Initially, a few strategically located hospitals will be reinforced structurally and nonstructurally to establish hospitals with a low probability of earthquake-induced functional disruptions. Other hospitals will primarily be repaired to recover their preexisting capacity and others will be reinforced to obtain a higher level of structural safety. This strategy will ensure a minimum health response capacity and a reduction in infrastructure and economic losses.

Keywords: hospital, structural damage, health, functionality loss.

THE PUBLIC HEALTHCARE SYSTEM IN EL SALVADOR

El Salvador is one of the most densely populated countries in Latin America, with a density of 280 inhabitants per square kilometer and a growth rate of ~2.2% per year. Forty-five percent of the population is located in urban areas, with a life expectancy of 73 and 66 yr for women and men, respectively. Child mortality is 38.9 deaths per each thousand born alive, and the country has a literacy rate of 73%. The population by department for year 2000 is shown in Figure 1. Two main health facilities networks exist in El Salvador: the public healthcare system administered by the Health Ministry and the social security system administered by Salvadorian Social Security Institute.

The Health Ministry hospital system is the institution that has the major population coverage, reaching the total national population (~6,350,000 inhabitants). It is organized on three basic levels of care as described by the National Health Regulation: Level I, with the following types of centers: health homes (with a national total of 161), rural nutrition centers (51), and health units (361); Level II, with peripheral general hospitals (11) and central general hospitals (14); and Level III, with special-

*rborosch@ing.uchile.cl

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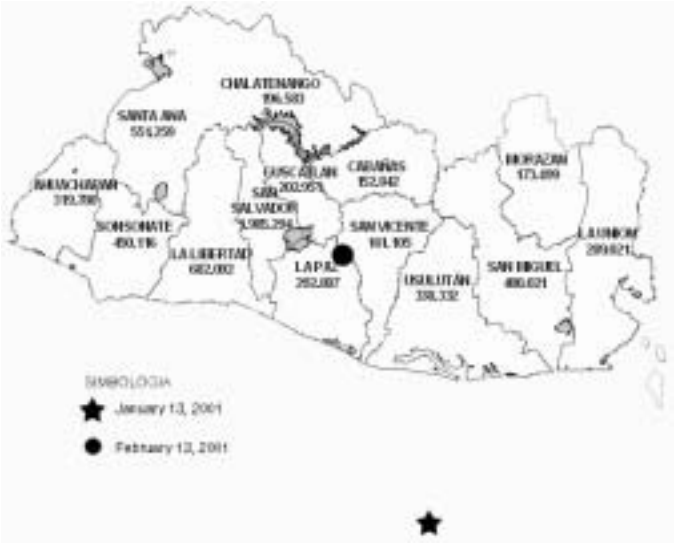

Figure 1. Political division and population distribution of El Salvador. Epicenter locations of the January and February events.

ized national hospitals (5). Some hospitals' characteristics are presented in Table 1. In general terms, one health unit is created for 5000 to 40,000 inhabitants, one peripheral hospital for 50,000 to 100,000 inhabitants, and one central hospital for each country department. In addition to the population density, variables such as distance and geographical difficulties are considered in the development and location of health centers.

The geographic distribution of the 30 hospitals that make up the network of the Health Ministry is displayed in Figure 2. There are 18 health departments, 13 of them corresponding to the national political division, and the remaining five health departments are located in San Salvador.

According to the Pan-American Health Organization (PAHO/WHO, 2000), Health Ministry (2000b), and Boroschek (2001), 57% of the hospitals have buildings that are 46 years old or more, 29% between 16 and 30 years old, and 14% between 1 and 15 years old. The average construction age, by hospital category, is as follows: specialized national hospitals, 80 years, general central, 73 years, and peripheral national, 28 years. Less than three-story-high construction is present in 77% of the hospitals. Their main structures are based on adobe, brick walls, or steel structures with steel or concrete infills (Rosales and Santa Ana hospitals). The remaining 23% have reinforced concrete frame-type construction with infilled brick walls. Most of these frames utilize structural details that provide limited ductility capacity. Just a few medium-rise buildings have structural walls, and if they exist, they are mainly located in elevator shafts (Rosales Surgery Building, Zacatecoluca, and San Pedro de Usulután main structures). Modern structural control techniques, such as base isolation, are not present in the Salvadorian hospital system.

The total constructed area of Health Ministry hospitals is ~296,500 m^2. By category, 33.4% corresponds to specialized hospitals, 48.4% to central hospitals, and 18.1% to peripheral national hospitals. These hospitals had an occupancy rate of 86% in the first half of the year 2000 (Health Ministry, 2000b).

Considering that there are a total of 4677 registered hospital beds, there is one bed for every 1358 inhabitants and for each 63 m^2 of hospital construction. Also, 35.7% of the beds are assigned to specialized hospitals. Of these hospitals, the Rosales Hospital, a 98-year-old building, and Santa Ana Hospital, a 155-year-old building, have 14% of the square meters and 21% of the country's beds. The next hospital in number of beds is the San Juan de Dios de San Miguel Hospital, with 8.3% of the beds. That is to say, the older hospitals show the highest number of beds and have been assigned 53% of the total country's population.

Specialties and Human Resources

According to PAHO/WHO (2000), all hospitals have the four basic areas: gynecology, obstetrics, pediatrics, and surgery, and internal medicine, with the exception of the specialized Benjamin Bloom Hospital (pediatrics) and the Maternity Hospital. The most complex hospital is Rosales Hospital with 22 specialties, followed by Benjamin Bloom with 21, San Miguel with 18, Santa Ana with 17, San Rafael with 14, and Zacamil with 10 specialties. Notably, specialized hospitals make up 22.4% of the significant surgical clinical procedures, the central general hospitals 48.7%, and the peripheral hospitals 28.9%. One important feature is that intensive care units are present only in five hospitals (Rosales, Benjamin Bloom, Maternity, Santa Ana, and San Miguel), requiring a quick transfer system between locations and hospitals for critical patients.

Because the size of the country is rather small, critical cases and the need for specialized treatment is solved by transferring patients from local hospitals to the greater San Salvador area. In normal times, it is possible to cross the longer axis of the country by car in 4 hours 30 minutes, and the shorter axis, with connections to Honduras and the Pacific Ocean, in 2 hours 30 minutes.

In addition to the hospitals, the Health Ministry has two national laboratories: the Dr. Max Bloch Central Laboratory and the Biological Laboratory, both located in greater San Salvador. The former certifies medicines and food and makes diagnoses for other laboratories. In fact, it is also dedicated to its own diagnoses, and it is an important center for national referrals. Other laboratories are located in the San Miguel, Santa Ana, and Rosales Hospitals, and they rely on Dr. Max Bloch Central Laboratory for specialized analysis.

The Biological Laboratory is committed to developing simple vaccines against hydrophobia. Also, the national medicine storage center is within its facilities.

Because of these characteristics, the Health Ministry services show a great concentration of infrastructure toward the coastal sector and in greater San Salvador. All specialized hospitals are located in greater San Salvador; 83% of these hospitals, which by regulation are specialized, actually render general services.

TABLE 1. HEALTH MINISTRY HOSPITALS: CHARACTERISTICS AND DAMAGE

Hospital	Age Main Structure	Construction M^2	# Beds	Ref Population	Surgery Rooms	Intensive Care	# Stories		Permanently Lost Beds %		Damage
							>3	<3	Jan.	Feb.	
Specialized National											
Rosales	98	25.000	531	National	15	X		X	0	0	Severe non-structural damage in Surgery Building: collapse of ceilings, damage partitions, elevator derailment, excessive motion and collapse of ducts and piping.
Benjamin Bloom	72	21.752	325	National	6	X	X		0	0	No damage—temporary evacuated.
Maternidad	46	17.792	308	National	10	X	X		100	100	Severe non-structural damage Fertility Building. 100% Evacuated several times. Damage to partitions, ceilings, and ducts.
Psiquiatria/General	105/2	23.002	216	284,003	3			X	0	0	
Neumologico/General	81	11.500	292	209,747	2			X	37	0	Minor non-structural damage. Damage to slab stucco.
General Central											
S. Juan Dios Santa Ana	155	15.750	473	319,252	13	X		X	0	0	Minor non-structural damage. Partition cracking.
S. Juan Dios San Miguel	176	37.122	390	321,418	15	X	X		36	0	Minor structural damage. Severe non-structural damage: collapse of partitions, ceiling, light fixtures, piping and duct. Elevator derailment.
Zacamil	7	11.985	255	1,212,551	7			X	0	0	
San Rafael	140/ND	1.766	222	682,092	7		X		100	0	Severe damage adobe structural. Moderate structural and severe non-structural damage in newer structure: heavy cracking partitions and facades.
Sonsonate	96	18.800	189	450,116	2			X	0	0	Minor non-structural damage
Zacatecoluca	ND	ND	155	292,887	5		X		100	0	January. Moderate non-structural damage: partition cracking. February: Moderate structural damage and severe non-structural damage: column shear failure, collapse equipment, ceilings, piping, ducts.
Francisco Menendez	117	14.227	157	319,780	5			X	0	0	Minor non-structural damage.
Santa Gertrudis	153	8.387	126	161,105	2			X	0	100	Moderate structural and non-structural damage.
San Pedro	27	4.345	130	161,243	2		X		100	0	Minor structural damage. Severe non-structural damage: collapse ceilings, rupture of piping, elevator derailment.
Dr. Luis e. Vazquez	28	6.000	94	110,466	5		X		0	0	
Cojutepeque	127	3.600	78	187,205	2			X	0	30	Moderate structural damage new structure: wall and partition cracking. Severe damage old structures.
La union	49	3.000	64	150,388	3			X	0	0	
Francisco Gotera	21	12.852	60	173,499	2			X	0	0	
Sensuntepeque	54	5.729	60	73,975	3			X	0	0	
General Peripheric											
Chalchuapa	20	4.990	78	162,405	1			X	0	0	
San Bartolo	21	4.436	65	262,374	2			X	0	0	
Ilobasco	12	5.300	59	78,867	2			X	0	0	
Nueva Guadalupe	12	3.800	55	90,078	1			X	0	0	
Jiquilisco	12	7.500	50	73,190	2			X	0	0	
Santiago de Maria	49	9.153	44	103,899	1			X	100	0	Infrastructure damage.
Metapan	47	2.000	41	69,602	2			X	0	0	
Santa Rosa de Lima	20	4.003	47	138,633	2			X	0	0	
Ciudad Barrios	20	4.662	41	68,525	2			X	0	0	Infrastructure damage.
Nueva Concepcion	19	5.278	40	86,289	2			X	0	0	
Suchitoto	60	2.650	32	15,746	1			X	0	0	

Note: Source: MSPAS Gestión en Salud. Bulletin N 1. 2000.
OPS Encuesta de actividades y recursos de los hospitales públicos de El Salvador, 2000.
COEN 2001

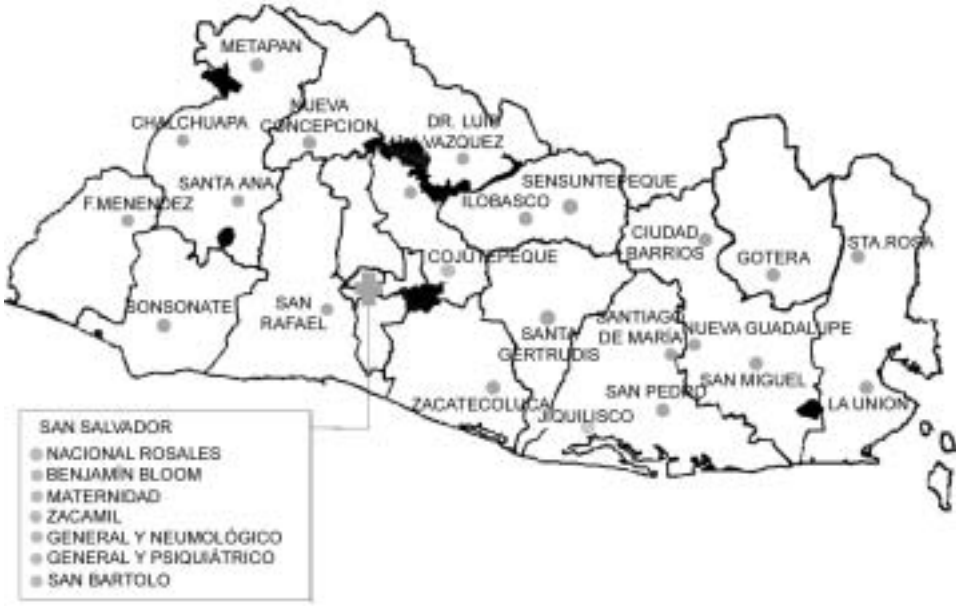

Figure 2. Geographic distribution of Health Ministry hospitals.

The Health Ministry health network is the largest in the country and has a close relationship with the Salvadorian Social Security Institute hospital network. This relationship implies mutual support and sharing of the infrastructure, generally owned by the Health Ministry.

SALVADORIAN SOCIAL SECURITY INSTITUTE HEALTH NETWORK

The network of the Salvadorian Social Security Institute covers 963,950 inhabitants, which represent 15.1% of the population and 21.2% of the economically active population in the country.

The Salvadorian Social Security Institute network has the following hierarchical structure: Level I, with communal clinics (31), company clinics (149), and medical units (35); and Levels II and III, with hospitals (18). The more complex hospitals, Level III, are Médico Quirúrgico (surgical-medical), Especialidades (specialties), Oncología (Oncology), and 1º de Mayo. Partial bed distribution is indicated in Table 2 and Figure 3 (SSSI, 2000a, 2000b). The Salvadorian Social Security Institute has 81.4% of its beds located in the greater San Salvador area. Communal and company clinics do not have beds and have a small resolution capacity: general medicine, epidemiology, and education.

HOSPITAL DESIGN CRITERIA IN EL SALVADOR

The Salvadorian seismic design code, like most of Latin American countries, is based mainly on U.S. codes and on its national seismic experience. Latin American codes, in general, were developed in the first half of the twentieth century. Before this date, engineering and earthquake-resistant design was not specified in codes, but applied by some experienced individuals. Countries such as Chile created their first seismic codes in the 1920s, but in that period of earthquake-resistant design, a clear objective of protection did not exist. From the 1960s, and after some destructive seismic events, engineers began to develop codes with the basic aim of protecting lives in severe events and allowing controlled damage in relatively moderate events. This philosophy of seismic design is currently accepted worldwide.

In these codes, hospitals were considered special structures, increasing the seismic loads with the hope that in this indirect manner the expectations of protecting the functionality required by the users would be fulfilled.

Until the 1990s, Latin American earthquake design codes were not dedicated to the protection of the investment or the functionality of hospitals. Therefore, it is unlikely that these objectives were accomplished in the infrastructure constructed before this date, or even today, if these aspects have been only considered at the design stage and not during the construction and operating stages (maintenance).

The first earthquake-resistant design regulation of El Salvador was published in 1966 and the second one in 1989, after the 1965 and 1986 earthquakes, respectively. The current seismic design code of 1994 (Ministry of Public Works, 1994) belongs to the groups of codes mainly oriented to protect the life of the inhabitants and not to protect the hospital's investment or function. Nevertheless, it has clauses that, if applied, could indirectly contribute to increasing the functionality protection.

The 1994 code is based on the 1991 U.S. Uniform Building Code and introduces the demands and requirements for the analysis of structural and nonstructural elements. This code establishes the seismic demands for El Salvador in two seismic zones (effective acceleration of 0.4 g and 0.3 g, respectively), which in rela-

TABLE 2. SALVADORIAN SOCIAL SECURITY INSTITUTE HOSPITALS (PARTIAL NETWORK): CHARACTERISTICS AND DAMAGE DURING THE JANUARY 13 EVENT

#	Department	Hospital	BEDS	DAMAGE DURING JANUARY 13, 2001
1	San Salvador	Medico Quirurgico	255	
2	San Salvador	Materno Infantil 1° de Mayo	239	Minor damage in secondary beams and moderate damage in facades and interior partitions.
3	San Salvador	Psiquiatrico	112	Minor damage in walls and non-structural elements and slab.
4	San Salvador	Especialidades	274	Minor damage in walls and non-structural elements and slab.
5	San Salvador	Oncologia	50	Moderate damage in structural walls. Severe damage in ceilings in 4th floor.
6	San Salvador	Neumologico	95	Minor damage in non structural elements (potable water).
7	San Salvador	Amatapec	165	Moderate damage in walls and electrical system. Severe damage in partitions and ceiling 4th floor.
8	San Salvador	Roma	70	Damages in roof steel structure and elevators.
9	La Libertad	San Rafael	70	Severe non-structural damage.
10	La Paz	Santa Teresa Zacatecoluca	16	Moderate non-structural damage.
11	San Miguel	San Juan de Dios de San Miguel	105	Severe non-structural damage (walls, partitions, ceilings, elevators, water supply, sewer).
12	La Unión	La Unión	14	Minor structural damage. Small cracks in columns and spalling.
13	Usulután	Santiago de Maria	10	Moderate damage in structural walls and severe damage to non-structural walls.
14	Usulután	Usulután	24	Severe non-structural damage and moderate structural damage.
15	Santa Ana	Santa Ana	135	
16	Sonsonate	Sonsonate	70	Moderate structural and non-structural damage.

Note: Sources: SSSI Department of Infrastructure, 2001, and Boroschek, 2001.

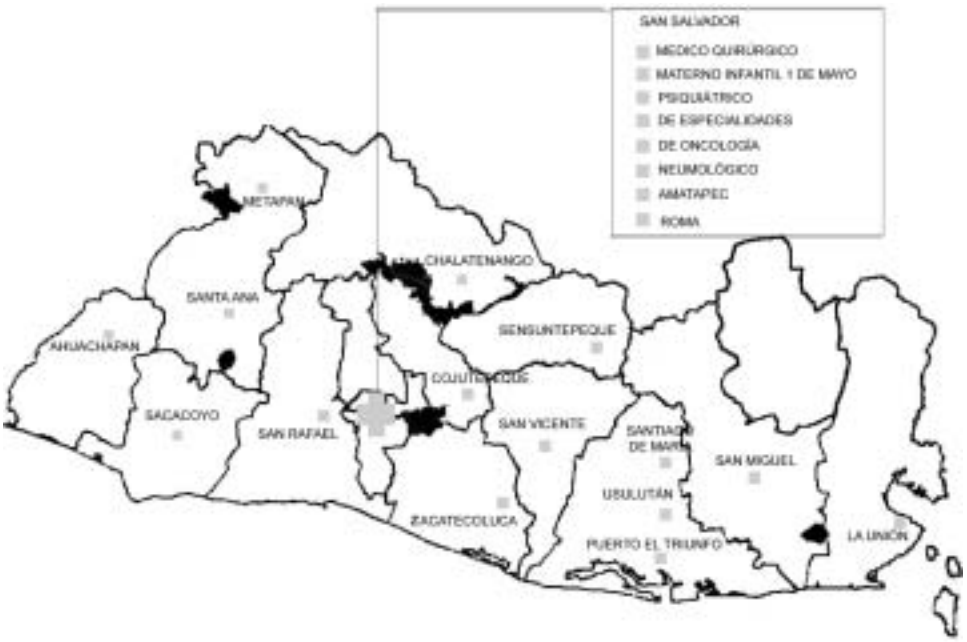

Figure 3. Geographic distribution of Salvadorian Social Security Institute hospitals.

tive terms, describes the whole country as highly seismic (Fig. 4). Additionally, for hospitals, the code requires a factor of 1.5 times the requirements established for structures with low occupancy, and additionally limits the relative drift between adjacent floors to a maximum of 1% of the floor height.

Due to the population distribution, 80% of hospitals (92% of the beds) and 100% of intensive care units are located in the highest-risk seismic zone. Most of the healthcare network is relatively old and was constructed with limited seismic design criteria. When it does exist, the seismic safety level is to protect

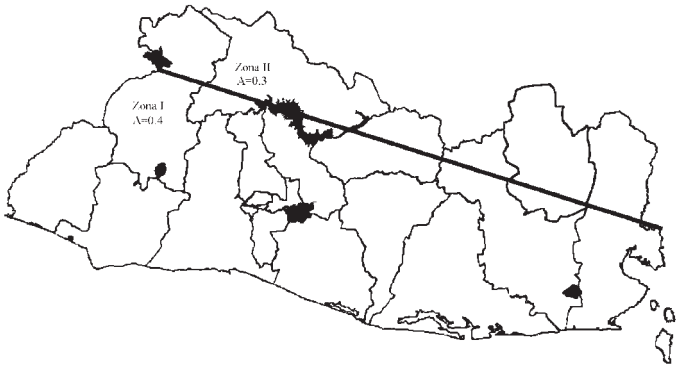

Figure 4. Seismic zones according to El Salvador seismic design code.

life and not to protect the infrastructure or functionality. This is the main reason for the observed damage of the healthcare system and imposes a big challenge to overcome years of design and construction that use a philosophy that nowadays is considered inadequate for critical facilities.

JANUARY 13 EARTHQUAKE

The earthquake of January 13, 2001, caused serious human casualties and infrastructure damage. The number of victims was 844, mainly concentrated in Las Colinas, Department of La Libertad, due to a landslide (Table 3).

As a result of its magnitude, the event severely affected an important number of hospitals (San Juan de Dios, San Miguel, San Pedro de Usulután, San Rafael, Maternity, General and Neumológico, Zacatecoluca, and Santiago de Maria, belonging to the Health Ministry; San Rafael, 1º de Mayo, Oncología, Amatepec, Roma, Usulután, San Miguel, and Sonsonate, from the Salvadorian Social Security Institute). Tables 1 and 2 describe the damage and functional consequences. This implied a temporary loss of 34% of the beds from the Health Ministry national total, necessitating the use of temporary shelters (Figs. 5 and 6). Detailed descriptions of the damages are given in Boroschek and Retamales (2001), Boroschek (2001), and Baroni and Quaglia (2001). In addition to the damage in hospitals, there was damage to 20% of the other components of the Health Ministry system. According to Ruales and Ayala (2002), 17 health units suffered severe damage, 21 suffered moderate damage, and 77 suffered minor damage.

The structural damage observed can be classified as severe for structures with low seismic capacity, such as adobe construction (San Rafael Hospital and others). In general, the main hospitals structured with moment resisting frames and frame-wall buildings suffered relative minor to moderate structural damage and no collapse (Fig. 7). On the other hand, nonstructural damage was generalized and severe. A visit to the main hospitals of the country indicated a complete absence of seismic design for architectural elements, medical and industrial equipment, and distribution systems such as piping, ducts, etc. Because of the severity of the earthquake and the relatively small size of the country, most of the hospitals in the coastal and central areas

TABLE 3. CASUALTIES IN THE JANUARY AND FEBRUARY EVENTS

Department	Total population	Affected population			Wounded			Dead		
		January 13 data 02/12/01	February 13 data 02/21/01	Total	January 13 data 02/12/01	February 13 data 02/21/01	Total	January 13 data 02/12/01	February 13 data 02/21/01	Total
Ahuachapán	319,780	71,086	0	71,086	247	0	247	0	0	0
Cabañas	152,842	2997	2368	5635	7	0	7	0	0	0
Chalatenango	196,583	1250	0	1250	4	0	4	0	0	0
Cuscatlán	202,951	38,119	106,120	144,239	43	1372	1415	20	165	185
La Libertad	682,092	143,215	0	143,215	1364	0	1364	585	0	585
La Paz	292,887	227,034	75,821	302,855	157	806	963	44	58	102
La Unión	289,021	15,062	0	15,062	8	0	8	1	0	1
Morazán	173,499	498	0	498	3	0	3	0	1	1
San Miguel	480,021	76,665	230	76,895	43	0	43	19	0	19
San Salvador	1,985,294	107,083	1370	108,453	386	0	386	24	4	28
San Vicente	161,105	92,395	66,443	158,838	53	1220	1273	29	87	116
Santa Ana	551,259	112,561	0	112,561	327	0	327	47	0	47
Sonsonate	450,116	101,487	0	101,487	1295	0	1295	48	0	48
Usulután	338,332	340,354	0	340,354	786	1	787	27	0	27
Total	6,275,782	1,329,806	252,622	1428	4723	3399	8122	844	315	1159

Note: Sources: OPS El Salvador and COEN, 2001; Estimated population, Dirección General de Estadística y Censos (DIGESTYC). From PAHO.

Figure 5. Temporary surgical rooms in Rosales Hospital.

Figure 6. Neonatology in outside shelter structure. 1° Mayo Hospital.

Figure 7. Typical structural system based on frame and infilled wall system.

were affected. Peak ground acceleration was recorded in several areas, so attenuation curves can be developed and damage correlated with earthquake intensity. The damage observed is attributed to an absence of seismic design of the nonstructural elements and an inappropriate structural system, with excessive flexibility, for a hospital. Damage can be divided and described as follows:

1. Severe damage and collapse of suspended ceilings and lighting fixtures (Fig. 8) due to absence of restraints, inadequate use of railings and supporting systems, and lack of structural expansion joints.

2. Severe damage and collapse of infilled walls and facades (Fig. 9) due to lack of expansion joints, inadequate expansion joints, and inadequate out-of-plane support.

3. Severe damage to elevator systems due to complete absence of seismic design for elevator systems and damage to elevator shafts (Fig. 10).

4. Severe damage to piping and ductwork due to lack of restraints, no consideration for structural expansion joints, and poor maintenance, shown previously in Figure 8.

5. Severe damage to medical equipment and supplies due to inadequate furniture and supports (Fig. 11).

6. Structure pounding between buildings due to inadequate separation or maintenance of expansion joints.

Figure 8. Damage to suspended ceiling, lighting fixtures, and air conditioning. Fertility building in Maternity Hospital.

Figure 9. Damage to partition and facades due to inadequate isolation. San Rafael Hospital.

Figure 10. Counterweight derailment in elevator system. Usulután Hospital.

This nonstructural damage caused total or partial evacuation and lost of functionality in the main hospitals at San Miguel, Usulután, Zacatecoluca, La Libertad, and San Salvador.

The extensive damage to hospitals in the coastal and central area and the damage to the road system due to landslides considerably limited the possibility of transferring critical patients from local hospitals to San Salvador or to undamaged units. For example, the Santa Ana hospital suffered no damage and had a high resolution capacity, but due to its location and a landslide on the main route, was not able to adequately respond to health demands.

Immediately after the event, the Health Ministry and the Salvadorian Social Security Institute organized evaluation groups to survey damage to the hospitals and to the central offices. Additionally, the Salvadorian Association of Engineers and Architects (ASIA), as well as international institutions such as the Pan-American Health Organization through the Collaborating Centre for Disaster Mitigation in Health Facilities, carried out evaluations. These evaluations allowed the establishment of safety areas for immediate use and a long-term recovery strategy.

FEBRUARY THIRTEENTH EARTHQUAKE

On February 13th, the second strong earthquake occurred. This event increased the fear of the population and caused damages in the Zacatecoluca, Santa Gertrudis of San Vicente, and Cojutepeque hospitals (Tables 1 and 2; Fig. 12).

Because this event had a shallow focus, the affected zone was very limited, and damage was not as widespread as the January earthquake. This allowed a relatively fast health response. Table 3 presents the casualties. As happened during the January event, landslides in the roads occurred, causing difficulties with transporting patients, especially between the San Vicente and Cojutepeque hospitals and San Salvador.

Figure 11. Medical equipment and supply damage. Surgery Building, Rosales Hospital.

Figure 12. Shear failure in column due the presence of partial-height infilled walls. Zacatecoluca Hospital.

EVACUATION AND TEMPORARY HOSPITALS

The events caused an immediate evacuation of most of the main hospitals in the affected region, producing a negative impact on the functionality of the healthcare system. Many evacuations after the earthquakes were made hastily, without any technical criteria. This behavior can be associated with:

1. The employees' perception of a possible structural collapse, considering the experience of the 1986 earthquake. During the 1986 event, a significant number of deaths occurred due to the collapse of structures in San Salvador. At that time, the health sector had complete functional loss of the General Hospital (Salvadorian Social Security Institute); partial collapse of the Benjamin Bloom Hospital in an aftershock (100% evacuated); damage to the Maternity Hospital (Health Ministry) in the surgery and laundry rooms (100% evacuated); and damage to the Rosales Hospital surgical rooms. In addition, the San Rafael (Health Ministry), Maternity 1° de Mayo (Salvadorian Social Security Institute), and the Military Hospital of San Salvador were evacuated.

2. The lack of contingency plans that clearly established the actions to be taken during an emergency, especially procedures on how to decide whether or not to evacuate.

3. The absolute absence of seismic design along with poor maintenance for nonstructural elements: ceiling, walls, facades, windows, plasters, lighting fixtures, medical and industrial equipment, furniture, and lifelines. Moderate and severe nonstructural damage caused chaos and the partial loss of the functional capacity, affecting the staff and response capacities. It is not possible for a health employee to establish the difference between nonstructural and structural damage and it is even less likely for a health employee to establish if it is a life-threatening situation.

4. The use of structural systems with little ability to tolerate damage. As presented before, the main Health Ministry hospitals

(Rosales and Santa Ana) are more than 80 years old; nevertheless, their older sections suffered no structural damage. Newer structures built after the 1960s are mainly based on moment resisting frames with relatively large floor flexibility and low ductility capacity.

These factors created a great insecurity in the hospitals' staff and made the decision to evacuate easier without knowing the real condition of the facilities and without considering the consequences on the health care capacity after the evacuation.

It is possible to conclude that the healthcare system of El Salvador was seriously affected by the January and February earthquakes due to the low seismic and functional safety of its centers (infrastructure and organization), the high concentration of its specialized services, the high dependence on highways to fulfill the specialties' treatments, and the limited organization for disasters considering its vulnerabilities. According to Ruales and Ayala (2002) the total loss in the health sector was U.S.$200 million.

Due to the evacuation of the most important hospitals, health care was performed outdoors. The operation required a large number of tents and temporary housing that was organized in the vicinity of existing structures (Figs. 5, 6, and 13).

A high percentage of hospitals remained evacuated for more than two years, so several field hospitals were installed in Santa Gertrudis, San Pedro de Usulután, Maternidad, San Rafael, Zacatecoluca, and San Juan de Dios de San Miguel. In some cases, existing room functions were reassigned, as in 1° Mayo, Neumológico, Rosales, and Cojutepeque. Others, such as Oncología, stopped functioning and had no alternatives.

Some hospitals had evacuated temporarily and worked outdoors. Later they returned to undamaged or partially damaged structures, but the tents were held in reserve in case of other earthquakes. In some cases, semipermanent shelters had even been constructed in case another evacuation was considered necessary.

A year after the earthquake, 28% of the total existing beds remained in field hospitals; the reasons, among others, are the following:

1. Existence of structural damage or real risk of damage in at least the following hospitals: San Rafael, San Pedro, Zacatecoluca, and San Juan de Dios of San Miguel.

2. Severe nonstructural damage requiring long-term recovery procedures.

3. Absence of previous knowledge about the condition and real risk of the structures. Response decisions require information that takes a relatively long time to gather.

Figure 13. Temporary shelters for long-term patients.

INFRASTRUCTURE RECOVERY PLAN

Due to the extensive damage, the reconstruction and recovery of the health system care capacity is taking a long time. The extensive loss of the infrastructure puts the health suppliers in the dilemma of either recovering themselves to the condition that existed before the seismic events of 2001, or trying to establish better conditions. These decisions have to be made considering that an important number of hospitals have an obsolete infrastructure. Therefore, the variables depend on the level of structural and nonstructural damage, the infrastructure obsolescence, the need to rebuild an urgently needed health network, the lack of redundancy in the system, the severe limitation of economic resources, and the lack of design and construction standards that allow a speedy process of reconstruction and that ensure that the seismic vulnerability that existed previously will not be reconstructed.

Initially, the Health Ministry has two recovery strategies. Under the first strategy, hospitals will be repaired to restore their present structure and service lines. These facilities are San Pedro de Usulután, Rosales, and Psiquiátrico Hospitals, and the Max Bloch and Biological Laboratories. In the second strategy, hospitals will receive a complete upgrade (structural and nonstructural). These are San Juan de Dios of San Miguel, Zacatecoluca, and San Rafael. Also, new structures will be considered for some of these hospitals.

Before the seismic events, the Health Ministry, with Pan-American Health Organization support, was developing a new scheme that decentralizes care while maintaining effective levels of response. The plan establishes two types of care: outpatient and inpatient care. For the outpatient case, three levels of care are established: Level I includes the health units, the health homes and the rural nutrition centers; Level II includes the health units with basic specialties (delivery care and basic emergencies); and Level III includes specialized institutes, central laboratories, and health units with specialties. For the inpatient case, the plan establishes Level II with peripheral hospitals and general hospitals of the department, Level III with regional referral hospitals, and Level IV with national specialized hospitals.

Regional referral hospitals will allow decentralization of healthcare, reducing the dependency on greater San Salvador

facilities. The preliminary proposal recommends one hospital in the west, one in the east, one in the central coastal sector, and one in the central border region.

El Salvador's healthcare system is confronted with the huge task of recovering its service capacities. The consequences of the damages could have been foreseen by vulnerability studies of the hospitals. This is the approach that other Central American countries have decided to take. During 2001 and 2002, after Hurricane Mitch, Honduras, El Salvador, Guatemala, and Nicaragua started to evaluate their health networks considering natural disasters. Costa Rica is the most advanced country in the area in this matter because since 1985, they have performed several vulnerability studies and structurally reinforced several of their hospitals. This mitigation strategy allowed the healthcare system of Costa Rica to survive the 1991 Limon earthquake.

The main problem of health infrastructure in developing countries is that most existing hospitals were constructed under design codes that do not protect the investment or its functionality. And even in the case that this protection was initially established, the maintenance budget is very small, so this protection becomes lost with time.

In order to overcome this situation, countries such as Chile, in South America, have established and applied regulations that require a vulnerability study of the infrastructure if more than 20% of the hospital has been affected by modification or repair. For new hospitals these regulations require design procedures for the protection of the investment and functionality, depending on their complexity and role in the healthcare system network.

CONCLUSIONS

Two major earthquakes that caused a large number of human losses and injuries affected El Salvador. The country's main hospitals suffered severe damage, and after three years, the healthcare system network still experiences a substantial loss of capacity. This loss can be attributed to several causes but especially to the high concentration of health services in San Salvador, the complete dependency on vulnerable lifelines, and a hospital seismic design philosophy whose only objective is to protect the life of the user and does not consider the protection of the health infrastructure investment, its functionality, and a fast and low-cost recovery of the system after a moderate or severe event.

Damage cannot be attributed to a limited application of the codes or use of poor materials. The damage observed is associated with an inappropriate design concept, which nowadays is no longer acceptable.

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