Evaluación de Riesgos Naturales
- América Latina -
Consultores en Riesgos y Desastres

ERN

CAPRA

CENTRAL AMERICA PROBABILISTIC RISK ASSESSMENT
EVALUACIÓN PROBABILISTA DE RIESGOS EN CENTRO AMÉRICA

BELIZE

TASK II
INVENTORY OF EXPOSURE AND VULNERABILITY

<u>TECHNICAL REPORT ERN-CAPRA-T2.2</u>

PROPOSED VULNERABILITY INDICATORS AND FUNCTIONS

CEPREDENAC

Estrategia Internacional para la Reducción de Desastres EIRD

IDB

ERN

Evaluación de Riesgos Naturales
- América Latina -
Consultores en Riesgos y Desastres

Colombia
Carrera 19A # 84-14 Of 504
Edificio Torrenova
Tel. 57-1-691-6113
Fax 57-1-691-6102
Bogotá, D.C.

INGENIAR

iTEC
INGENIERIA TECNICA Y CIENTIFICA LTDA

España
Centro Internacional de Métodos Numéricos
en Ingeniería - CIMNE
Campus Nord UPC
Tel. 34-93-401-64-96
Fax 34-93-401-10-48
Barcelona

CIMNE

México
Vito Alessio Robles No. 179
Col. Hacienda de Guadalupe Chimalistac
C.P.01050 Delegación Álvaro Obregón
Tel. 55-5-616-8161
Fax 55-5-616-8162
México, D.F.

ERN
ERN Ingenieros Consultores, S. C.

ERN Evaluación de Riesgos Naturales – América Latina
www.ern-la.com

Direction and Coordination of Technical Working Groups – Consortium ERN America Latina

Omar Darío Cardona A.
Project General Direction

Luis Eduardo Yamín L.
Technical Direction ERN (COL)

Mario Gustavo Ordaz S.
Technical Direction ERN (MEX)

Alex Horia Barbat B.
Technical Direction CIMNE (ESP)

Gabriel Andrés Bernal G.
General Coordination ERN (COL)

Eduardo Reinoso A.
General Coordination ERN (MEX)

Martha Liliana Carreño T.
General Coordination I CIMNE (ESP)

Specialists and Advisors – Working Groups

Julián Tristancho
Specialist ERN (COL)

Miguel Genaro Mora C.
Specialist ERN (COL)

César Augusto Velásquez V.
Specialist ERN (COL)

Karina Santamaría D.
Specialist ERN (COL)

Mauricio Cardona O.
Specialist ERN (COL)

Sergio Enrique Forero A.
Specialist ERN (COL)

Mario Andrés Salgado G.
Technical Assistant ERN (COL)

Juan Pablo Forero A.
Technical Assistant ERN (COL)

Andrés Mauricio Torres C.
Technical Assistant ERN (COL)

Diana Marcela González C.
Technical Assistant ERN (COL)

Carlos Eduardo Avelar F.
Specialist ERN (MEX)

Benjamín Huerta G.
Specialist ERN (MEX)

Mauro Pompeyo Niño L.
Specialist ERN (MEX)

Isaías Martínez A.
Technical Assistant ERN (MEX)

Edgar Osuna H.
Technical Assistant ERN (MEX)

José Juan Hernández G.
Technical Assistant ERN (MEX)

Marco Torres
Associated Advisor (MEX)

Johoner Venicio Correa C.
Technical Assistant ERN (COL)

Juan Miguel Galindo P.
Technical Assistant ERN (COL)

Yinsury Sodel Peña V.
Technical Assistant ERN (COL)

Mabel Cristina Marulanda F.
Specialist CIMNE(SPN)

Jairo Andrés Valcárcel T.
Specialist CIMNE(SPN)

Juan Pablo Londoño L.
Specialist CIMNE(SPN)

René Salgueiro
Specialist CIMNE(SPN)

Nieves Lantada
Specialist CIMNE(SPN)

Álvaro Martín Moreno R.
Associated Advisor (COL)

Mario Díaz-Granados O.
Associated Advisor (COL)

Liliana Narvaez M.
Associated Advisor (COL)

Juan Camilo Olaya
Technical Assistant ERN (COL)

Steven White
Technical Assistant ERN (COL)

Local Advisors

SNET **Francisco Ernesto Durán**
& Giovanni Molina El Salvador

Osmar E. Velasco
Guatemala

Oscar Elvir Honduras
Romaldo Isaac Lewis Belize

Interamerican Development Bank

Flavio Bazán
Sectorial Specialist

Cassandra T. Rogers
Sectorial Specialist

Sergio Lacambra
Sectorial Specialist

Tsuneki Hori
Internal Consultant

Oscar Anil Ishizawa
Internal Consultant

World Bank

Francis Ghesquiere
Regional Coordinator

Joaquín Toro
Specialist

Fernando Ramírez C.
Specialist

Edward C. Anderson
Specialist

Stuart Gill
Specialist

Contents

Figures index

Table index

1 Introduction

This chapter proposes a general classification of dominant types of structure in Belize, with special emphasis in Belize City for classifying vulnerability to different types of threat, and their distribution in homogeneous zones of the city

The procedure for classification of vulnerability of the components in the system is as follows:

a) Standardisation of types of dominant construction in infrastructure works to be analysed, based on existing information and opinions provided by local working groups.

b) Field visits to make the standard classification of the main types of construction, and characterisation of each of these systems which turned out to be a significant

c) Calculation of the functions of vulnerability of the characteristic types of construction. For this purpose, certain analytical models were developed, or certain functions were used as applicable, already published in the light of local and international experience. The functions of vulnerability proposed cuddlier bodied using the software tool ERN-Vulnerability

d) Establishment of a database for the dominant types of construction and the functions of vulnerability related to them for the different types of hazard.

e) General zoning of the city or zones of interest in homogeneous areas following the distribution of dominant types of construction and uses allocated to them. The allocation of approximate percentages of each type of typical construction in each zone.

f) For databases with information building by building, an allocation was made of a characteristic type of construction to each other components, and allocation of the vulnerability fuction related to it.

Vulnerability was characterised for each of these elements, and this was followed by an analysis of the risk related to the action of each of the hazards involved in the analysis

2 Classification of types of construction

2.1 Procedure for classification

Classification of each of the dominant types of construction in the city and in the rest of the country was effected by field visits and used existing documentation. A detailed survey was made for each of the types identified, with information on important buildings, on forms which summarised their principal characteristics, with photographs and descriptions of the main features.

In order to make the basic classification, reference was made to relevant information for seismic vulnerability, which included in general information related to the structural system, the dominant material in that system, and general characteristics such as types of floor and roof, height, typical open distances, geometry and other elements. Once the dominant structures were characterised from this characteristics, a sub-classification was made for the purposes of vulnerability to wind forces. In addition to the foregoing, this included the description of the type of facade, type of roof, and details of connections of these elements to the structure. At the same time, and another of sub-classification was made for vulnerability to floods (slow flooding), which includes materials, and types of finishings on floors, walls and roofs, and a description of contents.

In summary, with the information contained on the forms for each type of dominant construction, it was possible to establish a general classification to allocate vulnerability to earthquake, wind, flood, falling ash, landslides, and other phenomena analysed.

This analysis covers only the dominant types of construction characterised, as frequently present in each zone, or which represent at least 10% or 20% of the constructions in the zone.

Each type of construction was characterised as follows:

- General characteristics of the building (a range of the number of stories, typical open distances, maximum distances in roofing, etc)
- Structural system and materials in the main structure
- Material materials and system of intermediate floors
- Material and type of roof
- Material and type of facade
- Number of stories

In Figures 2-1 and 2-2, is shown a complete form used to characterise each of the important construction types:

ERN Evaluación de Riesgos Naturales - América Latina - Consultores en Riesgos y Desastres	FORMAT No :	IT- VI-012
	DATE :	06/02/2010
CAPRA (Central American Probabilistic Risk Assessment)	VERSION :	1.0
STRUCTURAL TYPES DESCRIPTION FORMAT	CLIENT :	BM
WOOD STRUCTURES - FLEXIBLE, LIGHT ROOF ,FLEXIBLE, LOW - 2	ID :	W-FLFB-2

Country: Belize **Completed by:** CEAF

City: Belize **Reviewed by:** SFA

PICTURE	SCKETCH
	

GENERAL FEATURES		SEISMIC RESISTANCE SYSTEM	MATERIAL
Stories (range):	2	[ ] Moment frames	[ ] Reinforced concrete
Story height (prom)	5.00 m	[ ] Braced frames	[ ] Precast concrete
Floor dim. (Approx):	10 X 10	[ ] Frames and walls	[ ] Masonry
Approximate age:	25	[X] Bearing walls	[ ] Steel
Diaphragm		[ ] None	[X] Wood
[ ] Rigid [X] Flexible [ ] None		[ ] Other:	[ ] Other:

SPECIAL FEATURES	CONSTRUCTIVE ANOMALIES	PRE-EXISTENT DAMAGES
[ ] Poor Foundation	[ ] Low quality (materials)	[ ] Settlements
[ ] Irregularity in plant	[ ] Masonry without locks	[ ] Cracks in columns
[ ] Irregularity in heigth	[ ] Low quality mortar paste	[ ] Cracks in beams
[ ] Short column	[ ] Slender walls without tie	[ ] Cracks in walls
[ ] Pounding	[ ] Poor roof Tie	[ ] Excessive deflections
[X] Other flexibilidad excesiva	[ ] Other	[ ] Other

Figure 2-1
Form for characterisation of construction types (Part 1)

ERN Evaluación de Riesgos Naturales - América Latina - Consultores en Riesgos y Desastres	FORMAT No :	IT- VI-012
	DATE :	06/02/2010
CAPRA (Central American Probabilistic Risk Assessment)	VERSION :	1.0
STRUCTURAL TYPES DESCRIPTION FORMAT	CLIENT :	BM
WOOD STRUCTURES - FLEXIBLE, LIGHT ROOF ,FLEXIBLE, LOW - 2	ID :	W-FLFB-2

Country: Belize **Completed by:** CEAF
City: Belize **Reviewed by:** SFA

ROOF FEATURES	BACKING ROOF	MATERIAL ROOF
Roof diaphragm	[ ] Concrete slab	[ ] Concrete slab
[ ] Rigid [X] Flexible [ ] None	[ ] Concrete beams	[ ] Clay tile
[X] Roof in good condition	[ ] Steel beams	[ ] Industrial tile
[ ] Roof in regular condition	[X] Wood beams	[X] Zinc tile
[ ] Roof in bad condition	[ ] Steel trusses	[ ] Wood
Roof support separation (m) 3	[ ] Wood trusses	[ ] Straw or palm
° slope 15 # surfaces 1-2	[ ] Other:	[ ] Other:

FACADE FEATURES	MATERIAL FACADE	INTERIOR WALLS
[ ] Walls dilated	[ ] Concrete	[ ] Masonry
[ ] Walls unexpanded	[ ] Masonry	[X] Wood
[ ] Precast	[ ] Steel	[ ] Precast concrete
[ ] Floating	[ ] Glass	[ ] Dryw all
[X] Other: Madera	[ ] Adobe	[ ] Light w alls
	[X] Wood	[ ] Adobe
	[ ] Other:	[ ] Other:

FLOOR FINISH		GENERAL QUALITY
[ ] Concrete		[X] Good condition
[X] Wood		[ ] Regular condition
[ ] Laminate		[ ] Bad condition
[ ] Carpet		
[ ] Land		
[ ] Other:		

OBSERVATIONS

Figure 2-2
Form for characterisation of construction types (Part 2)

2.2 Important construction types

We now present a description of important construction types found in accordance with the basic parameters of classification. Each of these construction classes are described on a form attached in the Annex ERN-CAPRA- T2-2-1

2.2.1 *Classification by structural system*

The first criterion to select the type of construction is the structural system and material of the main structure. In some cases, the material indicates directly the type of structure, such as adobe, mud blocks or concrete (in structures with a few stories), and daub-and-wattle.

Table 2-1
Description of important construction types.

Construction type	Code	Description	Image
Wood structures	W	This is a type in which wood is the main element in the principal structure. It forms a skeleton of wood covered with planks, though in some cases there may be sheets of other material. Wooden buildings in general correspond to structures of one or two stories, the intermediate floor acting as a flexible diaphragm formed by wooden or steel beams, and plank floors. The roof is generally light, formed by steel bars or wooden bars and zinc sheeting. This is mainly found in suburban areas, older districts, and settlements. It is very rarely used today.	
SIMPLE MASONRY		These are simple buildings of masonry are formed by brick walls, concrete block, stone blocks which may be placed with no material to join them, with cementing mortar or any other type of material. Most of these buildings are of one or two stories, with light roofing formed by metal strips and zinc sheeting. There are also roofs made of clay tiles, or concrete slabs. For buildings of two stories, in most cases there are flexible intermediate floor diaphragms formed by wooden or metal beams, wooden plank flooring. These buildings have a high seismic vulnerability, with major levels of structural damage. The failure of a construction usually occurs due to large cracks in directions parallel to the plane of the main walls, and progressive consequent deterioration of the masonry.	

Construction type	Code	Description	Image
CONFINED MASONRY	MC	This is masonry construction using reinforced concrete items (columns and tie-beams), on the perimeter, filled in with construction of a simple masonry wall as a reinforcement. In most cases, the roof is light, but there are also concrete slab roofs. The intermediate floors in most cases are formed by flexible wood or steel beams, with wooden flooring. The behaviour expected by this type of structural system may vary depending on the type of diaphragm and the arrangement of elements of confinement in reinforced concrete.	
REINFORCED MASONRY		Buildings in reinforced masonry are formed by breezeblock or clay walls perforated with some holes filled with concrete and reinforcing steel, generally in buildings of one or two stories, and a light roof in most cases. Buildings of two or more stories in most cases have intermediate floor diaphragms which are rigid, formed by metal beams with concrete flooring. There are also cases of flexible intermediate floor diagrams, formed by wooden or metal beams, floored in wood. These buildings have a low seismic vulnerability. In this type of construction, the system normally fails due to advanced cracking parallel to the plane of the main walls, and consequent progressive deterioration of the masonry. This is the commonest system of masonry construction today.	
REINFORCED CONCRETE FRAMES	PCR	This structural system is formed by columns and beams and monolithically-joined concrete columns and beams. This can be observed in buildings of one or more floors, in which case the intermediate floors are in concrete, and roofs may be light, heavy, or concrete slabs. The behaviour of this type of construction is characterised by the flexibility associated with the arrangement of the elements which form it, with no type of a stay or brace. These buildings are usually of intermediate vulnerability	
STEEL FRAME	PAR	These are structures where the main structural system consists of steel arches formed by momentum-resistant beams and columns, with no stays. In some cases, these arches are filled with concrete or masonry walls, as a form of enclosure	

2.3 Summary of main construction types.

This analysis can be used to establish the following classification of characteristic construction types. Table 2-2 summarises these types, and the reference for each of them

Table 2-2
Characteristic construction types for earthquake and wind

ID	CHARACTERISTIC
MC-RCSB-1	Confined masonry - Rigid, Concrete roof ,Unexpanded fragile, Low - 1
MC-SLSB-1	Confined masonry - No Diaphragm, Light roof ,Unexpanded fragile, Low - 1
MC-RLSB-2	Confined masonry - Rigid, Light roof ,Unexpanded fragile, Low - 2
MS-RLSB-2	Unreinforced masonry - Rigid, Light roof ,Unexpanded fragile, Low - 2
MS-SLSB-1	Unreinforced masonry - No Diaphragm, Light roof ,Unexpanded fragile, Low - 1
MR-SLSB-1	Reinforced masonry - No Diaphragm, Light roof ,Unexpanded fragile, Low - 1
MR-RLSB-2	Reinforced masonry - Rigid, Light roof ,Unexpanded fragile, Low - 2
PAA-SLSB-B	Steel braced frames - No Diaphragm, Light roof ,Unexpanded fragile, Wharehouse - B
PCR-RCSB-2	Concrete Frame - Rigid, Concrete roof ,Unexpanded fragile, Low - 2
PCR-RLSB-2	Concrete Frame - Rigid, Light roof ,Unexpanded fragile, Low - 2
W-FLFB-2	Wood structures - Flexible, Light roof ,Flexible, Low - 2
W-SLFB-1	Wood structures - No Diaphragm, Light roof ,Flexible, Low - 1

3 Allocation of vulnerability functions

For the allocation of vulnerability functions we employed the procedures and methods proposed in the report ERN-CAPRA-T1-5-Vulnerability of Buildings and Infrastructure. A vulnerability function for the purposes of earthquake, wind, flood, slippage, falling ash, lava flows and pyroclastic flows was allocated to each of these characteristic construction types

3.1 Seismic vulnerability

Each of the above systems is characterised from the point of view of variables which affect allocation of seismic vulnerability. The forms presented in scheduled T2-5-1 summarise the information of the parameters allocated to each type of characteristic construction

Further, Table 3-1 summarises the principal parameters for the allocation of a particular function of vulnerability for each type.

Table 3-1
Parameters of capacity and damage to each type of construction.

ID TYPE	H(m)	T(s)	Cs	GAMMA	LAMBDA	MIU	ALPHA 1	ALPHA 2	PLASTIC DAMAGE	MAXIMUM DAMAGE	CURVATURE 1	CURVATURE 2	COLAPSE FACTOR (MEAN)	COLAPSE FACTOR (DEVIATION)
MC-RCSB-1	2.50	0.08	0.20	1.50	2.00	5.00	0.75	0.75	0.00	1.00	1.60	0.00	0.40	3.50
MC-SLSB-1	2.50	0.26	0.19	1.30	1.30	5.00	0.75	0.75	0.05	1.00	8.50	3.30	0.40	3.50
MC-RLSB-2	5.00	0.08	0.20	1.50	2.00	5.00	0.75	0.75	0.00	1.00	1.60	0.00	0.40	3.50
MS-RLSB-2	5.00	0.15	0.16	1.30	1.50	1.50	0.75	0.75	0.15	1.00	6.50	5.00	0.40	3.50
MS-SLSB-1	2.50	0.08	0.16	1.30	1.50	1.50	0.75	0.75	0.15	1.00	5.00	5.20	0.40	3.50
MR-SLSB-1	2.50	0.08	0.33	1.50	1.75	3.75	0.75	0.75	0.08	1.00	5.60	3.80	0.40	3.50
MR-RLSB-2	5.00	0.30	0.16	1.30	1.30	5.00	0.75	0.75	0.05	1.00	8.50	3.80	0.40	3.50
PAA-SLSB-B	2.4-5.0	0.40	0.33	1.50	1.75	3.75	0.75	0.75	0.20	1.00	2.30	4.00	0.40	3.50
PCR-RCSB-2	5.00	0.36	0.33	1.50	2.25	5.25	0.75	0.75	0.08	1.00	2.50	2.80	0.40	3.50
PCR-RLSB-2	5.00	0.36	0.33	1.50	2.25	5.25	0.75	0.75	0.08	1.00	2.50	2.80	0.40	3.50
W-FLFB-2	5.00	0.44	0.17	1.50	2.50	5.00	0.75	0.75	0.08	1.00	2.50	2.90	0.40	3.50
W-SLFB-1	2.50	0.26	0.17	1.50	2.50	5.00	0.75	0.75	0.08	1.00	2.70	2.70	0.40	3.50

H: Building height

T : Structural Period

Cs: Design seismic coefficient.

γ: Relation design stress and stress yield.

λ: Relation design stress and stress yield.

μ: Ductility capacity

$\alpha 1$: Actual weight fraction in the main vibration mode

$\alpha 2$: Fraction high point of displacement.

Table 3-2
Parameters of Miranda to each type of construction

ID TYPE	# STORIES	INTERSTORY H	α	a	Te	μ
MC-RCSB-1	1.00	2.50	1.00	0.10	0.08	5.00
MC-SLSB-1	1.00	2.50	1.00	0.10	0.26	5.00
MC-RLSB-2	1.00	2.50	1.00	0.10	0.08	5.00
MS-RLSB-2	2.00	2.80	1.00	0.10	0.15	1.50
MS-SLSB-1	1.00	2.80	1.00	0.10	0.08	1.50
MR-SLSB-1	1.00	2.80	1.00	0.10	0.08	3.75
MR-RLSB-2	1.00	2.50	1.00	0.10	0.30	5.00
PAA-SLSB-B	1.00	5.00	5.00	1.00	0.40	3.75
PCR-RCSB-2	2.00	2.80	11.00	0.10	0.36	5.25
PCR-RLSB-2	2.00	2.80	11.00	0.10	0.36	5.25
W-FLFB-2	2.00	2.80	1.30	0.10	0.44	5.00
W-SLFB-1	1.00	2.80	1.30	0.10	0.26	5.00

Of Floors: No. of floors

H of mezzanine (Δz): Mezzanine height

α: Parameter that defines the type of deformation (bending or shear)

a: Factor that defines the lateral load

Te: Periodo estructural

μ: Ductility capacity .

Figures 3-1 to 3-12 present the allocated vulnerability functions.

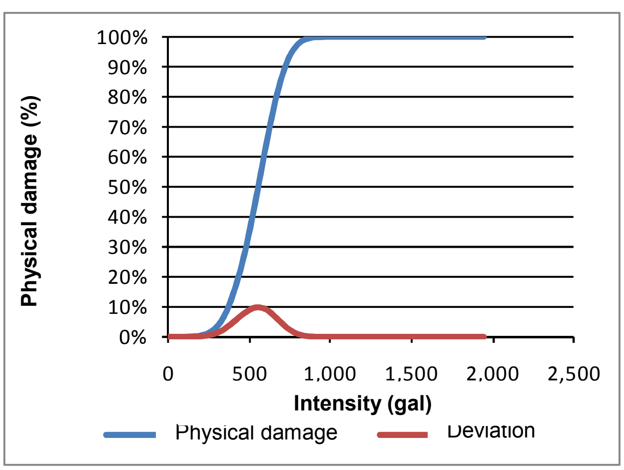

Figure 3-1 Seismic vulnerability function for construction type S_MC-RCSB-1

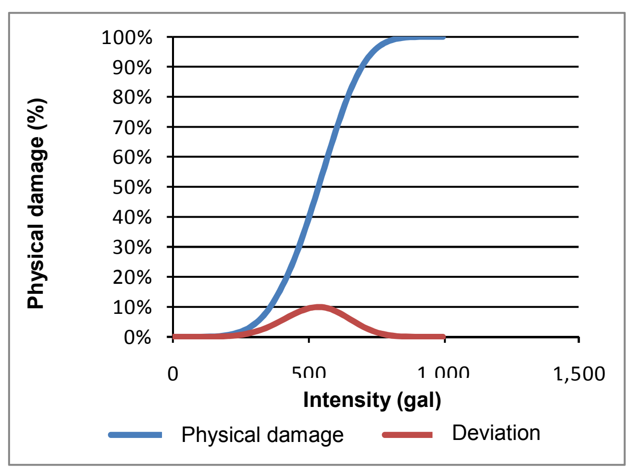

Figure 3-2 Seismic vulnerability function for construction type S_MC-RLSB-2

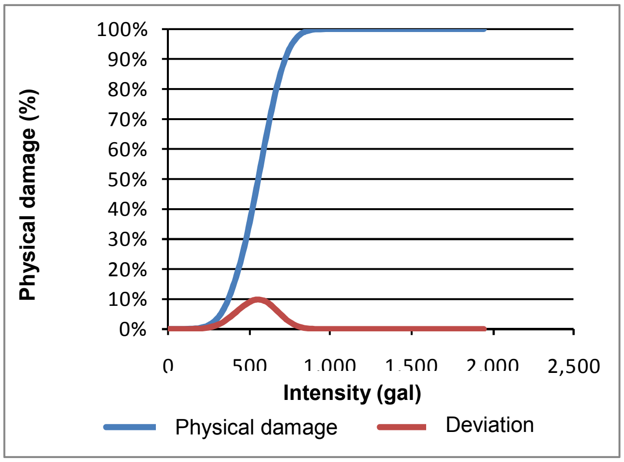

Figure 3-3 Seismic vulnerability function for construction type S_MC-SLSB-1

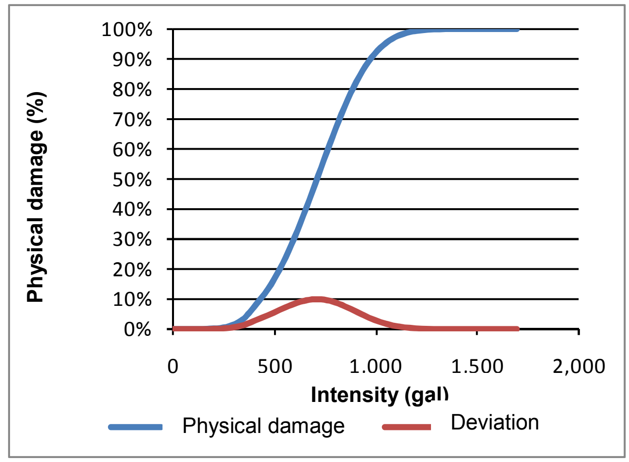

Figure 3-4 Seismic vulnerability function for construction type S_MR-SLSB-1

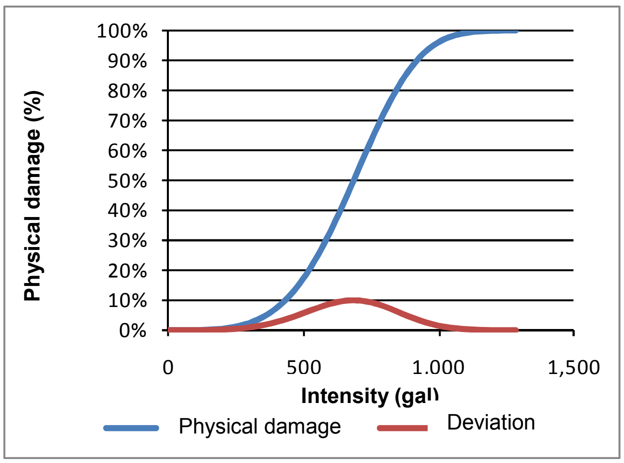

Figure 3-5 Seismic vulnerability function for construction type S_MR-RLSB-2

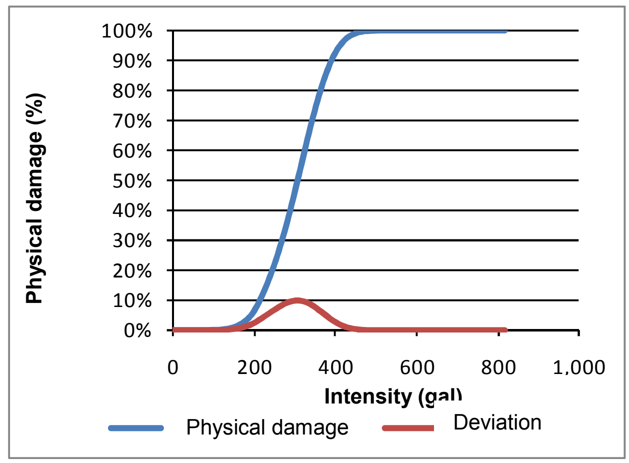

Figure 3-6 Seismic vulnerability function for construction type S_MS-RLSB-2

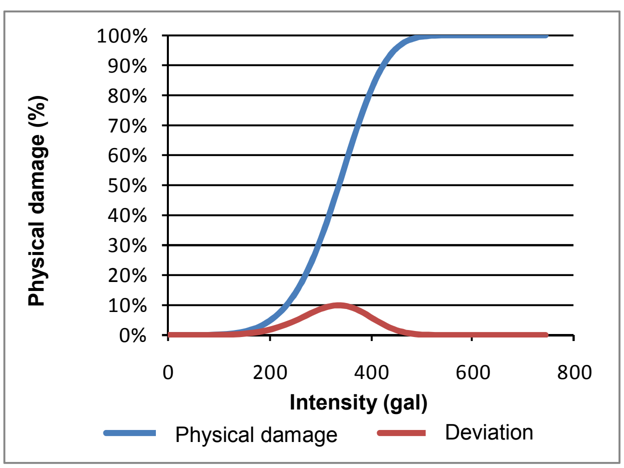

Figure 3-7 Seismic vulnerability function for construction type S_MS-SLSB-1

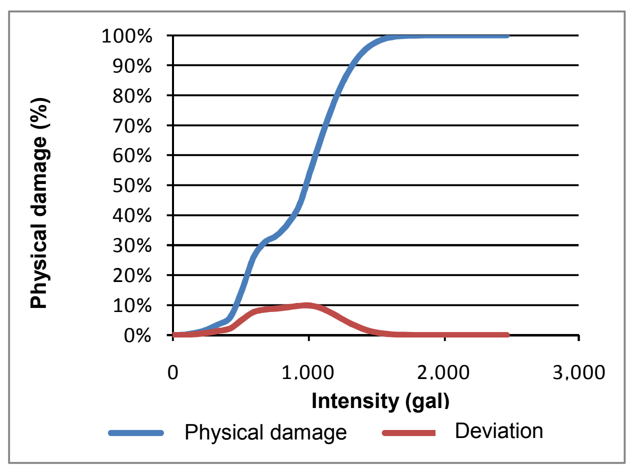

Figure 3-8 Seismic vulnerability function for construction type S_PAA-SLSB-B

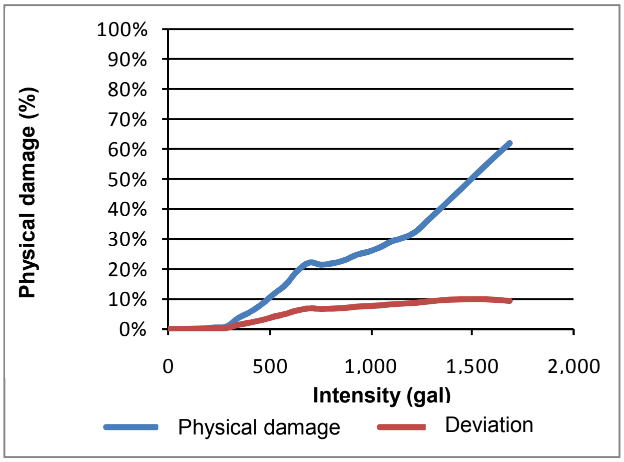

Figure 3-9 Seismic vulnerability function for construction type S_ PCR-RCSB-2

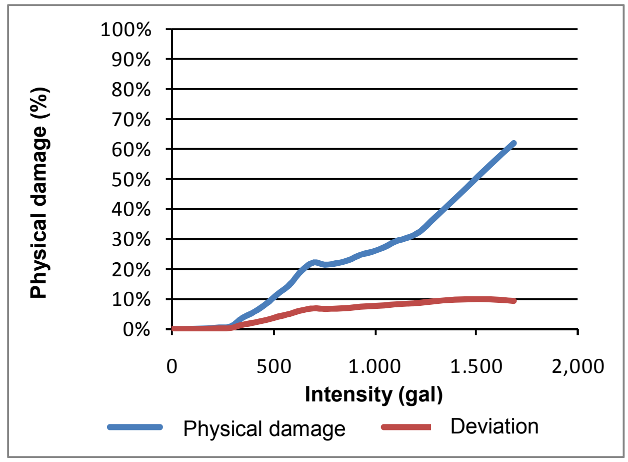

Figure 3-10 Seismic vulnerability function for construction type S_PCR-RLSB-2

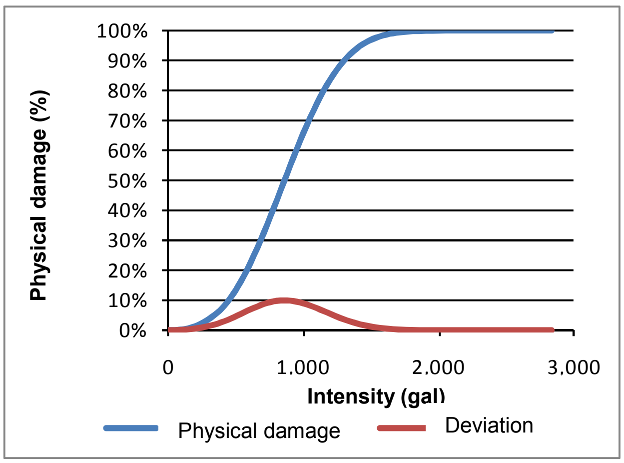

Figure 3-11 Seismic vulnerability function for construction type S_W-FLFB-2

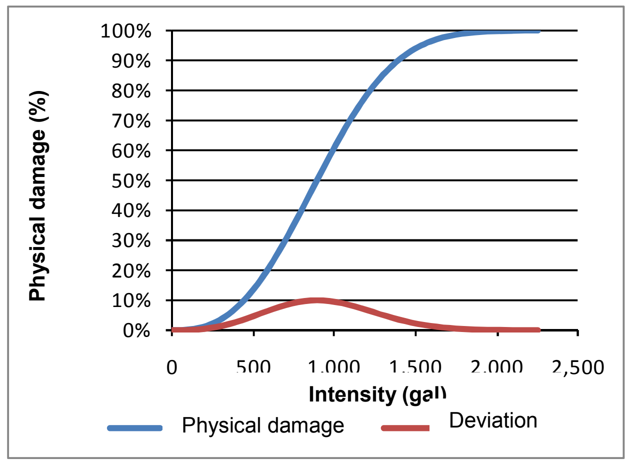

Figure 3-12 Seismic vulnerability function for construction type S_W-SLFB-1

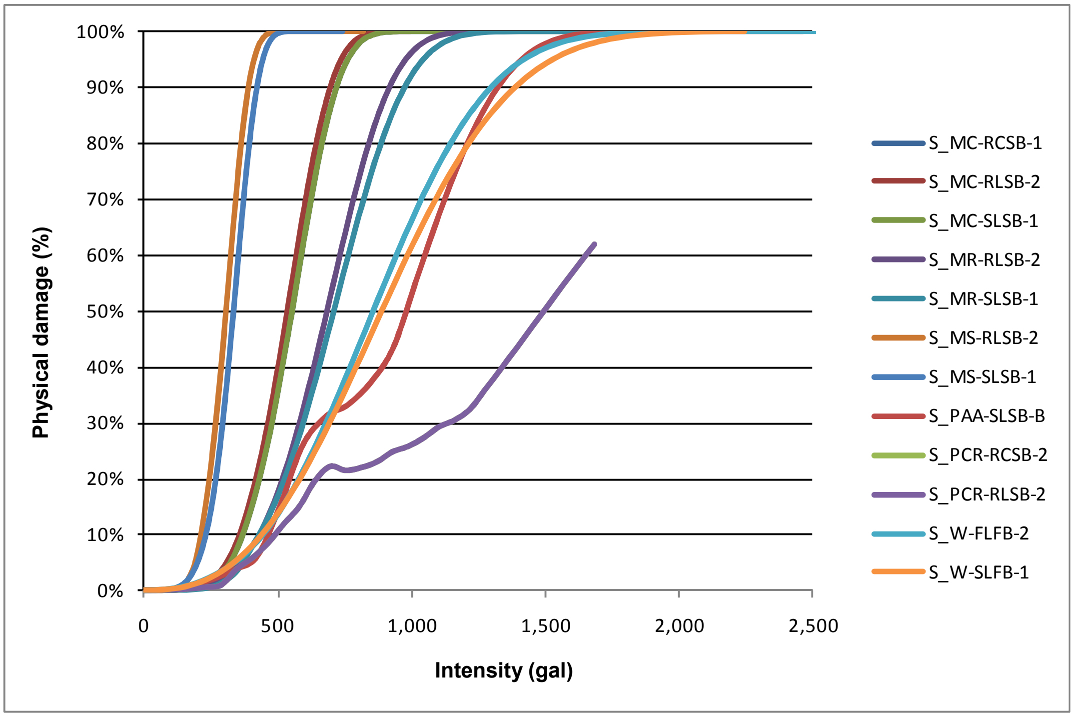

Figure 3-13 Seismic vulnerability function

3.2 Wind vulnerability

Each of the above systems was characterised from the point of view of variables affecting the allocation of vulnerability to wind speed.

Table 3-3
Parameters of wind to each type of construction

STRUCTURAL TYPE	ID	DESCRIPTION	MEDIUM INTENSITY OF DAMAGE	DEVIATION	MAX PHYSICAL DAMAGE
MC-RCSB-1	CS1	Concrete roof, Facade en mamposteria	300	8.1	10
MC-SLSB-1	LS1	Light roof, masonry facade	300	8.1	40
MC-RLSB-2	LS2	Light roof, masonry facade	300	8.1	20
MS-RLSB-2	LS2	Light roof, masonry facade	300	8.1	20
MS-SLSB-1	LS1	Light roof, masonry facade	300	8.1	40
MR-SLSB-1	LS1	Light roof, masonry facade	300	8.1	40
MR-RLSB-2	LS2	Light roof, masonry facade	300	8.1	20
PAA-SLSB-B	LS1	Light roof, masonry facade	300	8.1	40
PCR-RCSB-2	CS2	Concrete roof, masonry facade	300	8.1	5
PCR-RLSB-2	LS2	Light roof, masonry facade	300	8.1	20
W-FLFB-2	LF2	Light roof, Fachada flexible	180	7.4	30
W-SLFB-1	LF1	Light roof, Fachada flexible	180	7.4	60

Figures 3-14 to 3-20 show the functions of vulnerability allocated

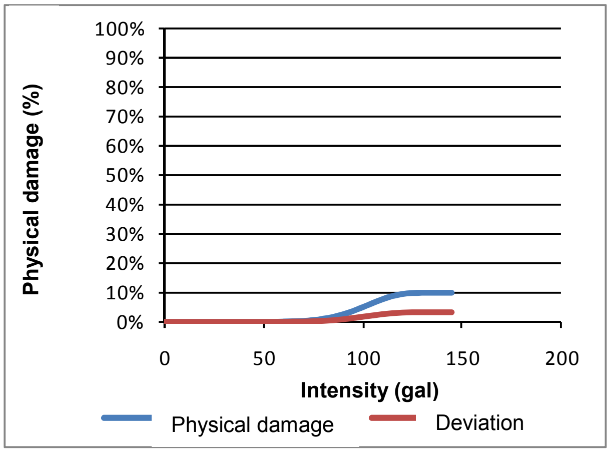

Figure 3-14 Wind vulnerability function for construction type, V_CS1

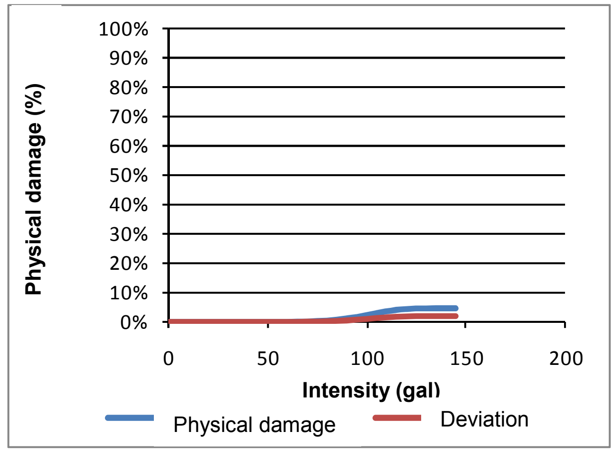

Figure 3-15 Wind vulnerability function for construction type, V_CS2

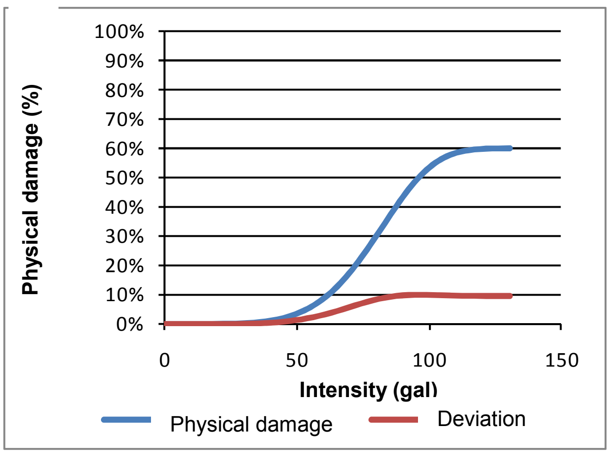

Figure 3-16 Wind vulnerability function for construction type, V_LF1

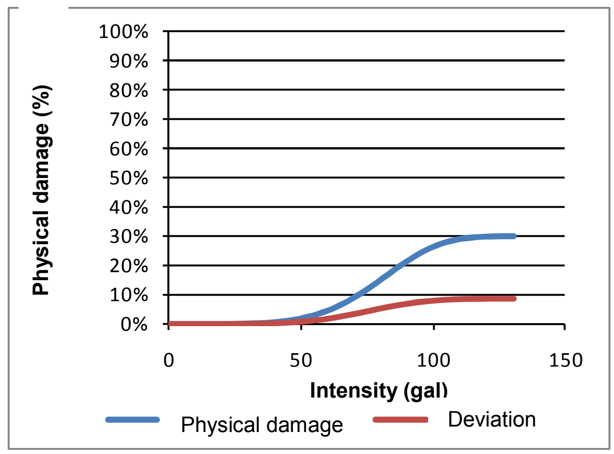

Figure 3-17 Wind vulnerability function for construction type, V_LF2

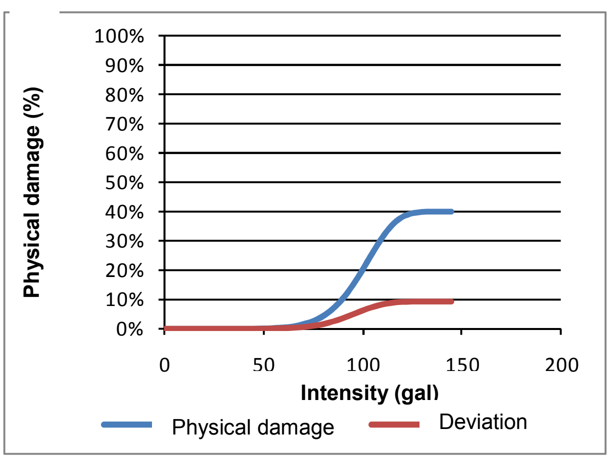

Figure 3-18 Wind vulnerability function for construction type, V_LS1

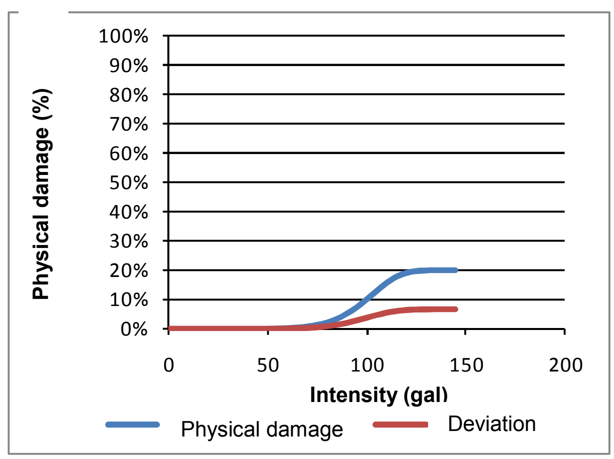

Figure 3-19 Wind vulnerability function for construction type, V_LS2

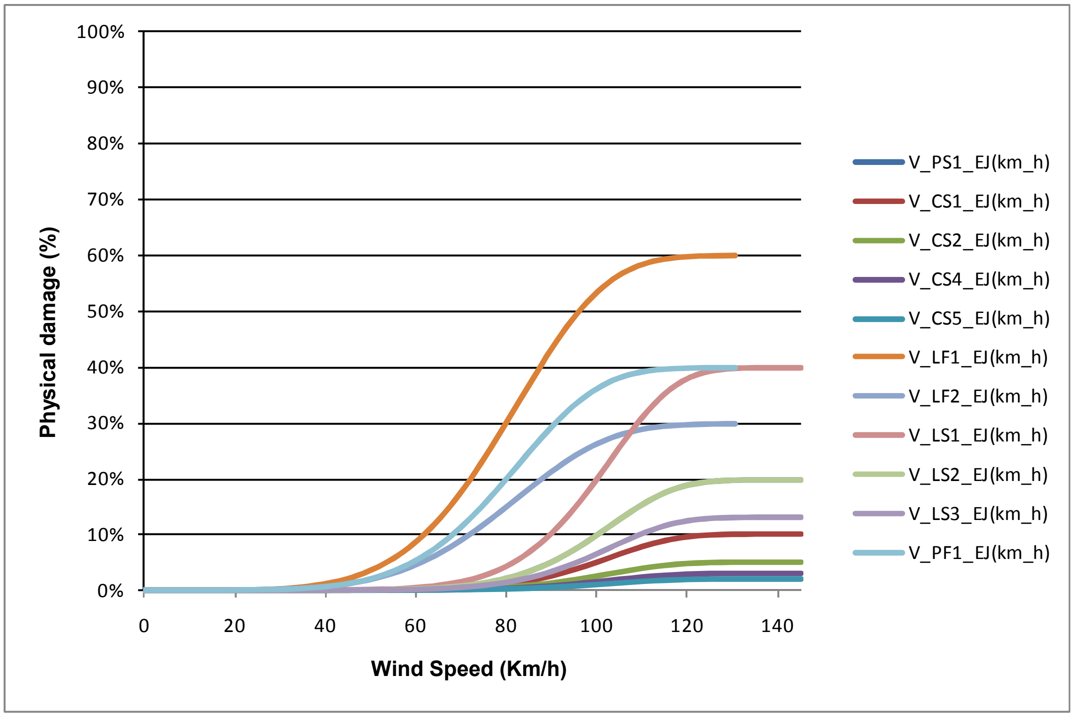

Figure 3-20 Wind vulnerability function

4 Belize City zoning by construction types

4.1 Definition and demarcation of homogeneous zones

The division of the city into homogeneous zones was made using criteria of use, construction and density, height, age, and socio-economic level. These parameters must be more or less constant in each of the zones defined.

The definition of homogeneous zones was based on the interpretation of satellite images, aerial photograph and reviewed by knowledgeable local specialists.

The classification was as follows for the zoning of the city by uses:

- Residential.
- Commercial.
- Industrial.
- Institutional

The classification for construction density was:

- Low ($D \leq 25\%$)
- Medium ($25\% \leq D \leq 60\%$)
- High ($D \leq 60\%$)

The sub classification for the number of stories was:

- Low: 1-2 stories
- Intermediate: 3-7 stories
- High: over seven stories

The sub classification for age was:

- Old
- Intermediate
- New or reconditioned

According to the above we obtain the classification of homogeneous areas indicated in Table 4-1:

Table 4-1
Homogeneous zones identified in Belize City

ZONE	USE	NSE	HEIGHT
Zone 1	Residential	High	Low
Zone 2	Residential	Medium	Low
Zone 3	Residential	Low	Low
Zone 4	Commercial	High	Intermediate
Zone 5	Commercial	Medium	Low
Zone 6	Commercial	Low	Low
Zone 7	Industrial	High	Low
Zone 8	Industrial	Medium	Low
Zone 9	Industrial	Low	Low
Zone 10	Institutional	High	Low
Zone 11	Institutional	Medium	Low

Figure 4-1 is the general zoning map proposed

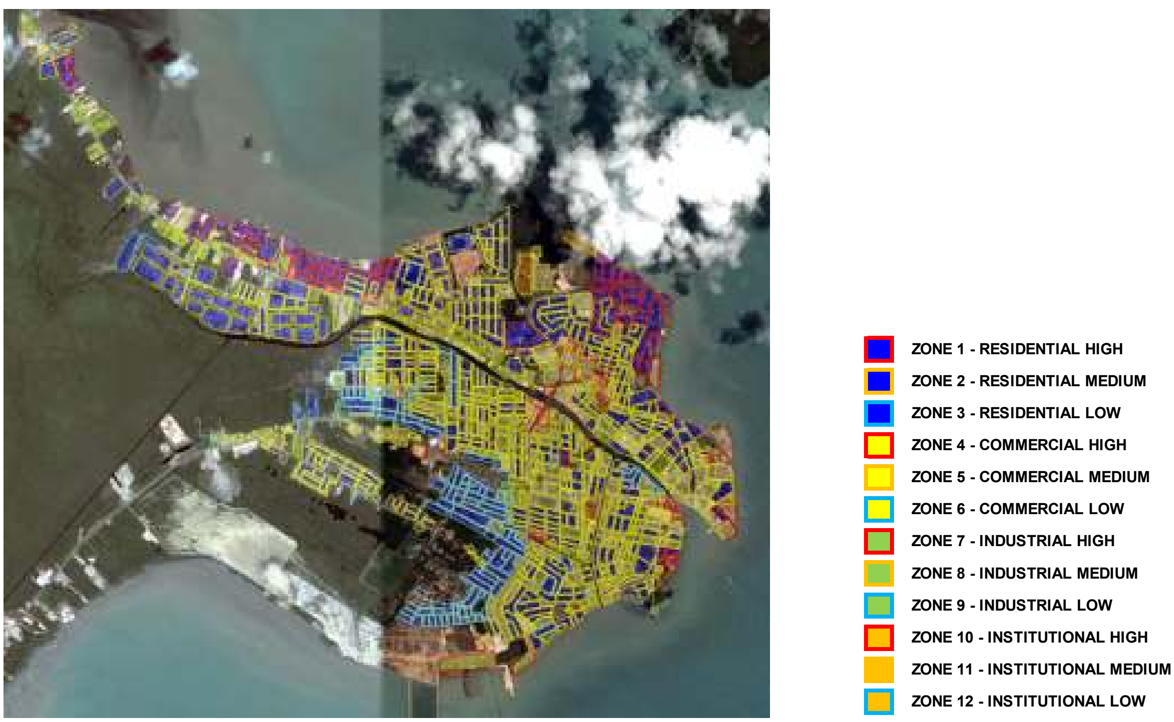

Figure 4-1
Distributional zoning proposed

4.2 Distribution of construction types by homogeneous zones

After zoning the city and defining the dominant types of construction, dominant types of construction were allocated to each zone. Consideration was only given to types of construction which were repeated a number of times and represent percentages of more than 10% of construction is a given area. The allocation was made as in the attached annex.

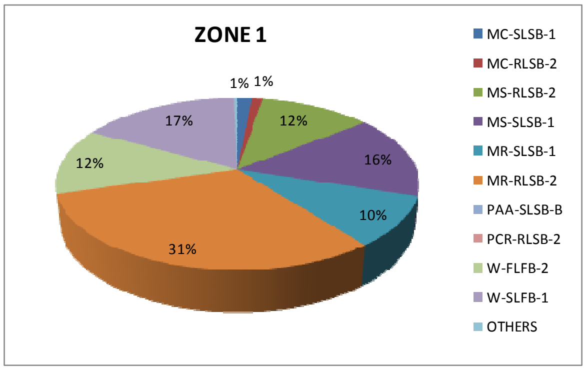

Figure 4-2 Share of structural systems in homogeneous zone 1

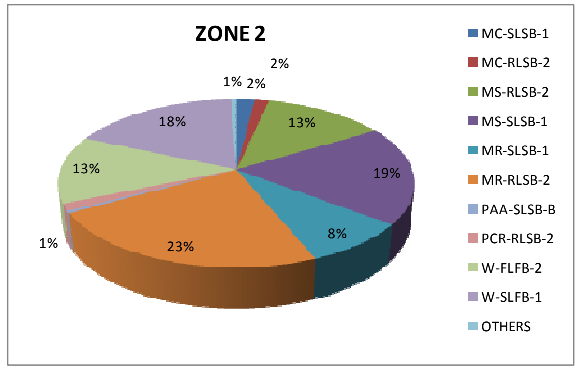

Figure 4-3 Share of structural systems in homogeneous zone 2

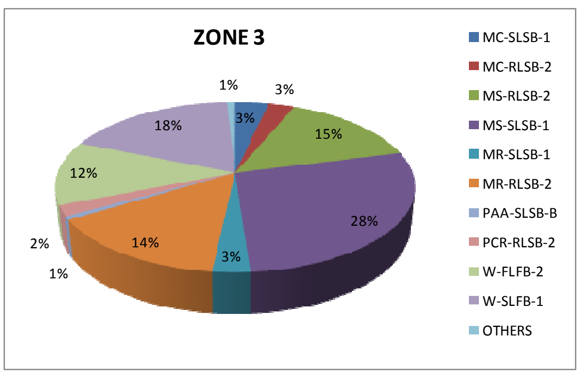

Figure 4-4 Share of structural systems in homogeneous zone 3

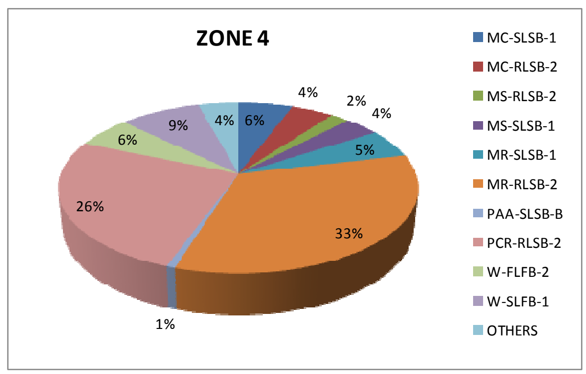

Figure 4-5 Share of structural systems in homogeneous zone 4

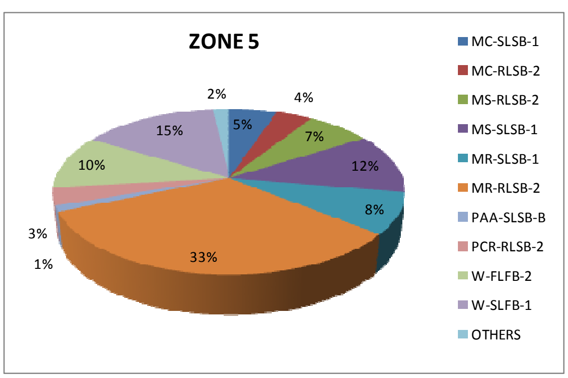

Figure 4-6 Share of structural systems in homogeneous zone 5

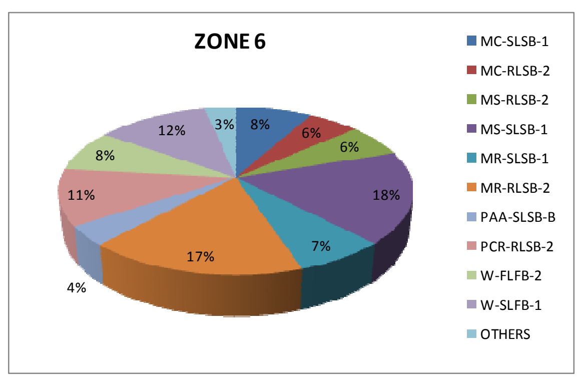

Figure 4-7 Share of structural systems in homogeneous zone 6

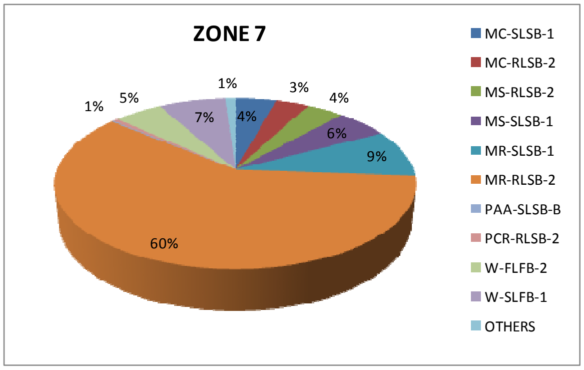

Figure 4-8 Share of structural systems in homogeneous zone 7

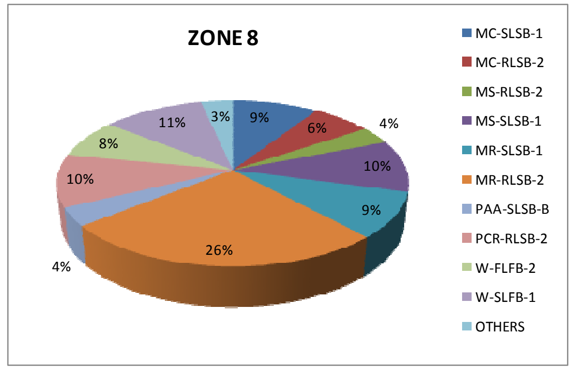

Figure 4-9 Share of structural systems in homogeneous zone 8

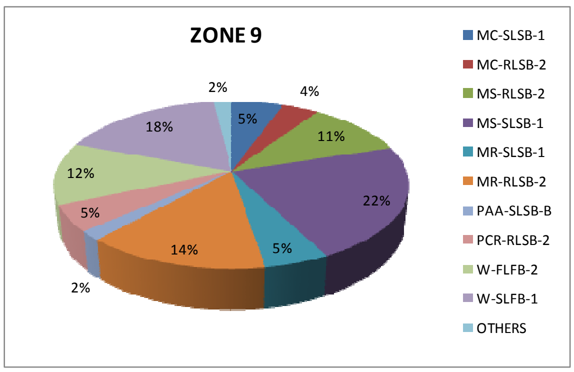

Figure 4-10 Share of structural systems in homogeneous zone 9

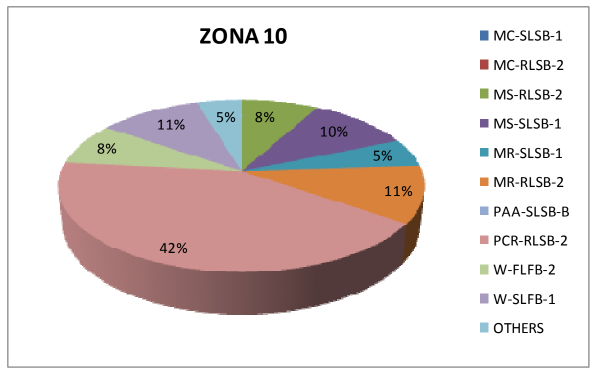

Figure 4-11 Share of structural systems in homogeneous zone 10

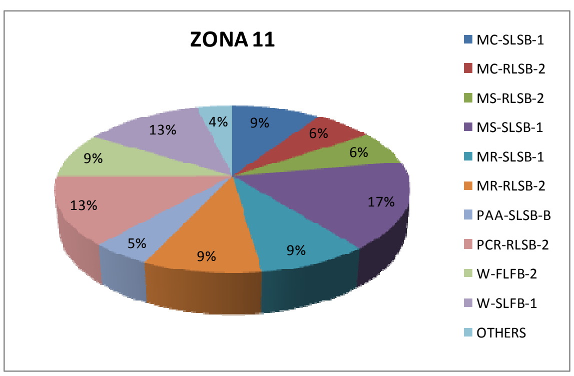

Figure 4-12 Share of structural systems in homogeneous zone 11

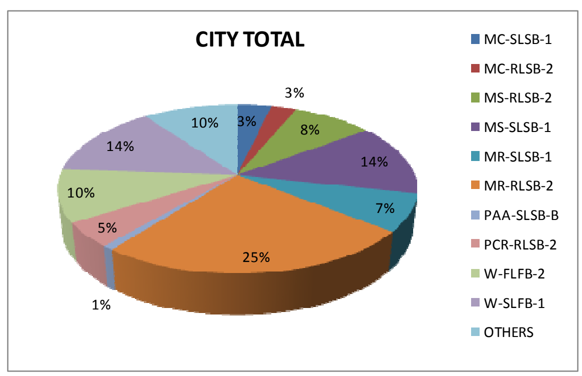

Figure 4-13 Share of structural systems in city total

5 Indicative vulnerability of urban and national infrastructure

For the purposes of analysis, functions of vulnerability were assigned to the main components in infrastructure nationwide. The functions of vulnerability were allocated based on functions available for similar components in specific studies, and were assigned as a purely indicative classification. If evaluations are to be made of specific zones or for a particular system, specific studies will have to be produced for the allocation of functions which correspond to the expected behaviour of the system to be analysed.

This summary presents only the allocation of functions for the case of seismic vulnerability.

5.1 Electricity substations and related urban and national networks

This corresponds to the system of substations and their related networks. The system contains a number of different types of construction, and the functions are obtained by the weighting of the behaviour of the various dominant components, such as towers, supporting arches, insulators etc., transformers and other buildings. Figure 5-1 shows functions of vulnerability adopted in terms of the expected value of loss and the related variance.

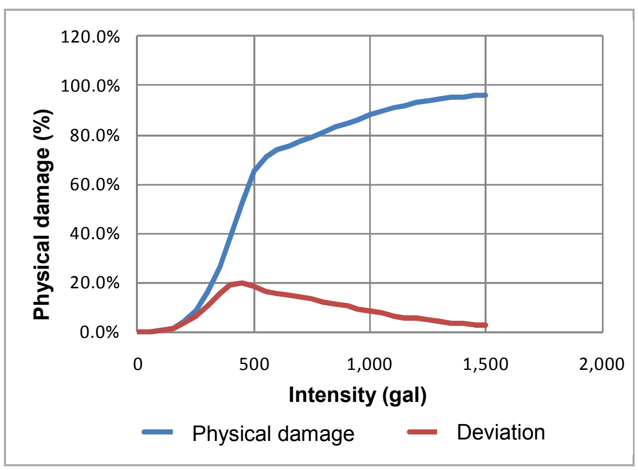

Figure 5-1
Vulnerability function for substations

5.2 Water and sewage tanks and plants

This in general corresponds to low constructions with a relatively rigid and relatively low seismic vulnerability. In general, they are systems designed carefully, and with good quality construction. In general, it is not expected that part or all of them would fail, except with an unusually high intensity of earthquake. Figure 5-2 shows the functions of vulnerability adopted in terms of the expected loss, and the related variance

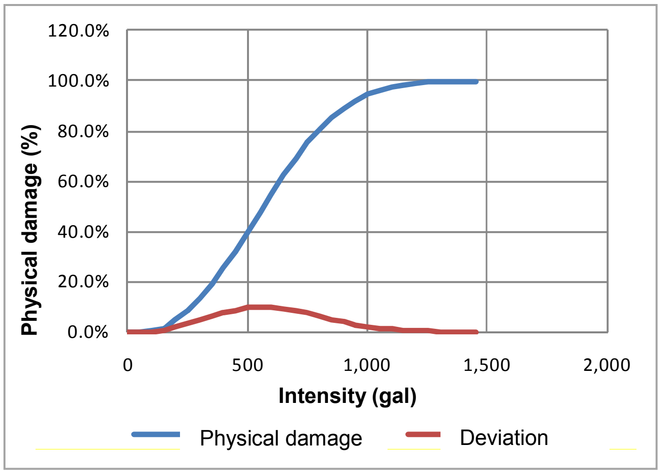

Figure 5-2
Vulnerability function for tanks

5.3 Dams

Although it is in general difficult to make general judgements on the seismic behaviour expected in this type of installation, in general dams are structures carefully designed and constructed with good materials and good quality control. In general, it is not expected that part or all of them would fail, except with an unusually high seismic intensity. In general, the type of damage expected is fissure, cracking, , or failure due to local instability. Figure 5-3 shows the functions of vulnerability adopted in terms of the expected value of loss and related variance

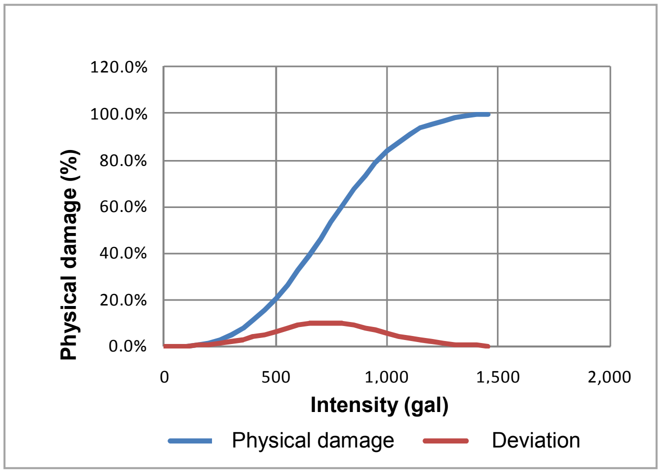

Figure 5-3
Vulnerability function for dams

5.4 Water supplies, sewerage and gas networks

The damage to pipe-based lines depends basically on the unit deformations imposed by the ground on a pipe, which in turn is associated with the velocity of wave propagation, and the maximum velocity of particles. In a simplified version, the functions of vulnerability here are proposed as dependent on the peak velocity of particles, a parameter which can be estimated directly from the calculation of threats. In this case, the parameter of threat needs to be transformed into the terms of maximum acceleration of the ground.

The functions of vulnerability of this type of component should take account of the fact that a given failure in one of these elements implies the repair of a stretch of pipe of the order of 6 m. This means that an estimate must be made of the unit cost of the eventual repair to a characteristic event of damage, and that this should then be applied to the total expected number of instances of damage or failure per unit of length of pipe.

Some general curves fragility have been selected and used as a reference for the proposal in Figure 5-4

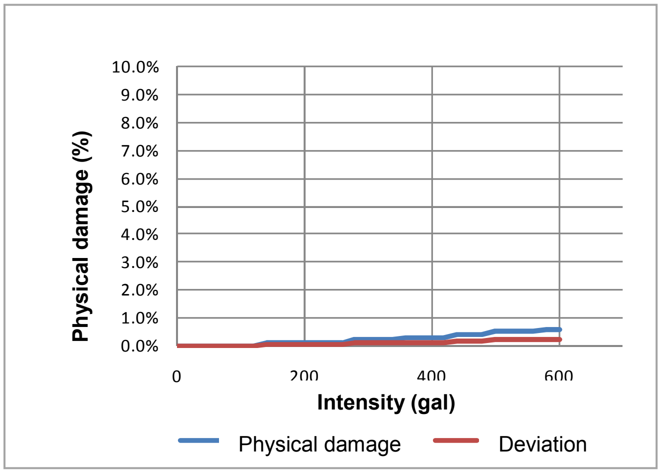

Figure 5-4
Vulnerability function for pipes

5.5 Airports

The behaviour of airport constructions is in general characterised by the behaviour for intermediate-height buildings (of the order of some five stories), with structural systems in reinforced concrete arches or systems of construction with large open spaces underneath such as stores or hangars. Given the major uncertainties associated with determining this type of behaviour, we have supposed a characteristic behaviour for buildings of intermediate vulnerability such as are illustrated in Figure 5-5, in terms of the expected value of loss and the related variance.

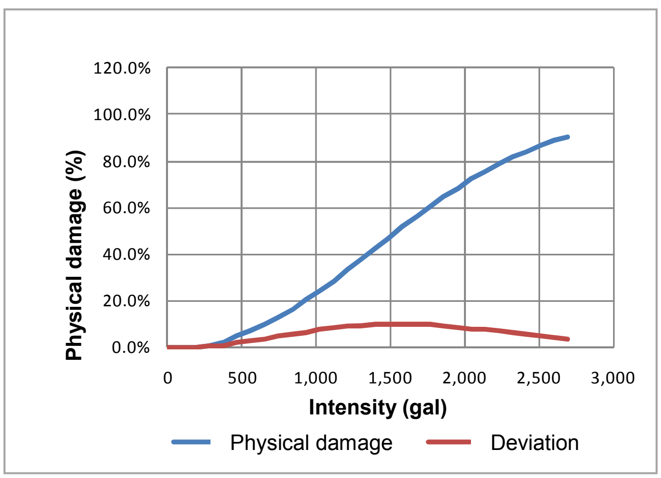

Figure 5-5
Vulnerability function for airports

5.6 Docks

The behaviour of dock constructions is also difficult to characterise in general. However, it may be supposed that that they have the behaviour of an arch-based system of one storey, supported on piles, with relatively good rigidity. In general, these are elements of reinforced concrete with a system of slabs which acts as a rigid diaphragm. All these structures are in general well-designed and built, with good materials, but the expected behaviour is not particularly good, mainly due to the process of deterioration to which they are subject due to direct contact with sea water, and generally common lack of maintenance. In this case, the functional vulnerability adopted it is illustrated in Figure 5-6 in terms of the expected value of loss and the related variance.

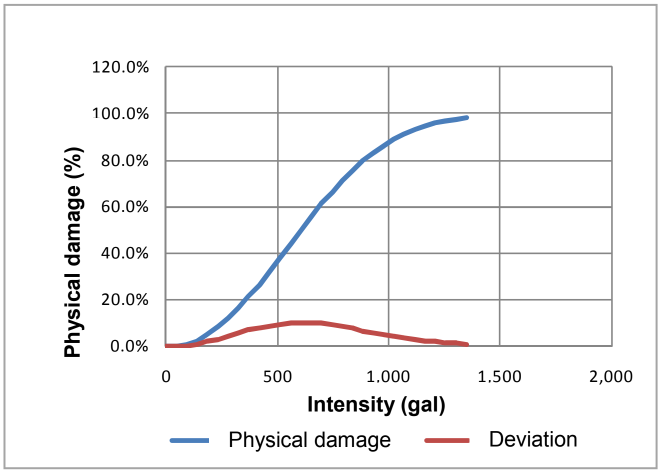

Figure 5-6
Vulnerability function for docks

5.7 Bridges in cities and elsewhere, main roads and secondary roads

In general, there are no functions of direct vulnerability for roads in terms of seismic threat, since the main effect of an earthquake is associated with the phenomena of stability of slopes, or associated phenomena such as the liquefaction of soils, which are not considered in this analysis.

The risk associated with the roads sector, in terms of seismic threat, is therefore concentrated on bridges. The expected behaviour of bridges of a certain age is not good, since in general there is an absence of shear bolts and anchors which limits the seismic displacement of the body of the bridge with respect to the supporting piles, and which are in general the main sources of damage in reinforced concrete bridges. For special bridges, vulnerability in general would be lower, due to the better quality of design. However due to their generally old construction, seismic resistant designs are only considered in the region as a secondary component in the design process, and in many cases are not taken into account at all.

These considerations suggest the use of the function proposed in Figure 5-7 in terms of the expected value of loss and related variance, which in general represent a relatively high vulnerability.

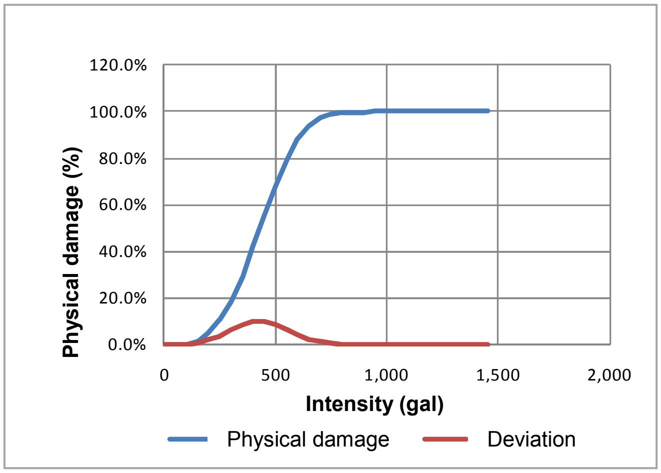

Figure 5-7
Vulnerability function for bridges

5.8 Steam and geothermal plants

The behaviour of dominant constructions in steam and geothermal plants, that is, those which accumulate the highest value exposed, in general matches that of industrial constructions several storeys high, with important contents such as special equipment, like turbines, boilers, generators, etc. These constructions can be characterised as reinforced or horizontally steel-braced buildings, with good construction quality, good technical quality, good quality control and maintenance, and relatively good behaviour expected in the event of an earthquake - that is, a relatively low seismic vulnerability. The function illustrated in Figure 5-8 is adopted, in terms of the expected value of loss and related variance.

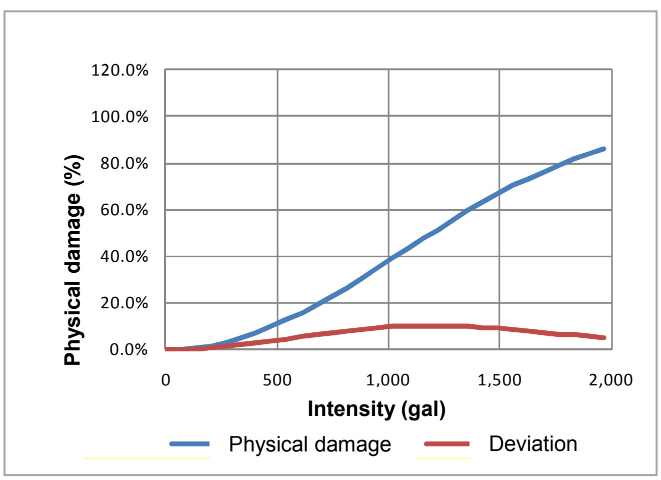

Figure 5-8
Vulnerability function for steam plants

5.9 Oil and gas

For this sector, a global functional vulnerability is considered in terms of the relatively low seismic vulnerability of industrial construction, as illustrated in Figure 5-9, in terms of the expected value of loss and related variance.

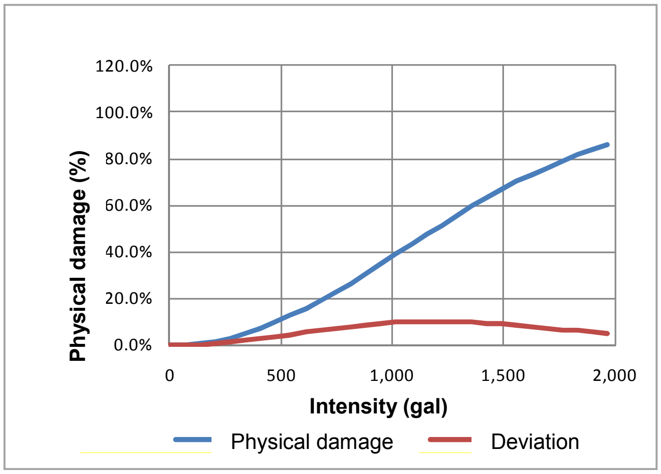

Figure 5-9
Vulnerability function for pipes

ANNEX ERN-CAPRA-T2-2-1
Summary information on parameters assigned to each type of characteristic construction