Tsunami damages assessment : Vulnerability functions on buildings based on field and earth observation survey

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1.Classification of buildings vulnerability and damage level

The main objective of defining and determining the notions and criteria of building vulnerability is to allow the assessment of tsunami hazard and crisis management by production of hazard maps, damage maps and evacuation plan for various tsunamis scenarios.
Two types of vulnerability parameters influencing the level of damage that could affect the buildings have been differentiated and studied as part of a FP6 funded project, the **SCHEMA European Project (Scenarios for Hazard-induced Emergency Management, www.schemaproject.org)** : the primary criteria that are intrinsic of the construction (building types) and the secondary or extrinsic criteria corresponding to parameters from environment (sol nature, floating objects…).

Building class typology depending on
the resistance characteristics of the constructions

Adapted from Leone et al. (2006), Peiris (2007), Garcin et al. (2007), Reese et al. (2007).

Class		Building types
I. Light constructions	**A**	Beach or sea front light constructions / Shantytown /Old town *Wooden, timber, clay materials, slabs of zinc*
II. Masonry constructions & not reinforced concrete	**B**	*Brick not reinforced,Cement, mortar wall,Fieldstone, Masonry*
	C	Individual buildings, villas *Brick with reinforced column & masonry filling*
	D	Large villas or collective building, residential or commercial buildings *Concrete not reinforced*
III. Reinforced concrete constructions	**E**	Residential or collective structures or offices, car parks, schools *Reinforced concrete, steel frame*
IV. Other constructions	**F**	Harbour and Industrial building, hangar *Reinforced concrete, steel frames*
	G	Other, administrative, historical, religion buildings

Qualitative scale for damage level ranking

Adapted from Leone et al. (2006), Peiris (2007) and Garcin et al. (2007)

Credit photo: Narayan *et al.* (2005)., Benfield (2005) , *Leone et al.* (2006),FEMA (2008)

D0 *No damage*

No significant damage

D1 *Light damage*

No structural damage

D2 *Important damage*

Important damage but no structural damage

D3 *Heavy damage*

Structural damage

D4 *Partial failure*

Structural damage that could affect the building stability

D5 *Total collapse*

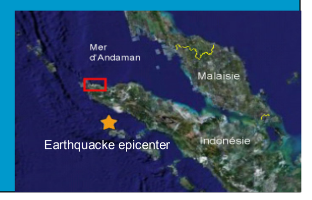
Complete collapse

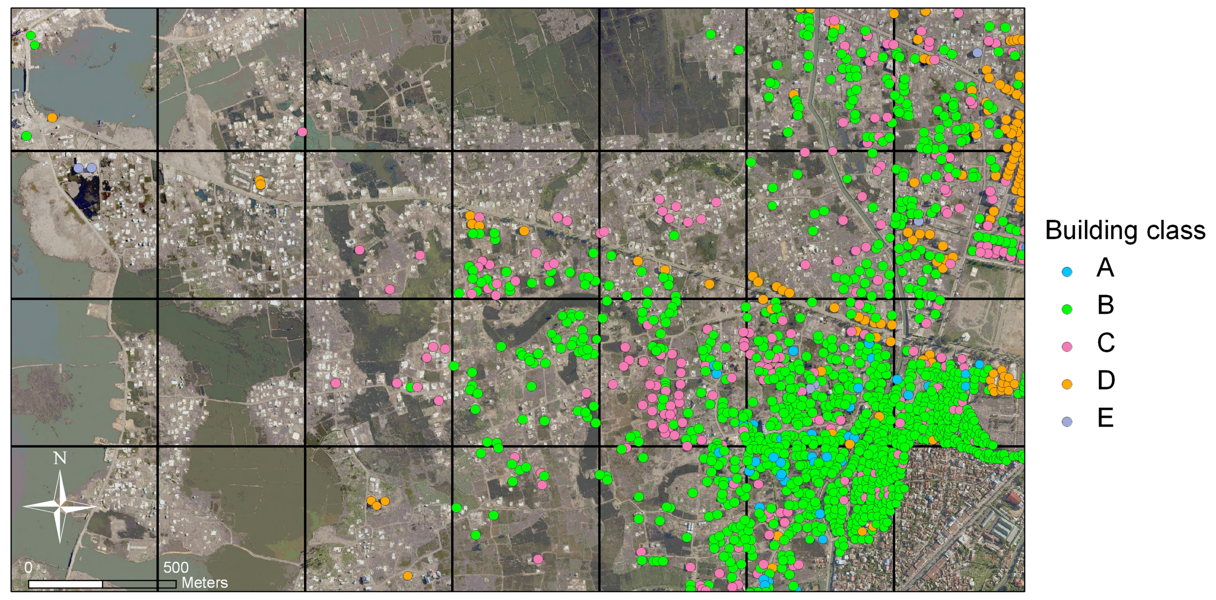
2. Methodology for vulnerability functions elaboration

Database

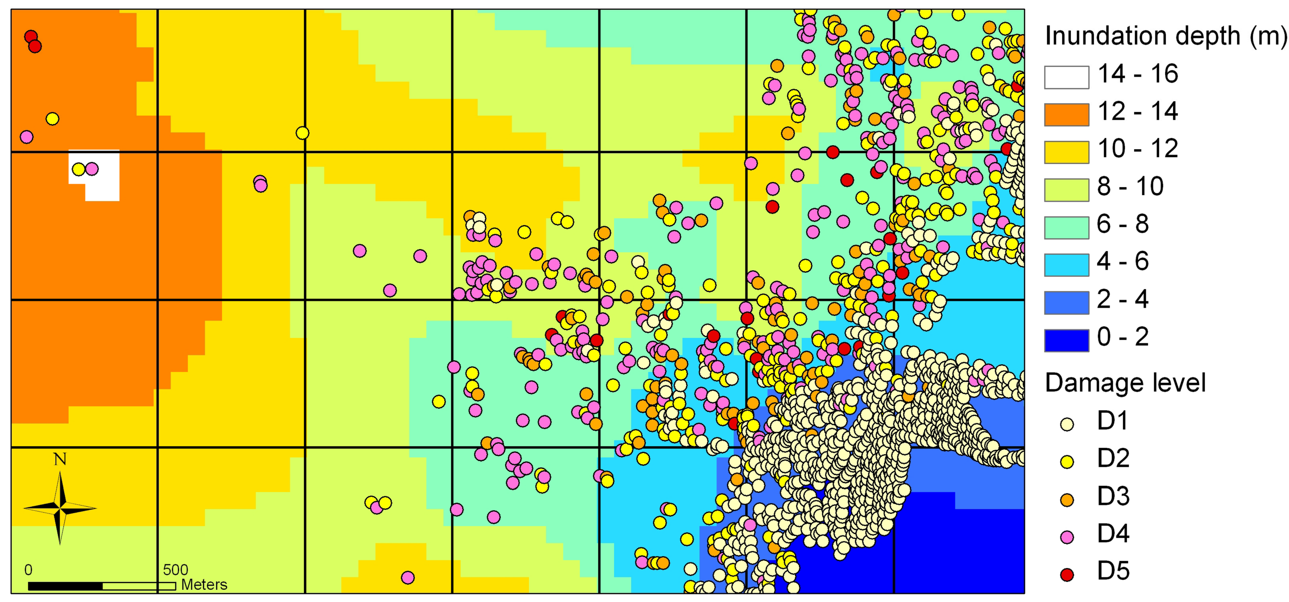
Constituted by field survey & earth observation after the 26/12/2004 tsunami event at Banda Aceh, Indonesia:

- Building classes
- Damage level on buildings
- Max water elevation

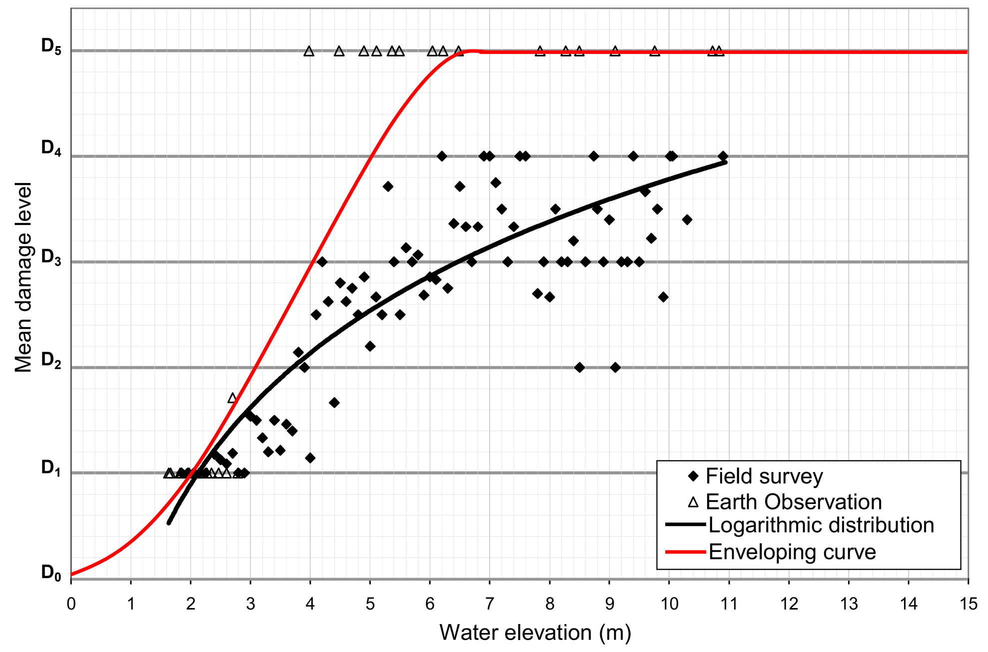




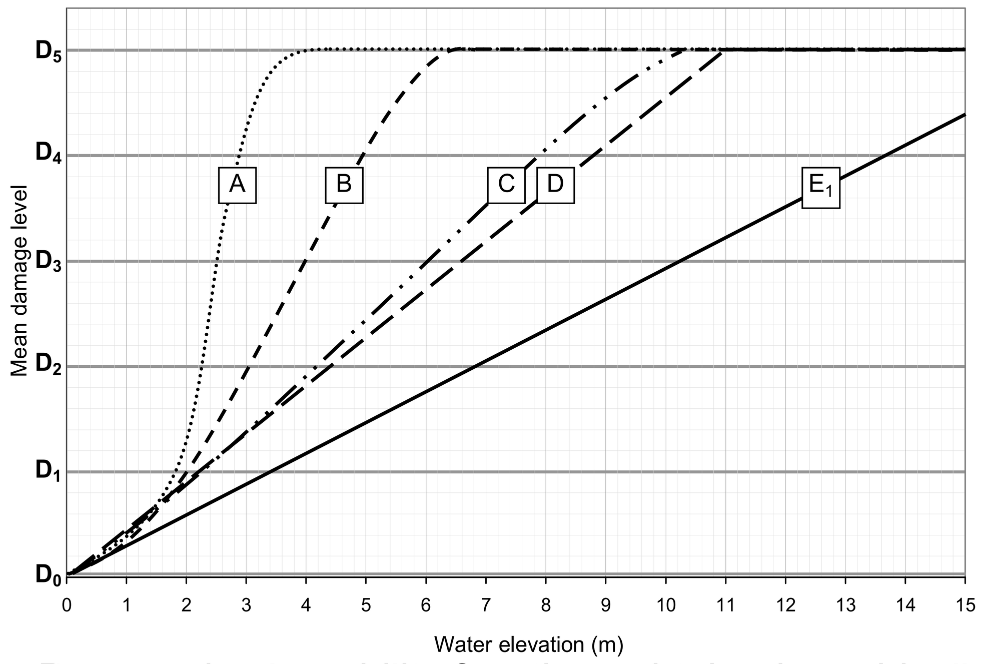
Building classes collected by field survey



Damage level for building observed by field survey and earth observation and interpolation of max water elevations



Example of vulnerability function built by the enveloping curve method



Proposed vulnerability functions obtained empirically for each building class

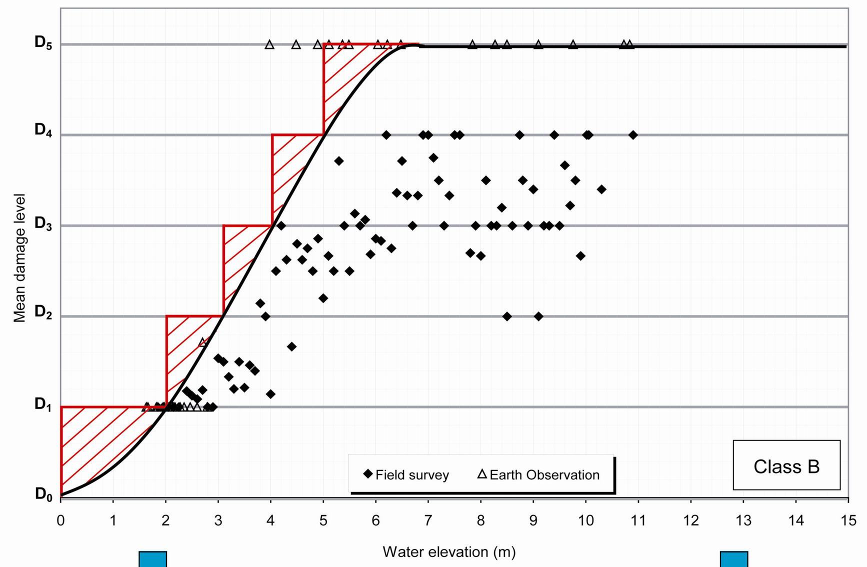
Limits

- Do not take in consideration tsunami parameters such as the stream velocity or the hydrodynamic force
- The curves integrate secondary factors of vulnerability as effects of prior earthquake, erosion, floating objects...

Vulnerability functions

- Empirical method.
- Mean damage level (ponderated) linked to the max water elevation measured on field considering each building class.
- Enveloping curve method chosen rather than logarithmic distribution in order to take in consideration the worst cases.
- Discretisation of the curves in thresholds in order to produce a vulnerability matrix to allow the damage mapping by GIS.

Matrix of damage derived from vulnerability curves



Damage level		Class A	Class B	Class C	Class D	Class E_1
No damage	D_0	0 m	0 m	0 m	0 m	0 m
Light damage	D_1	0 – 1,8m	0 – 2m	0 – 2,5m	0 – 2m	0 – 3m
Important damage	D_2	1,8 – 2,2m	2 – 3m	2,5 – 4m	2 – 4,5m	3 – 6m
Heavy damage	D_3	2,2 – 2,6m	3 – 4m	4 – 6m	4,5 – 6,5m	6 – 9,5m
Partial collapse	D_4	2,6 – 3,8m	4 – 5m	6 – 8m	6,5 – 9m	9,5– 12,5m
Total collapse	D_5	> 3,8m	> 5m	> 8m	> 9m	> 12,5m

3. Application : Conceptual model for damage map production using a GIS

The matrixes derived from an empirical analysis are used in order to produce damage maps on vulnerable locations to tsunami hazard. These damage maps can serve as base of evacuation maps.

Example (not real case) of damage map on Baie Sainte Anne in Seychelles Island for the 26/12/2004 high tide tsunami scenario. Inundation and extension height calculated by ComMit model.