ESTIMATING WASTE INDUCED BY EARTHQUAKES WITHIN DAMAGE SCENARIOS

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Abstract: The objective of this work was to find and test tools to estimate waste tonnage caused by earthquakes. These estimations can be useful for prevention actions like exercises or waste plans but also during the seismic crisis management. Three different methods have been tested using building damage scenarios done in Nice city (Southern France): Hirayama method which is based on Japan experience and Japanese building stock, MECADEPI-HAZUS method which is a hybrid method based on works done in France about floods wastes and HAZUS methodology used in the USA and finally a method based on L'Aquila experience in Italy. Even if needed input data is quite different for the three methods, results using these methods tends to the same order of magnitude on inert rush. Finally the work compares potential waste tonnage caused by seismic scenarioswith local/regional annual waste storage and treatment capacities, as a measure of the waste overflow.

Introduction

The present work has mostly done within the project DSS EVAC (French Research program), which is focused on population evacuation after disasters. In post-seismic situation one of the important aspects in population evacuation is road network connectivity. In this aspect one of the main problems are damaged or collapsed buildings, which generate tons of wastes and consequently road network is blocked. Post disaster waste is in general one important aspect, often underestimated, in territory resilience. Brown et al. (2011) observe the waste management after Christchurch earthquake in New Zealand. They underline that an important work should be done not only of a technical point of view but also organizational. Several disaster waste management plans exist, as for example Asari et al. (2013) work in Japan. In their opinion tools to estimate waste volume after disasters are still necessary.

In France several research programs and waste prevention plans focus on after floods waste (Beraud et al. 2012, MECADEPI project), which is the main natural hazard in France mainland. This work purpose to extend this first works to other natural hazards which could impact large portions of the territory as earthquakes.

The objective of the present work was to propose one methodology which could be combined with earthquake damage scenarios in order to estimate the tonnage of debris generate by the earthquake and, if it possible, distinguish between waste type (inert, wood...). These tools are useful for prevention and post-disaster situation. For example new Waste Prevention Plans in France – done at department scale - should give some responses to the question "How to deal with waste overflow generated by natural or technological disasters?"

Three different methodologies are been used or has been adapted to estimate the debris tonnage. These three methods would be applied to damage scenarios results obtained by Lemoine et al. (2014) in Nice city in Southern France.

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Seismic damage scenario

Two seismic deterministic scenarios have been simulated based on historical events in the area. The goal was to reproduce two situations quite different, one earthquake causing slight-moderate damage and one earthquake causing heavy damage.

Seismic risk in Nice city has been assessed by several projects, being the most important the RISK-UE project, with a great work of vulnerability assessment of current building (Mouroux et al. 2004). In this work in order to produce a damage scenario data coming from Risk-Ue is directly used, only updating in number of dwellings and buildings have been done. Only current building has been considered, commercial, industrial, education buildings and monuments are out of the scope of this work. The seismic scenario methodology used in this work is explained by Sedan et al. (2013) using Armagedom software. Damages for current buildings are estimated as a distribution of number of buildings and dwellings by EMS98 damage states (Grunthal et al. 1998). The whole hypothesis on the choice of seismic sources in Nice region, ground motion simulation, vulnerability and damage assessment are explained by Lemoine et al. (2014).

The slight-moderate damage scenarios consist on an earthquake, near Vesubie area in Nice inland region. Simulated intensities are VI-VII, being VII mostly on the zones with lithological site effect. Consequently potential damages are limited.

One of the most important historical earthquakes in the area was in 1887, called “Liguria or Imperia earthquake”. This earthquake had intensity IX in several Italian localitiesand VIII in Nice city (Sisfrance). Lemoine et al. (2014) take into account newest magnitude estimation done by Larroque et al. (2011, 2012) and decided to displace the epicentre to the West, near Nice area. Simulated intensities in Nice municipality varies between VIII-IX when felt intensity in 1887 was VIII.

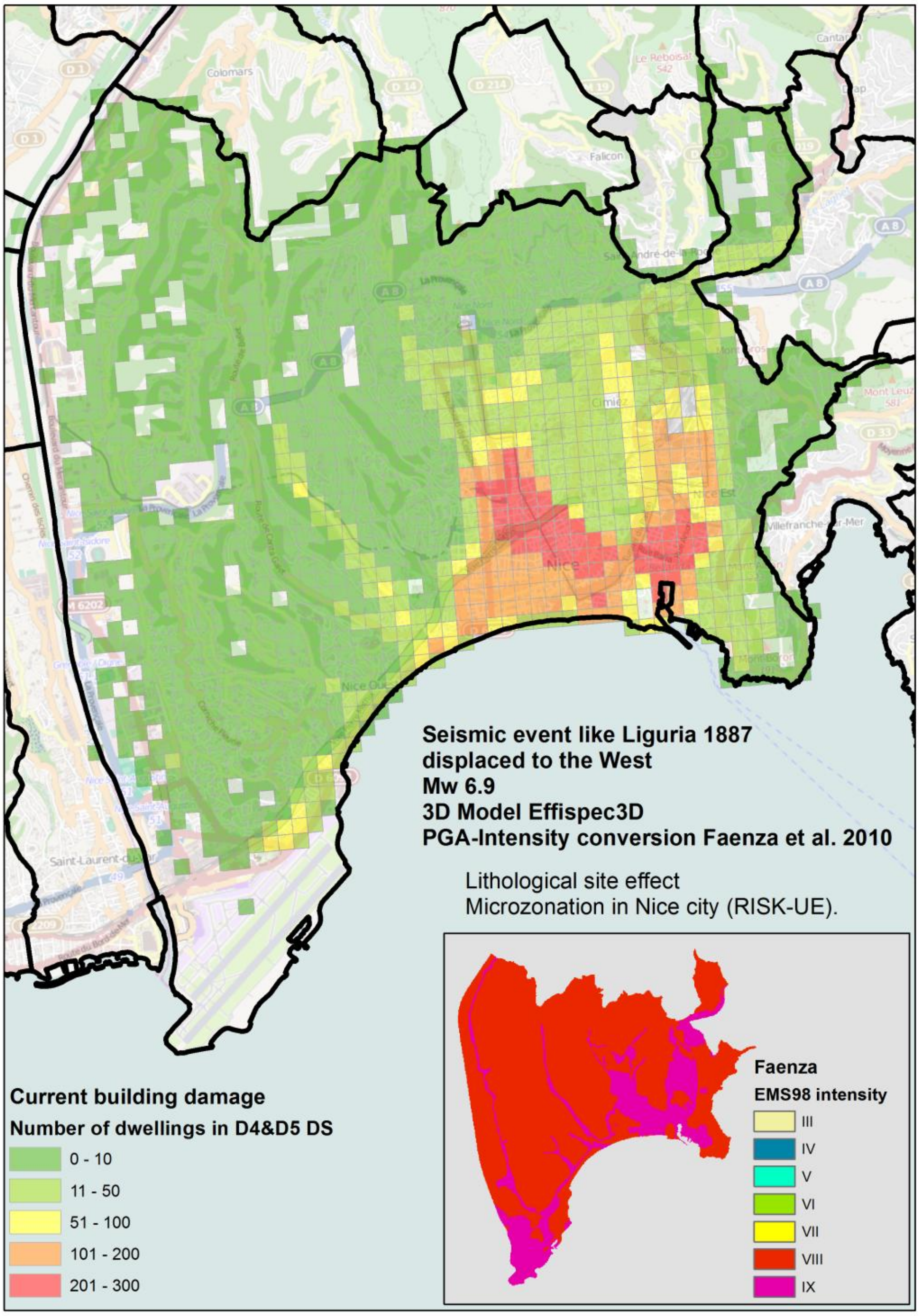

Figure 1.Damage scenario for Liguria event, number of dwellings heavily damaged (D4 and D5).

Table 1.Simulated intensities in Nice municipality and estimated mean damage for buildings.

Seismic scenario	Max intensity in Nice	% buildings damaged (DS D3)	% buildings collapsed (D4 and D5)
Vesubie	VII	1.8%	0.2%
Liguria	IX	14%	9.4%

Hirayama et al. (2010)

Three methodologies are tested in order to estimate waste tonnage produced by the two simulated earthquakes in Nice city. The first one method is ratios given by Hirayama et al. (2010) for Japanese current building stock. Even if Japanese building stock is very different from European one this method has been used because it is quite simple to apply it. Ratios of tons by household are given for three cases (max, min and mean) and for two damage degrees: moderate and complete collapse (MC and CC for i cases).

Complete collapsehouseholds have been considered households in damage states D4 and D5. Moderate collapsehouseholds have been considered buildings in damage state D3 and 50% of D2. Total waste tonnage (Wi) is estimated directly multiplying Table 2 ratios by the corresponding damage distribution in numbers of dwellings (Equation 1).

$$W_i = CC_i \times HH_{D4+D5} + MC_i \times HH_{D3+0.5D2} \qquad (1)$$

Table 2. Hirayama et al. (2010) waste production ratios in tons/household for earthquakes.

	Complete collapse	Moderate collapse
Case 1	60	30
Case 2	85	42.5
Case 3	113	56.5

MECADEPI-HAZUS

The second methodology which has been used is a combination of several ones and its adaptation to French context. For floods in France the MECADEPI project (Beraud et al. 2012) has developed ratios to estimate debris tonnage (Table 3). Because earthquake and floods damage mechanisms are very different it is not possible to adopt directly this method. However MECADEPI says how to estimate the mean weight of furniture, equipment and other contents by household. Moreover MECADEPI is adapted to French stat data format (INSEE).

Structural collapse it is not really considered by MECADEPI method. US HAZUS software brings this information but it is adapted to USA building types. Consequently it has been decided to conserve only empirical HAZUS ratios in % (Table 4). Which is the weight of a typical French building? As done in ASURET project (Rouvreau et al. 2012) estimations can be done based on built area. Empirical ratios are derived from demolition French guidelines (ADEME 2000), expressed in tons by built surface unit. At this state of the work only RC and masonry buildings are distinguished. This method permits to distinguish between inert waste (concrete, stone, bricks...) and other ones (wood, metals, plastic, etc.).

Table 3.MECADEPI parameters, median total contents per households in France.

Equipment (tons/household)	Mixed waste (in m^3)	Furniture tons/household	Total tons/household
0.218	7.09 (density could be considered 0.3 t/m3)	1.025	3.343

Table 4.Derived HAZUS-MECADEPI parameters.

	HAZUS based % waste produced by building collapse											
	% waste (building structure)					% waste (non-structural elements and contents)					Inert waste t/m² of gross floor area	Metal & wood structure waste t/m² of gross floor area
EMS98 DS	D1	D2	D3	D4	D5	D1	D2	D3	D4	D5		
Masonry	5	5	35	100	100	2	2	12	45	100	0.9	0.008
RC	5	5	35	100	100	1	1	7	35	100	1.067	0.2

Following this method, damage pattern has to be represented in damaged number of households and damaged gross floor area.

Building structure is mostly composed by inert materials as concrete, mortar, bricks, and stones, metal and wood. To estimate the tonnage of these types of wastes, which will be the most important after an earthquake, it is preceded as follows:

$$W_{t,z} = \sum_{i=0}^{i=5} D_i * S_z * T_t * r_{i,t} \qquad (2)$$

$W_{t,z}$ is waste tons in the zone z
Di is % of buildings in damage state i (0 to 5)
$S_z$is gross floor area in sq meters
Tt is the weight in tons of waste type t
$R_{i,t}$waste ratio for damage state i and waste type t.

Contents waste is estimated as follows, considering the households in damage state i in the area z:

$$W_{t,z} = \sum_{i=0}^{i=5} HH_{i,z} * T_t * r_{i,t} \qquad (3)$$

Observed in l'Aquila (Italy)

The third method which is used is based on l'Aquila earthquake observations (ITC-CNVF 2010), more concretely after weighting the waste of 4 damaged building demolitions.

They models geometrically buildings like parallelepipeds and calculate its volume (V). Solid portion of this volume (S_t) depends on building type and is expressed in %: RC 25%, masonry 35%, mixed type 30% and steel 15%.

A second relation links building damage (which is expressed here directly in EMS98 DSi) and waste portion (Table 5). The last step is to transform solid inert waste volume in tons.

Table 5.ITC-CNVF damage-waste conversion (rv_i).

EMS98 damage state	D0	D1	D2	D3	D4	D5
Waste volume/total building volume	1%	3%	12%	30%	60%	100%

Total inert waste is calculated (Equation 4), where V_z is the total building volume in the zone z and dw is the solid waste density, considered here 1.6 t/m^3.

$$W_{t,z} = \sum_{i=0}^{i=5} D_i * V_z * S_t * rv_i * dw \qquad (4)$$

Application and results

Coupling damage scenarios and the precedent methods, waste tonnage has been estimated for several seismic scenarios. This estimation is static (no evolution during the time)and limited to Nice municipality perimeter. It is important to note than simulated earthquakes would have an impact in all the area and not only in Nice municipality, so the total waste tonnage would be finally muchmore important. In Table 6 it can be seen that the order of magnitude of all results is relatively stable. As expected the majority of wastes are inert.

Table 6.Estimated waste tonnage for the 2 seismic scenarios following the 3 methods.

	Hirawaya (in million tons)			Hazus&MECADEPI (in million tons)			L'Aquila
	C1	C2	C3	Inert	Metal & wood	Mixed waste	
Liguria scenario	4.24	6	8	5	0.5	0.065	6.2
Vesubie scenario	0.6	0.8	1	.65	0.07	0.007	1

The continuation of this work and post disaster waste plans, is to try to answer to several questions. Waste overflow has to be compared with the local and regional capacity to treat waste. Which is the normal capacity of the area to treat inert debris? Waste overflow generated by one seismic event would be the equivalent of n normal years, how many?

The total building waste storage capacity in Nice region has been plotted in the figure 2(CCI 2013). The total annual capacity in the area is estimated around 1.2 million tons. If we look at Liguria scenario, estimated wastes in Nice city equals to 5 times the annual capacity of the whole area.

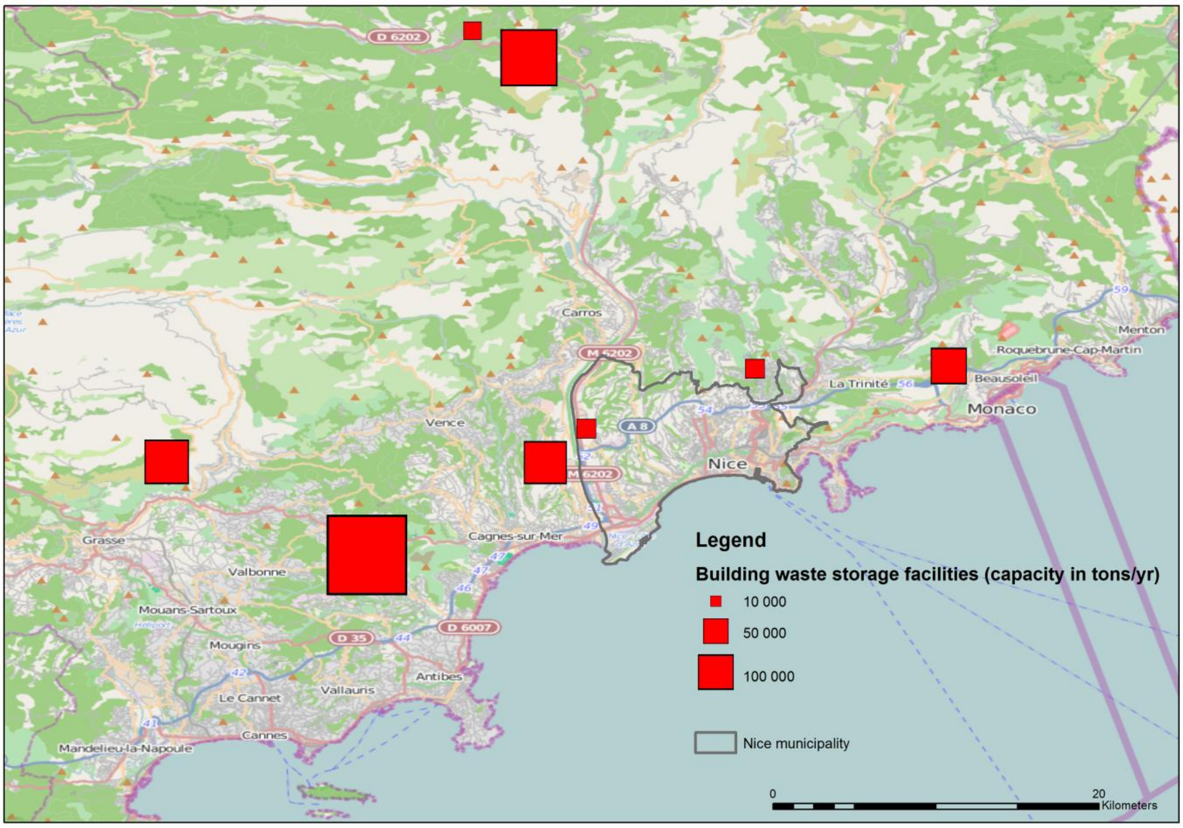

Figure 2. Building waste storage facilities in Nice area and its capacity in tons/year (from CCI 2013).

CONCLUSIONS

Three different methods have been tested using as input data seismic damage scenarios done in Nice municipality. Results are quite stable in order of magnitude of total waste tonnage; however there are many uncertainties, combination of epistemic uncertainties in seismic risk assessment and waste estimation.

This work shows that existing tools or methods can be combined with seismic scenarios in order to help local/regional authorities to plan disaster response and disaster waste overflows. Results should be interpreted as “potential wastes caused by earthquakes”.

Future works have to consider the “waste industry” as a basic lifeline for urban resilience after a disaster, in this case earthquakes. For example to evaluate several strategies, looking at different components: demolition or conservation strategy, optimization of transport, cost, possibility to create temporary storage areas, reconstruction strategies and inert waste recycle, potential induced impacts as pollutions, etc., as it has been done for example by Zhi-Hua et al. (2013) in China.

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