METHODOLOGICAL STUDY ON SEISMIC RISK ASSESSMENT

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SUMMARY

The study of seismic risk on Nice City takes into account numerous parameters:

First we have determined the regional hazard that is to say earthquake able to give the maximal acceleration on the site

Then we have estimated the local hazard, in other world site effects and induced phenomena as liquefaction and terrain movement. For the first item we used several approaches as well experimental, as numerical ones. A geological model has been established by analysing all the boreholes made on the city. A 1D calculation was systematically realised with a 100m by 100m net as well as microtremor measurements. Maps of terrain movement and liquefaction potential was realised using specific process. All these studies were made with the help of GIS.

The building vulnerability assessment needs to realise a typology of the different buildings. This process allows to give vulnerability maps of the city, taking account the local hazard. At present time this part of the study is not finished. Lifelines and roads are another part of the vulnerability system in the city. This aspect needs also to use GIS to elaborate this kind of map.

Finally it is possible to give some recommendations for city management, with the help of the persons in charge of the government and organisation of the city.

INTRODUCTION

Within the framework of the international decade for natural disaster reduction, we have elaborated with the help of French equipment ministry, a study in order to fix a methodology about seismic risk assessment. The second aim of this study is to develop several scenarios to evaluate the emergency plan response. This goal is not achieved at present time, but will be accomplished at the end of the year. This study is applied to the city of Nice, which is a good example for a medium city in a Mediterranean seismic context.

To drive this study we have determine regional and local hazard, vulnerability and finally scenarios.

REFERENCE'S EARTHQUAKE

The first item was to determine the regional hazard. In a moderate seismic context, like France, this determination is not evident. We have applied a deterministic approach, because of the lake of historical data that didn't allow using a probabilistic approach. We have chosen in a first time four faults able to produce an earthquake given big acceleration on Nice site. This choice was made according to the well-known tectonic context and the historical and recorded seismicity. We have kept two of these faults with the consensus of French and Italian geological and seismological community. We have taken afterwards, the shortest distances between the fault and the site of Nice, to put the reference earthquake. The magnitude was fixed according to the maximal historical intensity on these tectonic features.

Finally two earthquakes were taking account in this study:

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A 6.3 magnitude, 30 km from Nice, at 8 km depth

A 5.7 magnitude, 17 km from Nice, at 6 km depth

Because the surface of city is very extensive it has been necessary to calculate (from earthquakes references) the spectrum of bedrock, using numerous attenuation laws, for each point of the site. We have made this calculation for a 100m by 100m net, with the help of GIS software ARCVIEW.

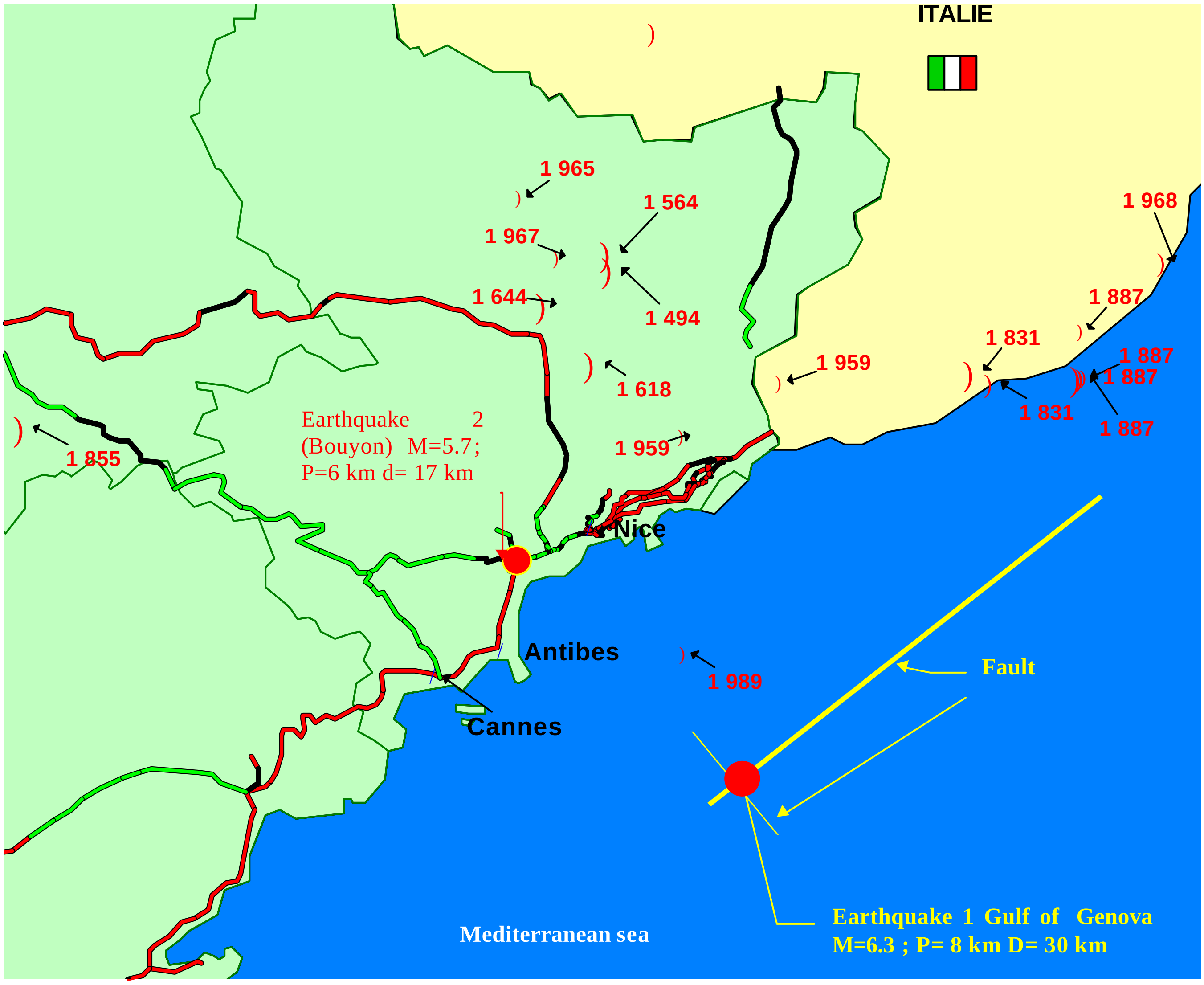

Figure 1 Map with the localisation of two retained earthquakes

LOCAL HAZARD

Site effects

The determination of the local hazard, obviously, taking into account site effects. We used for this goal several numerical and experimental methods, and particularly « microtremor records », which allows to get a lot of measurement points and so a very good assessment of site effects.

The method used in this study was initially proposed by M. Nogoshi and T. Igarashi, this method was going over again and applied by Nakamura in urbanised area of Japan Spectral ratio between horizontal and vertical component (H/V) bring to the force resonance frequency of the site. We will call one of the two following formulae:

$$\frac{S_{n-s}}{S_v} \lhd\rhd \frac{S_{e-w}}{S_v}$$

Where S is the mean spectrum n-s, the north-south component e-w the east-west component and v, vertical one

Nakamura gives an argument to justify this approach: the ratio H/V allows to eliminate the Rayleigh waves effect which masks the information given by shear waves. The figure hereafter shows this phenomenon.

More recently an another justification has been given, this one is probably more realistic than the precedent one. The waves give out by superficial sources are mainly surface waves and Rayleigh waves for the vertical component. In a horizontal structure the polarisation (H/V ratio) of this Rayleigh waves is dependent of the frequency.

In the last decade we improve this technique by using the ratio between horizontal and vertical components. We have tested this practice with several experiments, comparing results of this technique, on the one hand with site on reference tested method and on the other hand with numerical one D and two D procedure.

We have made numerous measurements in the city, with a 100m by 100m net. For each studied site, the ratio between horizontal component spectrum and vertical one are drawn; this ratio gives the fundamental period and its level. Two interpolation maps of these data, given hereafter show the frequency and the level distribution all over the city.

These results are in accordance with these given by site on reference method. To use this method we have put five recorders on selected typical geological sites and one recorder on bedrock. We have record several earthquakes and could to establish a transfer function for the five sites. An example of this study is shown on figure 4 where we can observe the own frequency site and this amplitude.

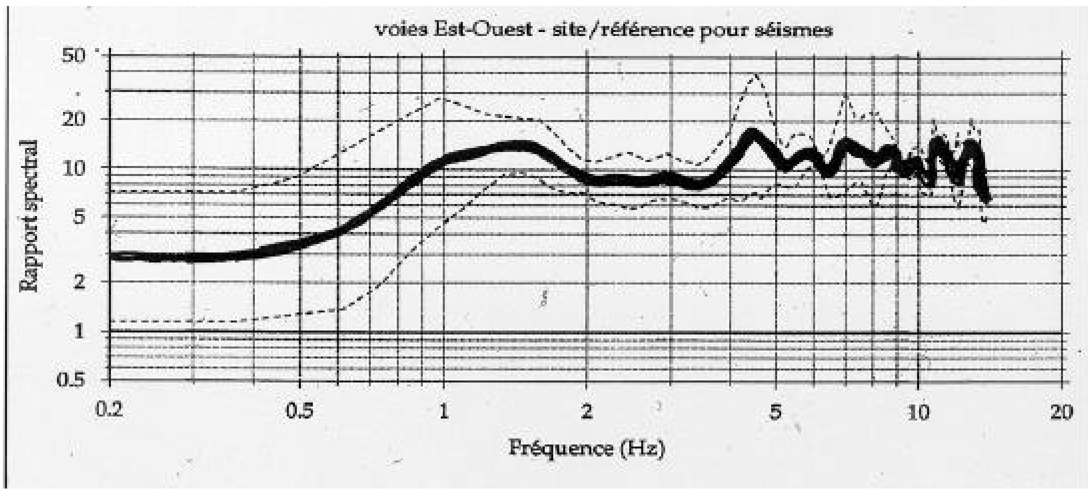

Figure2 Spectral ratio for the Alsace-Lorraine station. East-West component

We also have made a geological model of the city which is composed by three parallel alluvial valley isolated by Pliocene pudding hills. The depth of the bedrock in this valley varies from 30 to 150 meters. To elaborate this model we have analysed all the boreholes made on the city territory and numerized the most interesting ones. This model allows us to calculate the 1D response of the soil with a very dense net. In fact we have fixed points of this calculating net on H/V measurement points, in order to can made a good comparison between the two methods.

All these study permit to draw a response soil model excited by seismic waves, and in particular to define homogenous zone as far as his response is concerned. For each of these zones we give not only the transfer function but also even, the spectrum taking account reference earthquake. These spectra wedged on maximal acceleration at nil period, constitute the seismic parameter which will be convoluted with vulnerability of the city to obtain the seismic risk.

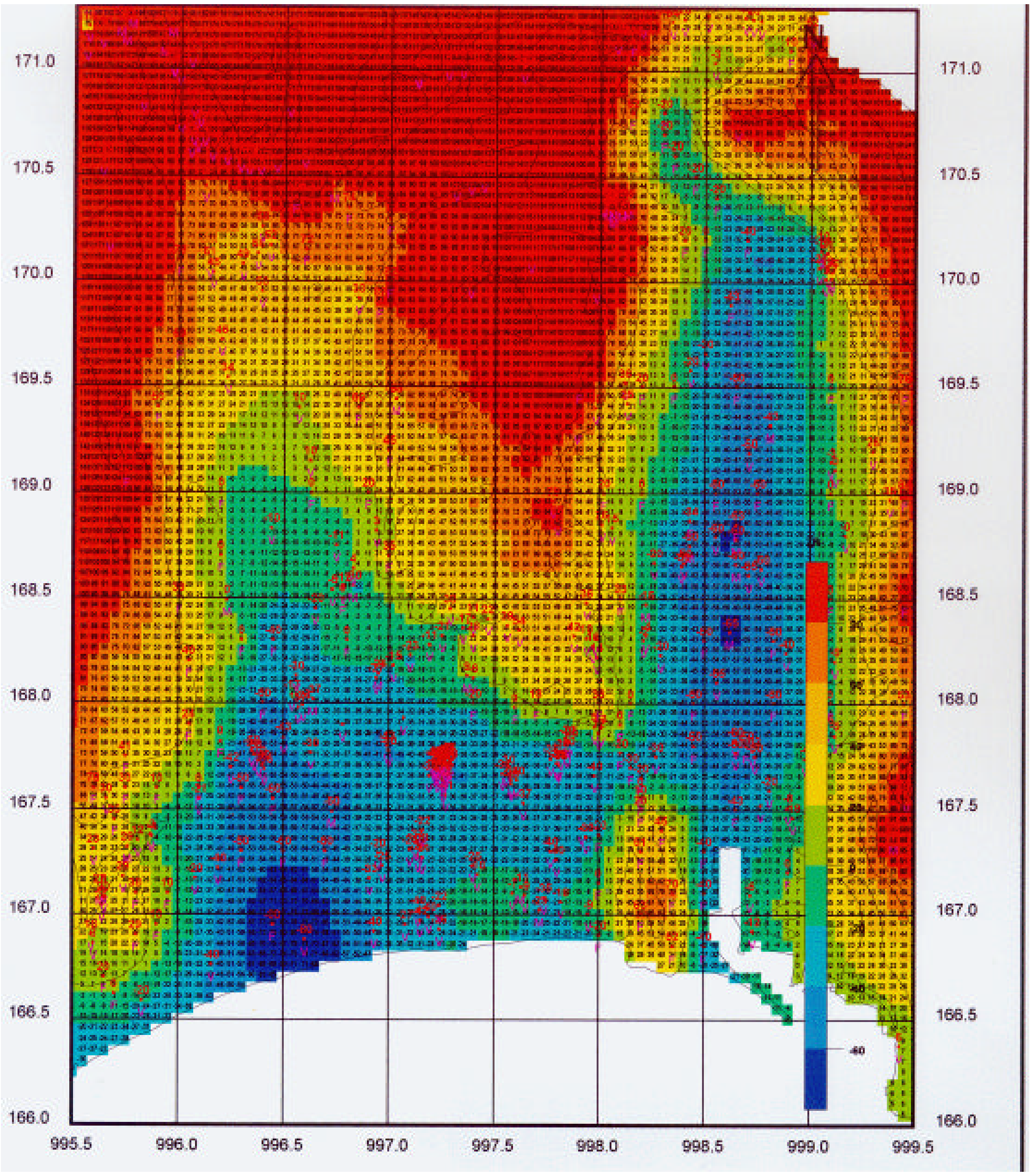

Figure 3 Geological model of alluvial valley in a center part of Nice. Dark blue shows the maximal depth of bedrock and light blue the minimum one. Orange and red illustrate the outcrop of substratum and their altitude.

Maximal frequencies given by H/V process between 0.5 and 15 Hertz

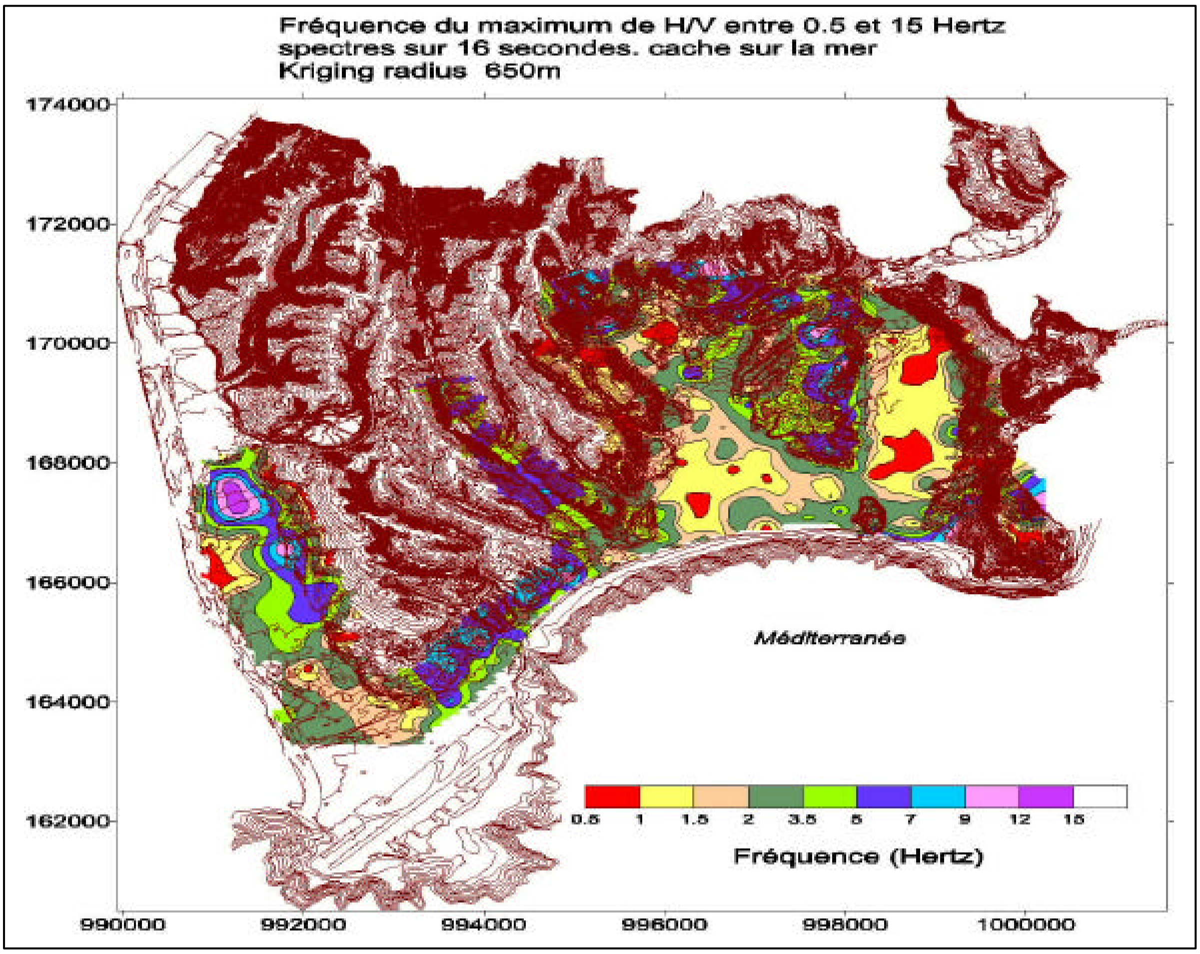

Figure 4 Map of maximal frequencies between 0.5 and 15 Hertz for all the city of Nice.

Terrain movements

One of the important components of the local hazard is, among induced phenomena, the terrain movements trigged by earthquake. To elaborate a dynamic map of terrain movements it is obviously necessary to draw in first time a map in static conditions. This kind of map is very classical and the methodology is built on the mapping of different parameters that cause the phenomenon. Among the different terrain movements it is above all landslides and rockfalls which are trigged by earthquakes. And for each of these phenomena we have elaborated a specific methodology to obtain maps in dynamic conditions. In a few words this methodology consist to start of static map where the different zones express a « static safety coefficient Fs » which is a function of the mechanical properties of the soil ‘C,Φ), of the slope geometry (β), and of pore pressure (u). Generally we distinguish four level of hazard

zone 1	**Fs>1.8**	**zone 3**	**1.25< Fs <1.5**
zone 2	**1.5< Fs<1.8**	**zone 4**	**1< Fs <1.25**

In a given area, where soil type and hydraulic conditions are homogeneous, the only factor that influences the stability will be the slope geometry, schematically represented by β. Based on the study and map described above the threshold value of β are determined that bound the various zone; βs is then one threshold value defined that corresponds to Fs value. The introduction of seismic action the leads to lowering boundary angle βd. we determine βd from βs with a ratio Fs/Fd = 1.15 to compensate the pessimistic aspect of the pseudo static conditions. In this manner it is possible to determine for each homogeneous area the change in the boundaries between different degrees of hazard.

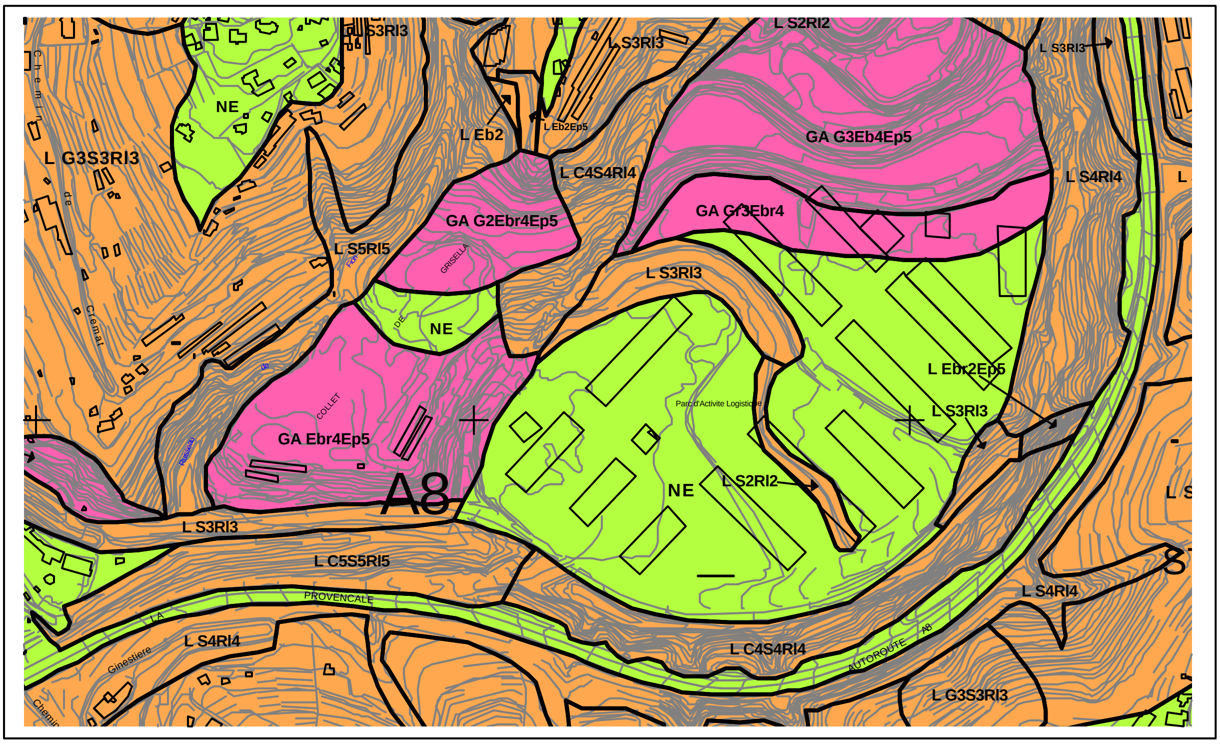

Figure 5 Part of dynamic terrain movement map with hazard level and indication of movement type. For instance G means slide and Eb rock fall. A number connecting with the safety factor gives the level of each type of movement. First indications are connecting with geographic importance of the phenomenon. GA means the potential movement should be very important. L is a limited movement with a possibility of local stabilisation process. And NE zones are without possibility of movement.

Liquefaction

Liquefaction is another important phenomenon able to cause huge damages to the buildings. The model created to calculate 1D response of sites has been used to assess liquefaction too. In fact we have established in the upper part of the different alluvial valleys, a specific model with the help of boreholes. We have analysed the grain sizes and the SPT, CPT and pressiometer results of the different layers from 0 to 25 meters depth, and we have mapping these parameters

Using Iwasaki methodology which consist to asses IL coefficient draws the final map.

$$I_L = \int_0^{20} (10 - 0.5\,z)\,F_L\,dz$$

where:

$F_L = 1 - FS$ if $FS \leq 1$; $F_L = 0$ if FS 1;z : depth (in m); and $FS = \frac{\tau_l}{\tau_e}$

with : $\tau_l = A(N_1)^{0.755}\, e^{0.06 N_1}\, \sigma'_v$; where A depending of grain size and seismicity zone

and : $\tau_e = 0.65 \frac{a_{max}}{g} \sigma_v r_d$; where rd depending of the depth.

• no liquefaction : zones without liquefaction : $I_L = 0$	• liquefaction likely : $5 < I_L \leq 15$
• liquefaction not likely : $0 < I_L \leq 5$	• liquefaction quasi sure : $I_L > 15$

Vulnerability

To study the vulnerability of the city we have, in a first time, taking account the different French classes of building, that is to say:

A Building with a minimal risk for people and economic activity.

B building which should give a current risk for people.

C building which should give an important risk for people.

D building which the safety is essential for people assistance and organisation and survival of the city.

In a second time we have elaborated a typology of the B and C buildings in order to map these different types. Because of delay of this study, these B and C building's map are not entirely drawn at present time. We also have taking account the lifeline's vulnerability as well as road. and bridges. We can observe on figure 6 simulation, that big part of main links between east and west would be probably cut by earthquake.

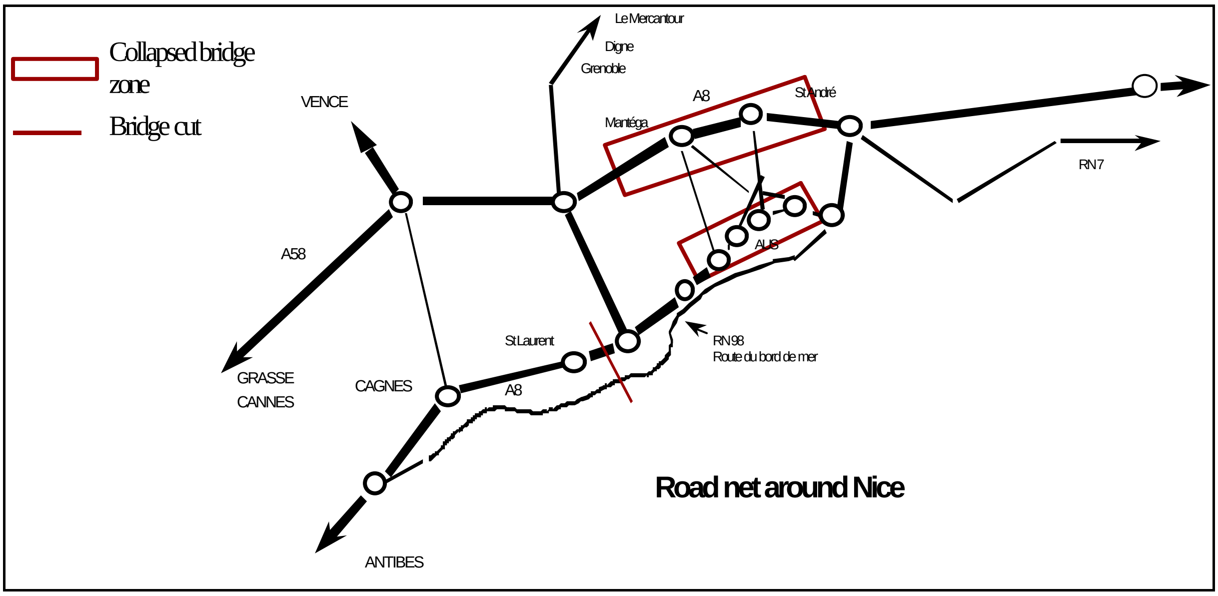

Figure 6 Main roads and highways around the city of Nice showing the vulnerability problems. In particular we can observe that the east- west links are probably destroyed by earthquake.

This diagnostic is very important to elaborate, not only aid politics, but the management of the future net road too. In other world what is, in this case, the best way? Is to reinforce the existent bridges and viaducts? Or to build for instance new anti seismic highways, which give, in addition, a new possibility for car traffic?

CONCLUSION

It is very difficult to describe this study in only 8 pages; moreover the work is not completely finished. The result of this study gives nevertheless important outcome in several fields. For these concerning assessment of hazard, the deterministic approach is probably the best one for medium seismic countries. The microtremor method is very successful and gives the same result than more expensive and time consuming methods, as experimental site

On reference one, or numerical methods. The use of GIS, not only to draw the map, but also above all to give, from the data, geographical interpretation of the different parameters, allows by crossing them, to obtain interpretative maps. The use of GIS is a fundamental application for this kind of study. It is impossible to have good results without this use. This conclusion is also valid for vulnerability and risk studies and scenarios.

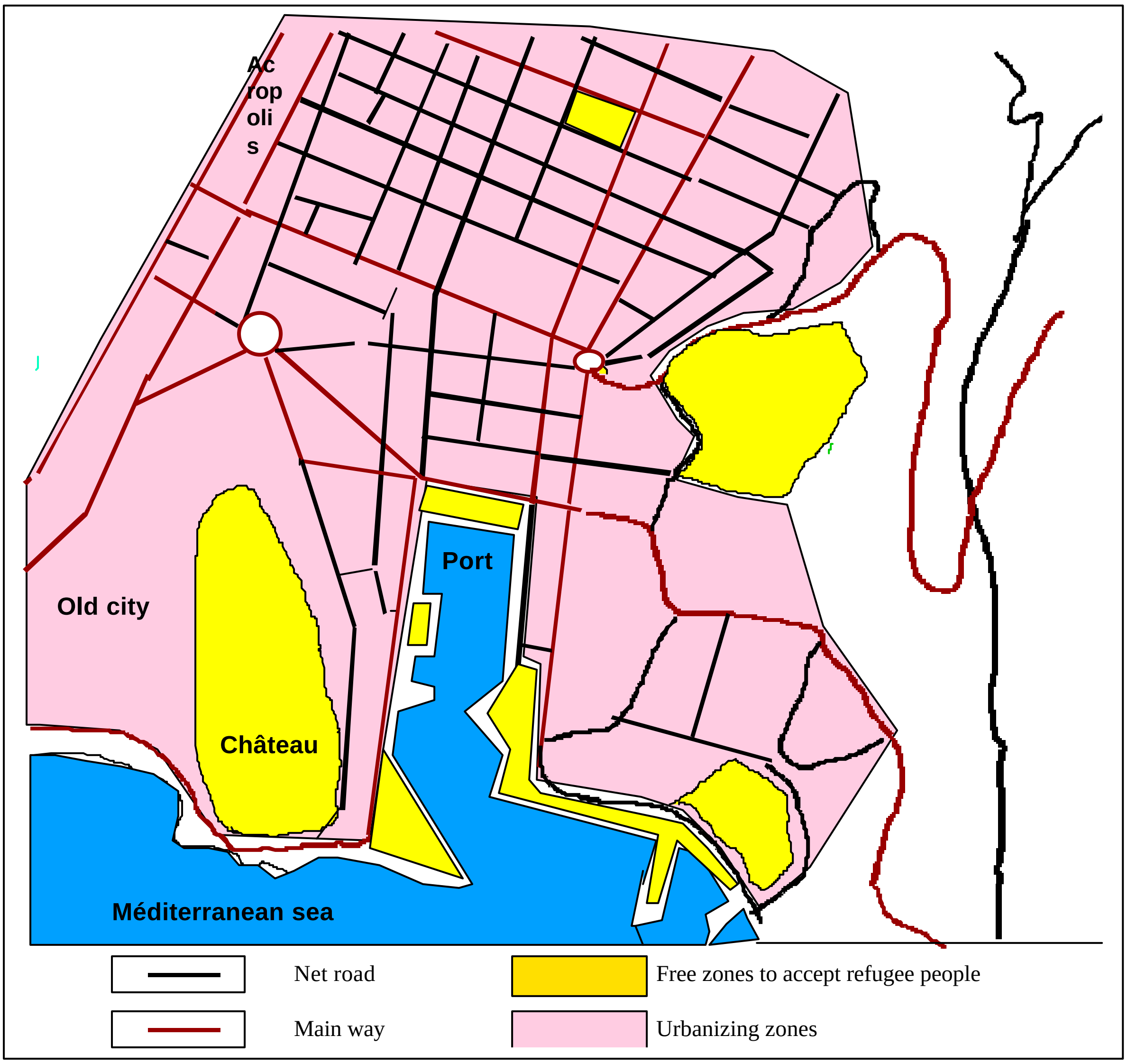

Figure 7 map showing (for a part of Nice), the free zones where people can take refuge after the earthquake.

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