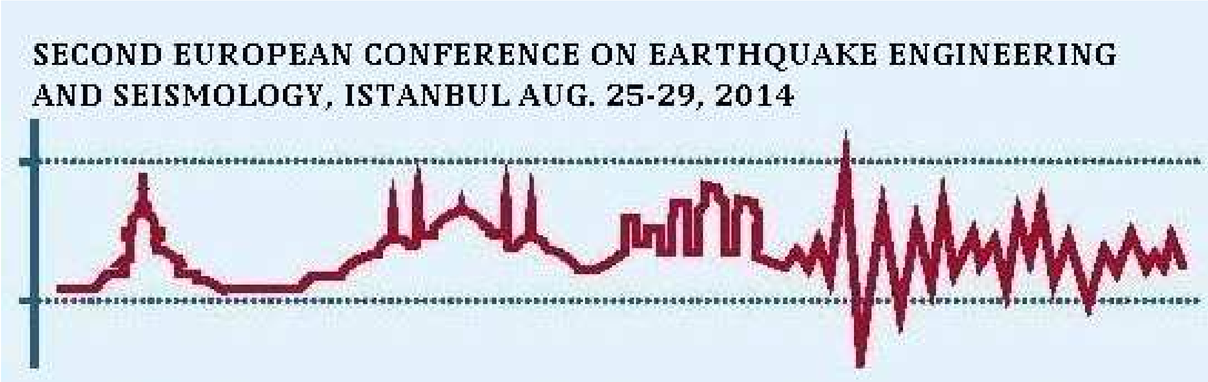

SEISMIC RISK MAPS FOR EUROCODE-8 DESIGNED BUILDINGS

Thomas Ulrich[1], John Douglas[2], Caterina Negulescu[3]

There is currently a move towards seismic design maps that are risk-targeted (e.g. Luco et al., 2007). In this framework, buildings conforming to the rules have a known annual risk of attaining or exceeding a certain damage state (e.g. collapse) that is uniform over a territory. The development of such maps relies on three independent inputs: a) seismic hazard curves derived using probabilistic seismic hazard assessment for each grid point on the map; b) fragility curves expressing the probability that a structure, designed using the building code, attains or exceeds a certain damage state given a level of shaking; and c) knowledge of the risk level that is acceptable to the local population. Douglas et al. (2013) develop seismic design maps using the risk-targeted approach for mainland France and they assess the sensitivity of the results to various inputs. This sensitivity analysis highlighted the importance of appropriate fragility curves for buildings designed using Eurocode-8 (EC8). When making the common assumption that fragility curves can be expressed as a lognormal distribution, the two parameters that need to be defined are: the probability X that a building attains or exceeds a certain damage state given shaking equal to its design peak ground acceleration (PGA), and the standard deviation β of the lognormal distribution. In view of the lack of estimates for X and β, Ulrich et al. (2013) develop a set of fragility curves for a series of regular reinforced-concrete buildings with three storeys (3 m high) three bays (4 m long) and four frames (4 m long) designed for different PGAs. For the risk of collapse, they find that X varies between 1.7×10^{-7} (for a design PGA of $0.7 m/s^2$) and 1.0×10^{-5} (for a design PGA of $3.0 m/s^2$) and β is between 0.4 and 0.5. These values are similar to the values assumed by Douglas et al. (2013) ($X=10^{-5}$ and $\beta=0.5$) when testing the risk-targeting approach for mainland France, although as shown below these apparently minor differences have significant impact on the results. For the risk of structural yielding, they find that X varies from 0.14 (for a design PGA of $0.7 m/s^2$) to 0.85 (for a design PGA of $3.0 m/s^2$).

Here we apply the findings of Ulrich et al. (2013), the seismic hazard model used by Douglas et al. (2013) and the French seismic design map currently in force (based on a constant return period of 475 years) to produce maps of the seismic risk for regular three-storey buildings in mainland France. Maps for both the risk of structural yielding and collapse are shown in Figures 1 and 2. The average annual probability of collapse nationally is 9×10^{-6}, which compares favourably to the risk level assumed to be acceptable for the French population by Douglas et al. (2013) (10^{-5}). However, this risk varies from 3×10^{-7} (in the areas of lowest seismicity, e.g. Paris) to 8×10^{-5} (in the most seismically active areas, e.g. the Pyrenees). Similar large variations are noticeable in the annual probability of structural yield (Figure 2), which varies between 0.03% and 2.3% with an average of 0.3% (i.e. about 300 times higher than the annual probability of collapse). The variation in annual probabilities of structural yield and collapse demonstrates that the French population is subjected to widely varying seismic risk (by a factor of more than 200 times for collapse) despite a design code that varies with geographical location.

[1] BRGM – DRP/RSV, Orléans, France, t.ulrich@brgm.fr
[2] BRGM – DRP/RSV, Orléans, France, j.douglas@brgm.fr
[3] BRGM – DRP/RSV, Orléans, France, c.negulescu@brgm.fr

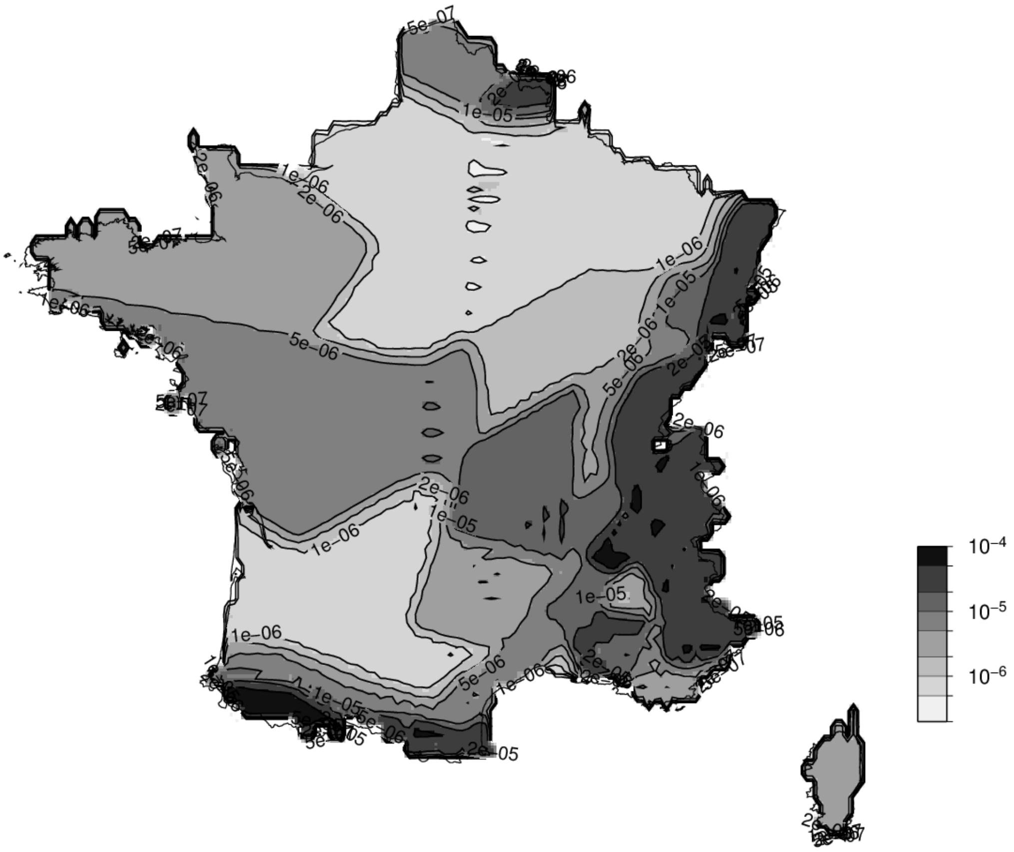

Figure 1. Annual probability of collapse of three-storey reinforced-concrete buildings complying with the current seismic design map

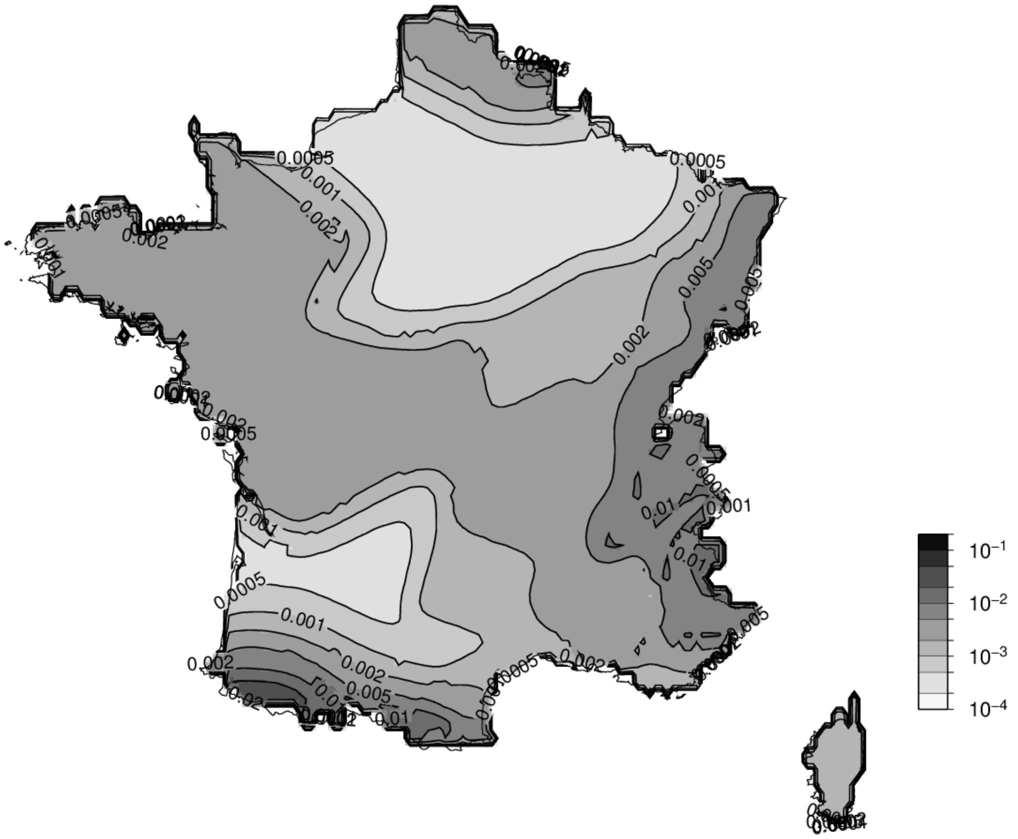

Figure 2. Annual probability of yielding of three-storey reinforced-concrete buildings complying with the current seismic design map

This observation is in contrast to the finding of Douglas et al. (2013) who found that the risk-targeting approach using the fragility curves they assumed would lower design loads in the areas of highest seismicity (e.g. Pyrenees) and raise them in seismically quiet zones (e.g. Paris) in order to obtain a constant risk level of 10^{-5}. This apparent contradiction can be explained by differences in the fragility curves for the various design PGAs assumed by Douglas et al. (2013) and calculated by Ulrich et al. (2013) (Figure 3). The design PGA has a limited impact on the actual fragility curves [in contrast to the assumption made by Douglas et al. (2013) of its importance] and hence differences in the expected ground motions for a given return period between seismically active and quiet zones play a greater role in controlling the risk than the risk-targeted results of Douglas et al. (2013) would suggest.

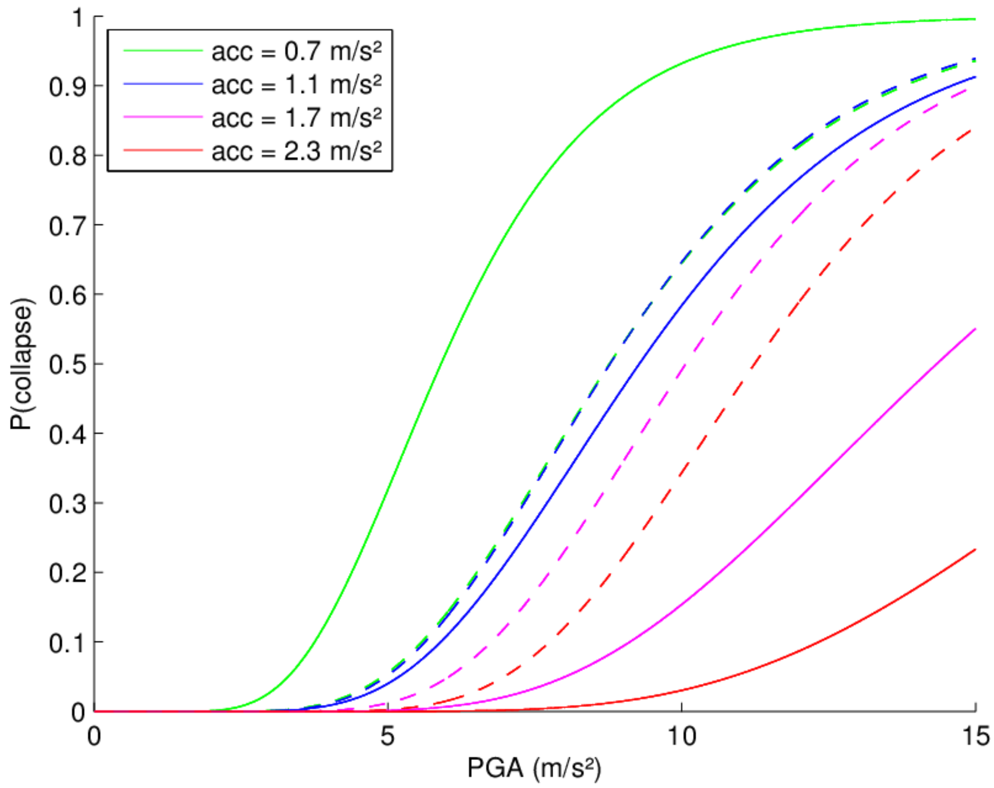

Figure 3. Fragility curves for collapse assumed by Douglas et al. (2013) for different design PGAs (solid lines) compared to those calculated by Ulrich et al. (2013) (dashed lines).

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