FCP - 46th ESReDA seminar

ABSTRACT

On-line monitoring and resilient design for a longer construction life

Alessandro De Stefano

To improve the lifecycle performance of buildings and infrastructures exposed to seismic risk a different and more sustainable design philosophy should replace the present-one. Till now the technical norms stand on the concept of “performance based design”. It means that the structural body shall respect performance prescriptions and rules useful to avoid collapse and serious failures.

The more recent earthquakes show that the structures can survive but allow heavy damages on non-structural components. Threats against human life are strongly reduced but not totally removed. The global cost, including damage components removal and replace, or repair, social and economic life interruption, failure of technical installations and production facilities, can be unbearably high and deny the expectation of effective prevention.

The new concept of “resilience based design” is a more efficient choice. Resilience is the attitude to recover functionality demanding short time and low global cost. A long step towards such a new philosophy is the adoption of some very simple criteria;

- Structural components bearing vertical loads should remain elastic or work only very slightly in plasticity domain
- The previous statement requires that different structural components (shear walls, dissipative braces, seismic isolators..), not supporting vertical loads, take full responsibility against the seismic action

To understand the real behavior of a construction a well-designed on-line monitoring action and periodical observation can largely improve safety and confidence.

The reliability of a structure, *R*(*t*), is defined then as the probability that the time to reach a reference limit state, t_b, is greater than a given time *t* (Lawless, 1982):

$$R(t) = P(t \le t_b)\ .$$

The hazard function, *h*(*t*), specifies the instantaneous rate of reliability deterioration during the infinitesimal time interval, Δ*t*, assuming that integrity is guaranteed up to time *t*:

$$h(t) = \lim_{\Delta t \to 0} \frac{P\left(t_b < t + \Delta t \ \middle|\ t_b \ge t\right)}{\Delta t}\ .$$

Function *h*(*t*) is correlated to the reliability function, *R*(*t*), by the following relationship:

$$R(t) = \exp\left(-\int_0^t h(x)dx\right).$$

Nevertheless, following such path, it is not trivial to include into the risk analysis the advantages offered by the application of on-line CM (Condition Monitoring).

To mark the role of the on-line monitoring, it is convenient to jump from the time domain into the symptom space. The symptom hazard function, *h*(*S*), is the reliability loss rate vs. the symptom increase rate; then, reliability can be rewritten as a function of the symptom variable, *S*, as it is the probability that a system, which is still able to meet the requirements for which it has been designed, displays a value of *S* smaller than the value S_b corresponding to the reference limit state (Cempel *et al*., 2000):

$$R(S) = P(S \le S_b \mid S = \text{suitable value}) = \int_0^S f_S \, dS$$

and

$$R(S) = \exp\left(-\int_0^S h(x)dx \right).$$

This formulation includes continuous time (slow degradation) or/and discrete time processes (earthquakes, storms, etc.), given that time and symptom evolution can be correlated by suitable laws.

An approach is here presented for multidimensional Condition Monitoring of mechanical systems in operation. This multidimensional approach is made possible by the use of the transformed symptom observation matrix (SOM) and by successive application of singular value decomposition (SVD). On this basis, one can obtain full extraction of fault-related information from symptom observation matrix by traditional monitoring technology, and also create several independent fault measures and indices. In other words, SVD allows to pass from the multidimensional-nonorthogonal symptom space to the orthogonal generalized fault space, of much reduced dimension. This seems to be important, as it can increase reliability of CM of critical systems in operation and can maximize the amount of condition-related information in the primary symptom observation matrix, pushing towards a redesign of traditional CM systems.