Earthquake Engineering: mechanical devices for energy dissipation versus capacity design

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Fortunately, not every structure will really experience its design earthquake. Hence it is state of the art not to request a poor linear behaviour during a large earthquake but to allow the development of plastic hinges at certain locations, which have a sufficient rotational ductility due to a proper design (especially sufficient lateral confinement by stirrups). These plastic hinges should develop in beams close to the nodes and not in colums in order to avoid total collapses. Besides the plastic hinges the structure shall deform elastically. This strategy is called Capacity Design. Normally only a linear analysis is carried out and the results are reduced using a “behaviour factor”, which depends on the structural type and on the applied measures in order to obtain a ductile behaviour.
It is questionable, if allowing of the development of plastic plastic hinges as the „main shield“ against the Design Earthquake is the best possible solution. Theoretical investigations for simplified structures exist, but there is only few evidence about the “plastic hinging” of complete structures under real earthquakes. It is quite clear, that in a cantilevered system the plastic hinge will normally develop at the base. In real structures, there are a lot of factors which will influence the location and proper development of the hinges (e.g. overstrength from various sources, among them also the influence from non-bearing elements). All these factors can be considered during design only in a crude way.

In the VAB Project (Advanced methods for assessing the seismic vulnerability of existing motorway bridges, Proj. ENV4-CT97-0574 (DG12-EHKN) it was found for the Warth bridge/ Austria, that under a strong earthquake the foundations will fail before plastic hinges can develop. With the assumption that the foundations are strengthened before, a plastic hinge would develop at an unexpected location of the tallest pier of bridge Warth/ Austria (around 8 m above the foundation) due to the curtailment (to 50%) of the longitudinal reinforcement. It is emphasized, that this will happen only in the “fictive case”, that bridge Warth is situated in a zone of high seismicity. For the actual site no problems are exspected. But the investigation was very important, because many bridges of a similar type exist in zones of high seismicity in Italy, Greece, etc.

Hence, it would be much more preferable to use mechanical dissipators in order to reduce energy to a „safe level“. For buildings such devices are not frequently used in Europe. Base isolation and other innovative energy dissipating devices are more and more used in areas of high seismicity outside of Europe. In Europe base isolation is sometimes used for the retrofit of bridges. But nowadays also examples of solutions for buildings using dissipative devices appear slowly in Europe (e.g. Italy: headquarters of fire brigade, center of telecommunication, etc.). From time to time new dissipating devices are presented in literature, e.g mechanical devices which are distributed over the structure and make use of relative movements.

As far as reliability, the civil engineering field is very conservative and reluctant in adopting mechanical devices as the main protection line against earthquakes, especially for devices based on friction or composed of many “moving parts”. In this sense a strong effort in disseminating results is needed. Unfortunately the relevant codes do not allow the designers the application of these devices in an economical manner. But simple and/or clear guidelines on how to analyse structures protected by mechanical devices would encourage their adoption in seismic codes and therefore their use by the designer.

In June 2002 an Expression of Interest for an Integrated Project *Integrated Seismic Risk Assessment of Important Existing Civil Structures (ISRECS)* was submitted to Brussels.
The proposed project is oriented towards priority thematic area 1.1.6.3/ Global Change and ecosystems/ natural disasters/ improved disaster preparedness and mitigation. The main goal is the focus on existing structures.

Much work in Earthquake Engineering was devoted to the improvement of earthquake resistant design of new structures. The European main effort into this direction is EC 8, which will be in several years the main seismic code for all European countries. But existing structures caused in many large earthquakes of the past the greater part of casualties and damages. **Hence, the assessment of the earthquake capacity of existing structures and prioritisation for retrofit will be a central task within the next decades (e.g. see resolution of the WS *Mitigation of Seismic Risk – Support to Recently Affected European Countries* in Belgirate/ Italy Nov. 2000: http://elsa.jrc.it/workshop2000/)**

Objective 3 of the proposal is the elaboration of Guidelines for retrofit. Retrofitting covers the whole structure- foundation- subsoil system, e.g. liquefaction, lateral spreading, vertical displacemets, etc can be the governing problem in a certain case. For some of the assessed structures also retrofit solutions will be elaborated. In each case several solutions ("classical" as well as "innovative") will be studied: comparison of several variants of retrofit methods for certain structures; application of innovative energy dissipating devices, comparison of these solutions with ductility concepts and capacity design.

Objective 5 of the proposal deals with the appropriate model of the earthquake loading as a function of the performance objective and type of assessment method. Hence, for some of the sites in different European countries, special earthquake time histories and response spectra, considering source, path and local effects will be calculated.

The skill of seismology to estimate realistic ground motions at a particular site may be fundamental to the acceptance of special energy dissipating devices and especially seismic isolation technology.The quantification of the critical ground motion requires the identification of the parameters that characterize the severity and the damage potential. Such critical ground motion can be identified in terms of energy and displacement demands which should be evaluated by considering the seismological, geological, and topographic factors that affect them.