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SEISMIC SAFETY LEVELS AND POST-EARTHQUAKE REPAIRABILITY OF EXISTING BUILDINGS: FUTURE PERSPECTIVES

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Existing structures exhibit poor seismic performance as demonstrated by the numerous collapse, either partial or total, surveyed in the aftermaths of moderate-to-high magnitude strong motions worldwide; damages provided by earthquakes is a concern for a society as a whole in terms of loss of life and direct and indirect costs. Recently the 2009 L'Aquila earthquake in Italy resulted in over 300 deaths and about 6,000 buildings with structural or not structural damages. These records along with those related to many other catastrophic earthquakes which occurred in the Mediterranean area, such us the 1999 Turkish earthquake in Izmit, have clearly shown that older buildings are far more risky than newer buildings. Only recently, progress of scientific knowledge on seismic risk has resulted in new seismic and more stringent codes provisions in many European countries. Thus, it is not surprising that older buildings, designed with obsolete seismic provisions and construction practices, are seismically deficient and prone to significant damages in case of seismic events. For these kind of sub-standard buildings the key question in the aftermath of damaging earthquakes is not only if a damaged building should be simply repaired or also retrofitted, but often if it is more convenient to repair and retrofit or to demolish and rebuild it. The financial impact of repair and retrofit interventions to increase the original seismic capacity of existing buildings up to current codes requirements it is sometimes not economically feasible; however, demolition and reconstruction is often not viable due to social factors or economic issues. It is worth nothing that if no actions are taken to mitigate the vulnerability of such structures, the financial damage resulting from future earthquakes can be even more devastating.
In this context, there is a strong need for future generations of the seismic Eurocode, EN1998, provide answers and provisions on several aspects: *i*) identification of buildings that present a significant risk to life safety; *ii*) definition of seismic requirements which have been specifically calibrated on existing buildings; *iii*) identification of rules and strategies to design sound and cost effective retrofit interventions for buildings identified as high risk; and *iv*) definition of reparability thresholds in post-earthquake phases.

The buildings not complying with new design standards are usually not considered adequately resistant and, in case of events or actions that require owners to seismically retrofit their buildings (commonly called triggers), they must not only be repaired, if damaged, but also retrofitted to a standard defined by code. Actually, the assessment of existing buildings is established through the framework of the code provisions stated for new buildings, but it might be helpful to suggest, in future generation of codes, that existing buildings be treated differently from new ones. Indeed, in several cases the existing building seismic capacity is far from the current code requirements; even if technically possible, the seismic strengthening up to 100% of current codes safety level is

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economically inconvenient (with respect to reconstruction), while the use of local strengthening strategies may significantly improve the seismic capacity of existing buildings by simply avoiding brittle failure modes. Thus, a safety threshold or a specific limit state of significant damage should be properly defined (e.g. it has been commonly accepted within the profession to perform the seismic capacity assessment of existing buildings with reference to a lower force level, 75% of design forces for new buildings, ATC-14 [1], ASCE 31-03 [2], ASCE 41-13 [3]). However, such lateral force reduction factor is somewhat arbitrary, and a new approach based on the assumption of a lower hazard for existing buildings with respect to new buildings is currently under investigation, 2010 California Building Code [4]. For instance, the 2010 CBC [4] allows selecting two different hazard levels and the committee can chose the reduced hazards associated with existing buildings. The use of a lower hazard seems to be a more rational approach based on the assumption that an existing building has a shorter remaining life than a new building. The use of different hazard levels may be associated to the definition of suitable performance objectives, explicitly calibrated for existing buildings. Out of these performance objectives, proper provisions should be also provided for non-structural elements in order to ensure that damages to these systems do not affect the human life safety (e.g. to protect life safety of the occupants against the overturning of internal partitions).

Another important aspect to be treated in future codes may be to establish some regulations for the reconstruction process of post-earthquake phases. Although, local jurisdictions commonly enforce specific provisions for the regulation of the post-earthquake reconstruction, basic principles and rules should be outlined in future generations of codes to define seismic safety level triggers for damaged buildings as well as to assess their reparability. In case of L'Aquila post-earthquake, specific Ordinances were issued on these themes. In particular, based on Ordinance 3790 [5], a threshold of 60% of safety level required for new buildings was set as a minimum safety level to be attained by means of retrofit interventions on buildings damaged by the earthquake. The adoption of recovery strategies may enable communities to return to levels of pre-disaster functioning (or other acceptable levels) as rapidly as possible once a damaging earthquake is occurred. Typically, the damage triggers to establish if buildings are "sufficiently damaged" to enforce retrofit are defined as a function of loss of lateral-load-carrying capacity. After the Loma Prieta earthquake of 1989, the city of Oakland, California, set a 10% loss of lateral capacity as the trigger to require seismic strengthening, while in Santa Cruz an ordinance required that all damaged buildings had to be compliant with 1970 Uniform Building Code [6]. The San Francisco Building Code [7] has used a 20% loss of capacity for this trigger for about 20 years. The L'Aquila emergency Ordinance 3881 [5] issued that the demolition and reconstruction of severely damaged buildings is the most favourable solution in case of: i) repair and retrofit costs higher than demolition and reconstruction; ii) masonry structures partially collapsed (more than 25 % in volume); iii) more than 50% of storeys columns with a residual drift larger than 1.5% for reinforced concrete structures; iv) average concrete compressive cylindrical strength lower than 8 MPa.

The authors strongly believe that in the future generation of Eurocodes, EC8 needs to incorporate the cited aspects to provide a sound support for practitioners involved in the seismic assessment and retrofit design of existing buildings.

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