



**INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI  
SHORT ABSTRACT OF THESIS**

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Programme of Study : Ph.D.  
Thesis Title:  
STOCHASTIC SIMULATION OF MAIN SHOCK-AFTERSHOCK SEQUENCES AND THEIR USE IN DAMAGE-BASED SEISMIC DESIGN OF REINFORCED CONCRETE STRUCTURES  
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The importance of aftershocks in seismic safety assessment is now widely acknowledged by the scientific community due to which, the recent practice demands a shift from the conventional single-event-based design to multiple-event-based design, where the adequacy should essentially be checked against a main shock aftershock sequence (MAS). Since an aftershock hits an already degraded structure, it is imperative to carry out nonlinear time-history analysis (THA) to characterize the aftershock-induced additional damage. Such characterization should be statistically significant and should also be specific for the seismological scenarios for the anticipated main shock and its aftershocks. However, it is not possible to have a recorded ensemble of MASs for any given set of seismic scenarios for the main shock and its aftershocks. Further, it is important to develop some simple design solutions for improving the seismic safety of structures against MASs. These issues are addressed in a step-by-step manner in the present study by carrying out extensive analytical and experimental work. An attempt is made first to simulate an ensemble of motions that are specific for a given seismic scenario. An attempt is also made to simulate aftershock motions when the main shock event has already taken place and hence known. With the help of proposed simulation techniques, MASs are simulated to perform a detailed statistical study on the damage during MASs for RC structures. Three reinforced concrete bare frames of different fundamental periods are modelled in OpenSees software with realistic material properties to carry out the numerical study. The damage in the frames is quantified by means of an overall damage index. It is found that for scenarios where the largest aftershock (magnitude-wise) is smaller than the main shock by 0.5 or more, all the three frames are mostly safe against MASs. Design modification in structures for the safety against collapse during any MAS is proposed by applying additional (fictitious) material safety factor. A 10–15% additional material safety factor is found to be able to address the safety against a large class of MASs. Experimental testing of quarter-scale RC bare frames, with different axial load ratios, are also carried out to investigate the additional damaging effect of the aftershocks on already damaged frames. An empirical predictive model is proposed for degraded natural frequency as a function of cumulative energy dissipation, axial load ratio and size of loading cycle. Finally, based on experimental results, material properties are calibrated in OpenSees to replicate the observed behaviour of RC frames. The calibrated material properties are used to validate the proposed design approach for safety against MAS. It is found that the proposed concept of additional material safety factor can be a viable solution to ensure safety against main shock aftershock sequences, without making a structure too over safe against the conventional single design event.