

NEESR-Adaptive-Structures (NEESR-Adapt-Struct) Research

Completion of first phase experiments for proof of concept

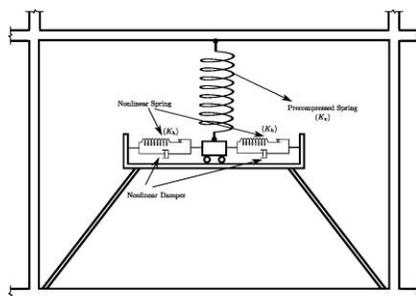
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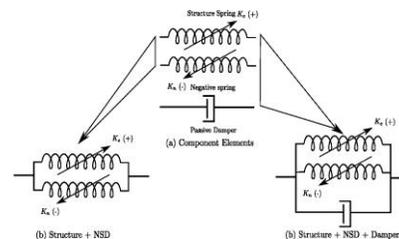
By designing a ductile structure and letting the structure yield under strong earthquakes, the forces acting on the structure can be reduced to the level dictated by the yield level. However, the structure undergoes permanent displacement. In this study, yielding is emulated in a structural system by adding an "**adaptive negative stiffness device**" and shifting the "yielding" away from the main structural system—leading to the new idea of "**apparent softening and weakening**" that occurs ensuring structural stability at all displacement amplitudes. For this purpose a novel adaptive negative stiffness device, NSD, that is capable of changing the stiffness as a function of device displacement, is developed. By engaging the adaptive negative stiffness device (NSD) at an appropriate displacement (simulated yield displacement), which is well below the actual yield displacement of the structural system, a composite structure-device assembly, behaves like a yielding structure is achieved. The NSD has a re-centering mechanism thereby avoids permanent deformation in the composite structure-device assembly unless, the main structure itself yields. Essentially, a yielding-structure is "mimicked" without any or minimal permanent deformation or yielding in the main structure. Due to the addition of NSD the stiffness of the combined structural system is reduced substantially beyond simulated yield point resulting in increased structural deformations. Addition of a nonlinear passive damper reduces and controls these deformations without any considerable increase in the base shear.

In the first phase of this study, the prototype of a negative stiffness device was designed at University at Buffalo (UB), built by Taylor Devices, Inc., and tested by the researchers at UB and Rice University in a three stories structural model isolated with elastomeric bearings. Without the negative stiffness device the accelerations in the structure are larger than desired. In the presence of the negative stiffness devices the model experiences lower accelerations and base shear, while the increased deformations are controlled and reduced by viscous-fluid supplemental dampers.

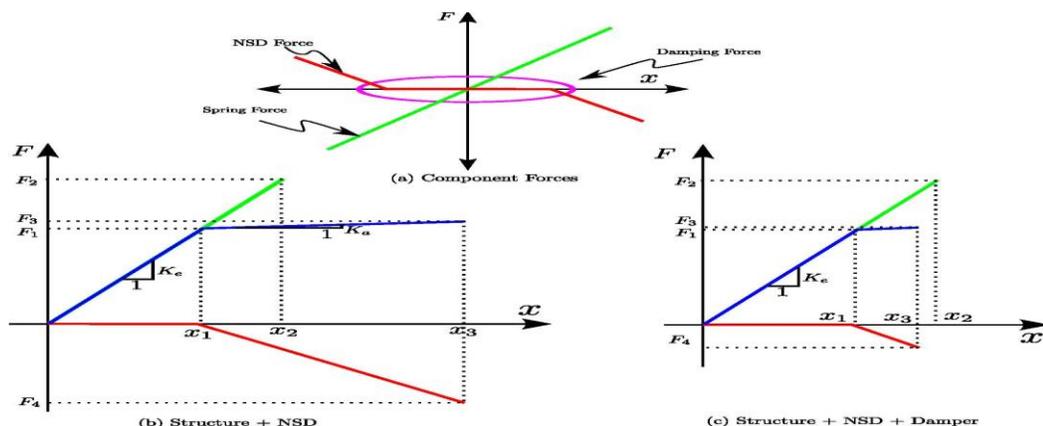
The first phase testing verified the concept and determined the influence and efficiency of "gaps" in the device, the imperfections in construction and placement of devices, and in the full characterization of the rigid body dynamics influencing the devices.



Negative Stiffness Device--NSD



(a) Component elements (b) Linear system + Negative stiffness Device (c) Linear system + Negative stiffness device + Damper



Working principle of ANSS (a) Component F-D plots (b) Linear system with Negative stiffness Device (c) Linear system with Negative stiffness device and Damper [Green- Base-structure, Red- NSD, Blue- Assembly]

References:

Nagarajaiah S., Reinhorn A. M., Constantinou M. C., Taylor D., Pasala, D. T. R., Sarlis, A. A. S., (2010), "True Adaptive Negative Stiffness: A new Structural Modification approach for seismic protection", *Proceedings of 5th World Conference on Structural Control and Monitoring*, July 12-14, 2010, Tokyo, Japan