# Adaptive Structures: Infinitely Stiff, Extremely Slender, Ultra-Light Weight

Designing structures with minimal environmental impact is now a serious concern in the construction sector. Active control has been used in civil engineering structures for a variety of purposes. The most widespread application so far has been in vibration control. The potential of using adaptation to save material mass has been investigated by some but whether the energy saved by using less material makes up the energy consumed through control and actuation is a question that has so far received little attention.

During this seminar Dr Gennaro Senatore of University College London will present the formulation of a novel methodology to design adaptive structures. This design method seeks to synthesise structural configurations that are optimum hybrids between a passive and a fully active structure in order to minimise the sum of the embodied and operational energy of the structure. Instead of using more material to cope with the effect of loads, here strategically located active elements redirect the load path to homogenise the stresses and keep deflections within limits by changing the shape of the structure. To ensure the embodied energy saved this way is not used up to by actuation, the adaptive solution is designed to cope with ordinary loading events using only passive load bearing capacity whilst relying on active control to deal with larger events that have smaller probability of occurrence. A nested optimisation scheme finds the active-passive system that corresponds to the minimum of the sum of embodied and operational energy.

Using this method, a large scale prototype structure was designed and built in collaboration with Expedition Engineering at the UCL Structures Laboratory. The prototype is an ultra-slender 6m (length) x 0.8m (width) x 0.16m (depth) (37.5:1 span to depth) cantilevered truss structure controlled in real-time to maintain serviceability conditions under loading. The structure is 80% lighter than an equivalent passive one, the data gathered from the experiments in terms of energy savings confirm the numerical findings obtained with the numerical simulations. This prototype has been shortlisted for an IStructE Structural Award 2016 and it was exhibited in a few key locations including the IASS 2015 in Amsterdam and a month solo exhibition at the London Building Centre.

The research to date has successfully demonstrated that up to 70% reduction in structural weight and 50% of the whole-life energy (embodied and operational) was achievable on truss like structures. Several case studies will be presented ranging range from planar portal frames and catenary arch bridges to space trusses including doubly curved grid-shells and exoskeleton structures. More info:

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The Adaptive Truss Prototype, UCL Structures Laboratory

Dr Gennaro Senatore

**Dr Gennaro Senatore**
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Gennaro Senatore is a research engineer specialised in computational methods for the design and realisation of complex/adaptive structures. During his doctorate (successfully completed in 2016) Gennaro developed novel mathematical methods and control systems to design Adaptive Structures: namely high performance structures (stiffer, lighter, slenderer) capable of counteracting the effect of loads actively by means of sensors, control intelligence and actuators. Using these methods, a full scale prototype of one such adaptive structure, in the form of a very slender space truss was designed and built in collaboration with Expedition Engineering at the UCL Structures Laboratory. The prototype structure performed successfully as predicted. Gennaro's work on adaptive structures has been exhibited internationally.

Gennaro also developed an interactive/real-time physics engine which has been used for teaching structural engineering as well as the design of light-weight structures. The model, based on dynamic relaxation and the co-rotational formulation, can be used to design/analyse structures with non-linear geometric behaviour (arbitrarily large displacements including rigid body motion) and perform shape optimisation. The model has been implemented as the java applet PushMePullMe and the iOS app Make A Scape both distributed free of charge and adopted by several users and universities worldwide.

Gennaro previously worked as head of computational design & research at Expedition Engineering and collaborated with various architectural/engineering practices and artists. He graduated in mechanical engineering MEng (Hons) at the Federico II University (Naples, Italy) in 2006 and afterwards he was awarded with distinction the MSc in Emergent Technologies at the Architectural Association in 2008, the MSc in Computing and Design at the School of Architecture and Visual Arts of the University of East London in 2009.

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