

The Changing Dynamic of Wind Effects on Structures: A Transition to a Non-Stationary, Non-Linear and Non-Gaussian Outlook

Ahsan Kareem

Historically, structures have been designed to resist external loads under the tacit assumption of stationarity and Gaussianity, with the exception of special cases. Recent recognition of the need to capture the non-stationary and non-Gaussian features, based on the realization that most environmental load effects typically bear these features, has led to many advances in these areas that have matured to the stage that they are ready to be embraced by the design community. Areas where there is a need to account for non-stationary features include: transient wind conditions experienced in thunderstorms by aircrafts aloft and structures near ground exposed to gust fronts, which may lead to an overshoot in pressures, significantly enhancing demand; transient patterns of ground motion in near-field earthquakes rich in both amplitude and frequency modulations; rogue waves encountered by ships and offshore platforms in open seas and tsunami waves encountered by coastal construction; and a host of other examples. Similarly, in many cases the loads and their effects may significantly depart from Gaussianity, which may result in a response that may not bear any resemblance to the linear/Gaussian response and its extremes may far exceed the corresponding estimates relying on Gaussian assumption. Examples though not exhaustive, include: response of offshore platform systems exposed to wind and nonlinear wave fields that interact nonlinearly introducing splashing and slamming loads and giving birth to new frequency contents, which could potentially excite modes otherwise dormant; aerodynamics of long-span bridges exposed to turbulence that exhibit hysteretic behavior with respect to the wind angle of attack and intermodal coupling caused by correlated loads; performance of wind turbines under turbulence.

While the contributions of the Fourier transform to signal processing cannot be denied, the fact that data is often characterized by localized or time-varying features. The infinite bases of the Fourier transform may obscure these features which has prompted a departure from this classical approach towards a time-frequency analysis framework. The wavelet transform, rooted in a strong mathematical basis, has gained widespread popularity in this context. In the nonlinear/non-Gaussian domain, a number of recent advances have promoted the use of a number of schemes that range from translational models (static transformation) to rheological models, including neural networks and Volterra series. The seminar will highlight recent advances in these areas with applications and introduction to the next frontiers to facilitate a much needed change in our way of thinking about and addressing these problems in research, applications and education to ensure the safety and integrity of the infrastructure.