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Analysis of the effect of air temperature on the building response: observation and numerical modeling

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Over the last two decades, ambient vibrations methods for assessing the modal parameters of structures have received considerable attention. Frequency and damping are then key parameters for earthquake design and seismic vulnerability assessment because the adjustment of structural models must assume a large set of unknown parameters influencing the response of existing buildings. Knowing frequency and damping can reduce the range of errors and epistemic uncertainties for representing the vulnerability as fragility curves. Finally, ambient vibrations modal analysis methods provide an effective tool for short- and/or long-term monitoring of building health indicators, such as aging effects or after extreme events. The basic idea is that any modification of the stiffness, mass, or energy dissipation characteristics of a system may alter its dynamic response. Variations in these modal parameters can result from a change in the boundary conditions (e.g., fixed- or flexible-base structure), mechanical properties (e.g., reinforcement or retrofitting), or the elastic properties of the material (e.g., Young' s modulus). The causes may also be related to nonlinear responses of the buildings. For example, transient variations are observed during seismic excitation due to the nonlinear response of the soil-structure boundary, to the closing/opening process of preexisting cracks within the elements of the reinforced concrete buildings, or to the nonlinear elasticity and slow dynamic process present in buildings. Permanent variations may also appear due to structural damage caused by strong seismic motion. Finally, these variations can be long term, reversible, and slight: in most cases, the fluctuations of the fundamental frequency of buildings was correlated to the temporal variations of the atmospheric conditions (such as temperature and humidity) influencing the properties of the building and the soil, that is to say, modifying the soil-structure interaction and the boundary conditions. Similarly, most previous studies conducted in civil engineering structures have shown that temperature is the most significant cause of variability of modal frequencies.
As the natural fluctuations of modal parameters have been reported by several authors, and because the variation in these parameters is used for structural health monitoring, two important points must be clarified: (1) what are the smallest variations in modal parameters that can be detected by ambient vibrations and related to structural health (in some cases, the amplitude of the variability of modal parameters caused by temperature may be such that it masks the changes due to physical damage); and (2) are variations in modal parameters always related to external conditions with the same trend regardless of the building typology? The main purpose of this study is to analyze the long-term variations in the frequency and damping coefficients of ten existing buildings with temperature. This paper highlights the strange and anomalous correlation between frequency and damping and the effect of the air temperature on this variation. Contrasting behaviors are observed, including correlation and anti-correlation with temperature variations.