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Rotation in civil engineering structures: analysis of the City-Hall (Grenoble) building using 3C and 6C sensors

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Civil engineering structures are often modeled as single-degree-of-freedom systems, taking into account only horizontal translation forces. However, their response to seismic loading produces rotational forces that can in some cases generate considerable stresses and resultant damage. These rotational forces are essentially related to (1) rotational deformation about both horizontal axes (rocking), resulting from ground-structure interactions, considering the structure as a rigid body; (2) rotation about the vertical axis (torsion), essentially activated when the centre of mass (i.e. where the seismic inertial forces apply) is offset from the centre of rigidity (i.e. where the elastic forces apply). The simplified model including the rotations of the ground-structure interaction is based on modal decomposition, i.e. each component of the motion is assumed to be independent of the others. Thus, in structures, only translational sensors are usually installed and the rotational components are evaluated via the spatial derivatives of the horizontal and vertical components. However, there are combinations of translations and rotations and rotations can only be evaluated by measuring all 6 components of motion (3 translations and 3 rotations). In this presentation, a simple analysis is made to explain the rotations observed in the City Hall building in Grenoble (France), a 12-storey reinforced concrete building. This building has been continuously monitored for 10 years, with 3-component accelerometers located at the bottom and top. Modal decomposition is performed using ambient vibrations. A set of earthquake records is then used to evaluate rotations using derived functions and compared with the records of a 6C rotation sensor temporarily installed at the top of the building. The comparison between the direct rotation measurement and the spatially derived rotation is performed.