FROM ROCK CONCERTS AND SOCCER MATCHES TO IN-SITU, NON-LINEAR EXPERIMENTS : A NUMERICAL STUDY OF EXTREME MAN-INDUCED GROUND VIBRATIONS

Pierre-Yves BARD [1], ***Tanios AL KHALLY*** [1,2], ***Marc WATHELET*** [1], ***Bertrand GUILLIER*** [1], ***Cécile CORNOU*** [1], ***Emmanuel CHALJUB*** [1]

[1] ISTerre (Institue of Earth Sciences), Université Grenoble-Alpes, Université Savoie Mont-Blanc, CNRS, IRD, IFSTTAR, Grenoble, France

[2] Faculty of Engineering, Lebanese University, Beirut, France

There have been over last decades several examples of large ground vibrations caused by people gathering for special events: a rock concert in Ullevi stadium (Sweden) in 1985 generated strongly felt tribune vibrations, while there are more and more seismological recordings of goals in high stake soccer matches (for instance, the Barça "remontada" against PSG in 2016-17 Champion's league, or the vibration levels recorded by broad band networks in Croatia and France during the 2018 World Cup final). Such man-induced vibrations can be a concern for the design of stadium facilities, in case of coincidence between structural frequencies and man-made beating frequencies (around 2 Hz). The present work reports a numerical investigation about how extreme could be such vibrations at ground level. We use the discrete wavenumber approach to model the wave field generated by surface sources (corresponding to vertical forces) with an amplitude corresponding to the surface load estimated for jumping crowds. We consider a ground layering leading to resonant frequencies close to 1 to 2 Hz, and compute the ground motion at distances from a few tens of meters to one kilometer. The largest ground motion is found to correspond to the center of circular source sets, a beating frequency tuned to the Airy phase of Rayleigh waves, and an underground structure with significant velocity contrast and low damping. In such cases, for linear elastic soils, the ground displacement is found to possibly exceed several cm, while the velocity can reach several tens of cm/s at the very center of the circle. This series of results thus pave the way to investigations on the use of concentric, active surface sources that could be combined to perform in-situ measurements of soil non-linear characteristics.