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A numerical procedure for simulating the multi-support seismic response of submerged floating tunnels anchored by cables

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ABSTRACT

The modeling and seismic analysis of submerged floating tunnels moored by cables is addressed with particular attention to spatial variability of the excitation. Dissipation modeling issues and cables discretization are also discussed.

A uniformly modulated random process, whose spatial variability is governed by a single coherency function, is deemed adequate to model the multi-support seismic input for a given structure of large dimension undergoing limited plastic deformation, as the one considered here. A novel method to obtain response spectrum compatible accelerograms is proposed, based on the explicit expression of the median pseudo-acceleration response spectrum induced by the adopted power density function (PSD). This expression is used to identify the parameters of the PSD function that minimize the difference with the elastic response spectrum prescribed by EN 1998; the minimization process is discussed and parameters for the PSD spectra are obtained. Samples of the free-field motion are then generated using a proved and theoretically sound approach and reach a satisfactory agreement with the prescribed response spectra.

To model the cables, a 3 node isoparametric cable element is enriched by including hydrodynamic loading, within a numerical procedure for the dynamic time domain step-by-step analysis of non-linear discretized systems.

An example of application is shown that makes reference to the bed profile of Qiandao Lake (People's Republic of China), where a plan exists to build the first SFT prototype.

1. Introduction

Submerged Floating Tunnels (SFTs) can be a valid alternative to long-span bridges for crossing sea straits, fjords or inland waters. SFTs basically consist of a cylindrical tunnel floating at a certain depth below the water surface, moored by an anchoring system that relies on slender elements: either cables or bars. Since SFTs can be set at a specific depth below the water table, they do not need long and/or steep approaching roadways that are, instead, necessary for conventional underground tunnels or traditional immersed tunnels resting on the seabed, and can be thus more economic.

The dynamic response of SFTs to several environmental actions is of interest, among which are waves, current and consequently vortex induced vibrations, and earthquakes. Finally, these induce not only inertial loads but also hydrodynamic ones. Non-linear dynamic analyses are required to correctly model both the hydrodynamic loads and the geometrically non-linear behavior of the anchoring system, whose stiffness and resistance depend also on the SFT buoyancy effects. Whenever the SFT length requires it, seismic analyses must account for the spatial variability of the ground motion.

The work presented herein is focused, first, on accounting for the above-mentioned ground motion spatial variability while satisfying a code prescribed response spectrum and, second, on some modeling aspects of an SFT moored by cables.

As for the first goal, in Sections 2 and 3 we propose a generation procedure of the seismic input that leads to the results harmonized with EN 1998 [1] prescriptions. When a multi-support analysis is required, due to the lack of data, one has often to resort to artificial time histories. In effect, as detailed in [2], EN 1998 requires more justifications in order to use recorded accelerograms, or simulated accelerograms generated through a seismological model, with respect to the use of artificial time histories. The problem of generating acceleration time histories representative of earthquake motion at different stations is probably one among those that attracted the largest interest by researchers; a recent overview of the concepts involved can be found in the over 130 references listed in [3].

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