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Theoretical Non-linear dynamics analysis of stability of a bridge pier under two-phase turbulent flow

Despite the development in Engineering, the structure such as bridge continue to collapse due to fluid loads effects. Their combination on a bridge pier can also induced catastrophic damages. Less attention in literature has been given to bridge pier dynamics under transversal flow. This work describes the dynamic vibration, including theoretical non-linear dynamics analysis, of a bridge pier under two-phase turbulent fluid flow. An overview of the description of a bridge pier and the different types of phase flow that can induce vibration in such a structure is presented. The external excitations due to two-phase flow are modelled first as two-frequency excitations, and secondly, for two-phase turbulent flow, the turbulence in the fluid load expression is given by independent unit Weiner processes. In both cases, the physical system is mathematically modelled as a non-linear partial differential equation. The mathematical framework, including Galerkin's method and some integrations taking good consideration of the space occupation of each phase of fluid flow along the beam, is developed to obtain the discrete general equation. To make the model more meaningful and practical, constant and parametric axial loads representing the bridge deck, taking into account their different states, are used in the modelling system. Using adequate analytical methods and numerical simulations, the non-linear dynamic behaviour of the bridge pier under turbulent two-phase flow or taking flows as frequency excitations is studied. This leads to the evaluation of non-linear dynamic responses through amplitude responses, time domain response diagrams, and phase plan diagrams. The results show good agreement between the analytical and numerical solutions. Moreover, with the obtained results, we show that the increase in wind velocity has a great impact on the heightening of the amplitude response of the system, unlike the rise in water velocity. Furthermore, we demonstrate that for certain values of fluid velocity and height of water, a bridge pier subjected to two-phase fluid flow is more stable than when it is subjected to one fluid flow. Thus, we come to the conclusion that the inertia effects of water contribute to the stabilization of bridge piers in the case of two-phase turbulent flow excitations in the chosen proportions.

Keywords: Bridge pier, Euler-Bernoulli beam theory, two-phase flow excitation, turbulent fluid flow, amplitude of vibration, non-linear dynamic response, water inertia effects, structural stability.

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