Mechanical effects of floods on river bridge pier foundations

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Summary

Limit states of the soil (G)–foundation (F)– river bridge pier (P) system, potentially occurring during a flood, are analysed. An original constitutive model (c.m.) first allows to simulate the displacements of a rigid, shallow F resting on compressible G, subjected to vertical, horizontal forces and destabilizing moments transmitted by P. The tilt and the stability of the G-F–P system are then modelled on the base of the c.m., by taking into account the complex relationships among the tilt of P, the scour of G and the hydrodynamic forces (horizontal force on P and uplift on F). It is shown that the tilt of P may increase towards a stable value, or reach a critical value (rotational instability) that occurs before the bearing capacity of the F–G sub-system is achieved.

Keywords: foundation; pier; flood; constitutive model; elasto-plasticity; high-rise buildings.

1. Introduction

Most bridge failures was caused by scour of soils [4] [5] [6] (G) and sediments surrounding piers (P) and supporting their foundations (F) [2], occurring during floods (fig. 1). Scour reduces the bearing capacity of the G–F geotechnical sub–system: plastic displacements may follow (fig. 2).
Hydrodynamic pressures are applied on the front of P: a destabilizing moment is thus applied to the G–F sub–system. If P is a tall structure, an additional destabilizing moment on G–F is applied.
Thus, the safety of river bridge P must be evaluated through the analysis of the limit states achievable by the G–F–P system or its composing sub-systems, taking into account the bearing capacity reduction of G-F and the rotational instability of G–F–P, both related to the applied loads.

2. Problem setting

2.1 Geometry

A rigid, leaning (tilt angle ϑ) P, with height h_P and rectangular cross section (*b*, width; *l*, length), under the action of a flood (fig. 3) is considered. P is connected to a rigid, shallow F, rectangularly shaped (*B*, width; *L*, length) with thickness h_f, resting on cohesionless and compressible G*; D* is the depth of the F plane and $d_S(y)$ is the scour depth of G surrounding F, depending on the elevation *y* of the river during the flood; h_W is the distance between the center of the F-G contact area (point O, fig.1) and the center of gravity of the F-P sub-system; $h_T = h_p + h_f$ is the total height of F-P.

2.2 Acting forces

The slenderness of tall river bridge P is the main responsible of their high sensitivity to perturbation factors (excavations, vibrations, earthquakes, water level variations, wind,..). The limited horizontal extension of F compared to the height and the not negligible weight of the P-F sub-system,

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