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The effect of buoyancy force on structural damage: A case study

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ABSTRACT

In most decades, the height of structures and the number of basement floors have been increased especially in the valuable sites. By constructing the piles around the construction for safety purposes, a pool environment is occurred. Water accumulation in the excavation site due to various reasons might cause basement floors, forming a closed volume, to move upwards. This very risk is also prevalent for all the structural elements below soil in flood susceptible areas. This problem, which arises when necessary precautions are not taken, is generally overlooked by the engineer while aiming for the completed structure weight. Floating damage is completely different from the liquefaction of soil, which results from unexpected movements in a structure due to the loss of the bearing capacity of the soil. Unfortunately, this underestimated hazard is indicated in the standards and codes only for port structures in coastal areas. In this study, it is aimed to point out that the structural damage due to the buoyancy force can be avoided by paying attention to basic mechanical concepts and design procedures That's why, an office building in Hatay/Turkey which was damaged during construction as a result of the buoyancy force occurred in a flood has been chosen and examined as a case study.

1. Introduction

The causes of structural damage must be well understood by engineers to get effective design of a safe building. The designers usually consider the weight of the structure on the vertical plane along with the earthquake and wind forces on the horizontal plane [1, 2]. However, since the 1995 Kobe earthquake, earthquake engineers also have to pay attention to the earthquake force on structures on the vertical plane [3]. A tsunami is another critical issue that makes it mandatory to investigate the vertical impacts in a structure [4, 5]. The tsunamis that happened in 1996 in Peru; in 1998 in Papua New Guinea; in 2004 Sumatra/Indonesia easily caused structures to float. Also, on March 11, 2011, the magnitude 9.0 earthquake and tsunami in Tōhoku area in Japan resulted in substantial financial damage as well as loss of 15.828 lives not including the missing [6]. After the earthquake, the tsunami waves in the area reached the heights of up to 37.9 m [7]. In tsunamis, the weight of a structure remains incapable of resisting the static and dynamic effects of water on the structure (Fig. 1).

There are other occasions other than tsunamis that cause structures to float. Floods, spates, tidal water from the sea, river flooding, excessive and fast water (or mud) flow due to intense and heavy rain, unexpected increase in the water table are some of the reasons causing structures to be flooded; therefore, they have become the critical issues that engineers have to think about (Fig. 2).

Spates are not only the reason of flooding of coastlines and riversides. Conditions such as excessive and fast rain, dam/aqueduct spates, landslides and even pipe damage in mains water system may lead to floods in coastlines, riversides and inland areas. Floods and spates might be destructive since they result in impact load against structures; also, they enforce a huge amount of load onto underwater structures. Although these effects are taken into account in the stability of offshore structures and submarine pipelines

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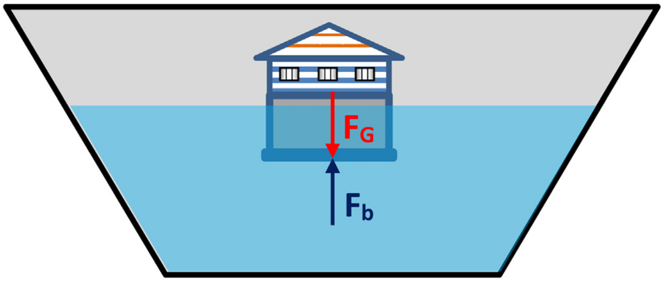

Fig. 1. The structural damage due to the buoyancy force (**F_b**), exceeds the weight of a structure (**F_G**).

Fig. 2. City centers after floods and spates a) Damage survey [8], b) Historic Antique Bazaar in Hatay.

[9–11], they are ignored for structures on land.

Drdacky M. [12] presents typical examples of damage to immovable cultural heritage due to flooding situations. It is reported in the study that the forces such as horizontal static pressure of raised water; upward hydrostatic pressure; dynamic low velocity streams; dynamic high-velocity streams; dynamic impact of waves; dynamic impact of floating objects; compacting of soils or infill; changes in subsoil conditions; saturation of materials with water; contamination of materials with chemical and biological agents; formation of barriers; ice floes and postflood effects can cause damage in this type of structures.

In this study, an office building in Hatay/Turkey which was damaged as a result of the buoyancy force occurred in a flood during construction has been chosen and examined as a case study. As a result of the excessive rain in Antakya city center, it was stated that the office building floated due to the buoyancy force, the foundation moved approximately 3 m upwards from the sub-basement elevation, and when the water receded, the structure was stated to rest in a higher elevation with inclined position, before the rain. The photographs of the structure from the southeast front before and after the floating have been presented in Fig. 3.

According to the meteorological data related to the last 20 years, the maximum amount of rain falling and the average annual rainfall in the site are 432 mm and 49.1 mm, respectively. Also, on the day of the event (between 06:00 September 23, 2016–06:00 September 24, 2016), the rainfall was measured as 57.6 mm. Therefore, the rainfall on the day of the event was measured to be below the maximum amount of the rainfall in the last 20 years (432 mm > 57.6 mm), yet it was above the average annual rainfall (49.1 mm < 57.6 mm).

Fig. 3. Photographs of the examined structure before and after the floating.