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Analysis of the Behavior of Foundations of Historical Buildings

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Abstract

The article is devoted to the analysis of the behaviour of the foundations of historic buildings. Some basic aspects of foundation engineering are discussed, with an emphasis placed on its development, applied techniques, and materials. Several different approaches and methods for the analysis of foundations of historical buildings are presented. A particular analysis has been focused on an example of a typical stone foundation from the sixteenth century. First, the calculations have been performed using the finite element method, then the bearing capacity and the settlement analysis has been determined according to EC-7. Next, the bearing capacity has been evaluated using simplified analysis. A settlement of the foundation has been also estimated using Kerisel's proposal. The information should allow for a better understanding of the behaviour of foundations discussed in this research, and especially of methods of their analysis. A comparison analysis has been performed and possible directions for further research in this field have been indicated.

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1. Introduction

Analysis of the behaviour of the foundations of historic buildings is usually quite difficult or even impossible. Their work can be carried out in many different aspects, taking into account in particular: the kind of foundation and the object placed upon it, the material, the shape and dimensions of the foundation, bearing capacity and settlement

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of foundation and geological substructure conditions. In a wider context, one can also consider a number of other elements such as the level of settling of the foundation, the hydrogeology, groundwater aggressiveness and other physical factors – chemicals that affect the foundation rotation or uneven settling of the foundation, etc.

Studies oriented towards a better understanding of the mechanical behaviour of old structures are still carried out. Some reviews of analytical methods dealing with masonry have been given by Theodossopoulos and Sinha [7] or Valluzzi et al. [8]. Giordano et al. [2] and Lorenzo [4] have applied different numerical techniques for the analysis of such structures. Unfortunately, in the literature, there are not many comprehensive studies devoted to foundations of historical buildings [1,3,5,6]. Most of the papers concern the diagnostics and maintenance of particular objects and only a few analyze the mechanical behaviour of old foundations. The issue of the necessity to analyze the foundations of historical buildings and some proposed resolutions have been discussed by Kerisel [3] and Dardzińska [1].

2. Characteristics of foundations of historical objects

Since the beginning of the history of construction the most popular materials were brick, stone and lumber. Brick foundations in ancient times were made initially with sun-dried mud bricks and later with fired bricks. It is obvious that dried bricks cannot be used to make foundations. Their uses in ancient times were due to the lack of alternatives and as a result led to a significant reduction in the durability of objects of this era. Significant differences were noted in the basic physical and mechanical characteristics of fired brick of past epochs versus those produced today. They arise from a different course of forming bricks and a different process of firing. A fundamental change in the method of the manufacture of bricks finally occurred in the mid-nineteenth century, as a result, inter alia, of the invention of the bend press that produced bricks with a pulling method; the use of a vertebral furnace; and the improvement of the drying system.

Stone foundations were mostly used for sacred buildings and public utility structures. Various types of stones were used, depending on the function of specific elements of a building, the available equipment and workmanship, and the geographic location. Often granite, limestone, sandstone, sandstone volcanic tuff, or even marble was used. The majority of stone foundations of historic buildings did not have offsets at all or they were not extended to the bottom. In addition, it would've been difficult in the past to find mortar that would be in accordance with currently recommended mortar strength requirements (excluding pozzolan). The fact that such foundations are still effectively supporting many historical buildings should therefore be explained by their oversized measurements. Figure 1 presents the views of a few medieval foundations located in two Polish towns.



Fig. 1. View of foundations: (a) historical building in Olsztyn at Staromiejska Street; (b) old granaries at Basztowa Street in Gdańsk; (c) old granaries at Chmielna Street in Gdańsk.

3. Analysis of the behaviour of foundations

3.1. Stresses and displacements – numerical analysis

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