# DETAILED ANALYSIS OF THE GRAVITIONAL EFFECTS CAUSED BY THE BUILDINGS IN MICROGRAVITY SURVEY

Monika LOJ[1] and Sławomir PORZUCEK[1]

[1]*AGH University of Science and Technology, Faculty of Geology, Geophysics and Environmental Protection, Department of Geophysics, al. Mickiewicza 30, 30-059 Krakow, Poland; mloj@agh.edu.pl*

## Introduction

In recent decades there has been a rapid growth in urban areas, where there are phenomena that threaten the security of urban infrastructure and thus the safety of residents. Some of these phenomena are related to the condition of the near-surface layers of the rock mass and can be research using geophysical methods. The application of geophysical methods in urbanized areas entails the need to take into account the urban factor. This means making additional corrections. One method that can be successfully applied in these conditions is the microgravity method. In fact, it has only two limitations as to its applicability. The first is the increase the measurement errors associated with increased ground vibrations, and the second is the gravitational impact of buildings and urban infrastructure. Reducing the impact of vibrations can be done by increasing the number of measurements at the observation station, while the elimination of the second cause is a greater problem. One of the possibilities is to locate observation station at appropriate distances from buildings, but this reduces the possibility of using the method. The second possibility is to calculate a correction eliminating the gravitational effects caused by the buildings (Panosova et al. 2012, Dewu 2014, Dilalos et al. 2018) The calculation of the correction is related to the determination of their geometry and mass. As we all know, the geometry of buildings, despite the apparent simplicity, is very complicated, which is why the most common aim is to simplify them. This involves determining the density of simplified objects in such a way that the gravitational effect calculated from them is as close to real as possible.

## Methods

There were three types of buildings selected for the analysis of the urban correction: detached house, tenement house and aerated concrete block, and the tenement house was analysed in three different wall thicknesses. The basic geometric models of all buildings were created from walls and ceilings, based on the available plans. It should be noted that the studies take into account the fact that there are also cellars in the buildings. Bulk densities of individual elements were adopted on the basis of the applicable building standards (PN-EN ISO 6946:2017-10) and archival materials (Płuska 2009). In this way, it was possible to create models of individual storeys with preservation of appropriate wall types. Based on the basic models, simplified models have been created, bringing each storey closer to one solid. In order to reproduce the elements of the models, rectangular prisms were used, based on the algorithm given by Nagy (Nagy 1966).

## Results

The building correction was calculated in a grid of 0.25 m side to 20 m around the building and at stations inside the building assuming that the calculation station was at least 0.2 m from the model element. The calculations inside the building were made on two levels: the ground floor, for a building without basement, and the basement if the building had a basement. For the sake of consistency with the actual measurements, the calculations were made assuming that the position of the measuring system was at a height of 0.3 m.

For each building, in the first place, the values of the building correction for the basic model have been calculated. They were a reference for the analysis of the values calculated for the simplified model. The simplification consisted in approximating individual storeys with one rectangular prism. Due to the shape of the buildings, the geometry of the simplified models was constant.

Under this assumption, the only variable in the calculation of the simplified model that could have changed was the bulk density. The value of density determined the matching of both models, and the degree of matching was determined on the basis of the determination coefficient. The adjustment analysis was

conducted for a set of stations where the calculated value of the correction was greater than 0.0001 mGal. The solution was considered final when the value of the error was the lowest.
In addition, based on the parameters of basic models, the average storey densities in all buildings have been calculated.
The analysis of the urban correction made it possible to determine the optimal bulk density for simplified models. An exemplary result of the analysis concerning a single-family detached home is presented in the table (Tab. 1). Calculation stations inside the building were located on the ground floor level.

***Table 1.*** *Optimal bulk densities for simplified the single-family detached home.*

| storey | all | | out | | in | | avg |
|---|---|---|---|---|---|---|---|
| | bulk density [$g \cdot cm^{-3}$] | error [mGal] | bulk density [$g \cdot cm^{-3}$] | error [mGal] | bulk density [$g \cdot cm^{-3}$] | error [mGal] | density [$g \cdot cm^{-3}$] |
| **cellar** | -1.70 | 0.0031 | -1.31 | 0.0005 | -1.74 | 0.0054 | -1.54 |
| **ground floor** | 0.65 | 0.0012 | 0.74 | 0.0004 | 0.62 | 0.0016 | 0.65 |
| **floor I** | 0.48 | 0.0006 | 0.51 | 0.0002 | 0.42 | 0.0004 | 0.49 |
| **house** | 0.56 | 0.0012 | 0.61 | 0.0004 | 0.53 | 0.0019 | 0,58 |

***all*** *– for all points,* ***out*** *– for points outside the building,* ***in*** *– for points inside the building,* ***avg*** *– average storey density*

## Conclusions

An analysis of the building correction carried out for several buildings has shown that simplified building models can be used, bringing them closer in solids covering entire storeys. This does not apply, of course, when the points are inside a given storey - then it is necessary to use a detailed model. The calculated optimum bulk densities for entire storeys deviate from the actual average density. The biggest differences are for the ground floor and basement and decrease with the subsequent storeys. When analysing the optimal volumetric densities for individual storeys, it can be seen that from a certain height it is possible to approximate the remaining storeys with a single solid

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Norm PN-EN ISO 6946:2017-10 Building components and building elements - Thermal resistance and heat transfer coefficient - Calculation methods.