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ScienceDirect

Procedia Engineering 162 (2016) 301 – 308

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on Efficient & Sustainable Water Systems Management toward Worth Living Development, 2nd EWaS 2016

Impact of Gravity on Fluid Mechanics Models

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Abstract

Mathematical formulae which describe fluid mechanics models include the influence of gravity. In the literature and practice, when considering numerical hydraulic models, gravity is taken as constant value ("gravitational constant"). Actually, gravity is not constant and it is changing depending on mass distribution into the body of the Earth, mass density, altitude and topography (relief shape and mas density above the geoid). This paper is focused on the gravity influence on the different hydraulics models and fluid mechanic formulae in order to point out that gravity acceleration should not be treated routinely as "constant".

Peer-review under responsibility of the organizing committee of the EWaS2 International Conference on Efficient & Sustainable Water Systems Management toward Worth Living Development

Keywords: Fluid mechanics; Hydraulics; Numerical models; Gravity; Geoid;

1. Introduction

Earth gravity field covers all around the planet and all phenomena on earth are influenced by it. This fact is stated through many hydraulics models which contain gravity as one of parameters which determine the fluid behavior. However almost all hydraulic formulae and models which describe water flows and hydraulic structures consider gravity as constant and its' value is often adopted without accurate determination for certain area. This approach is a consequence of fact that changes of gravity field are small and that influence on wholesale hydraulic models caused

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Peer-review under responsibility of the organizing committee of the EWaS2 International Conference on Efficient & Sustainable Water Systems Management toward Worth Living Development
doi:10.1016/j.proeng.2016.11.064

by error of gravity acceleration were not too significant. None of these reasons could be justified on the today's level of technology development because the gravity acceleration is not highly resource-demanding as it was before (some methods for approximate gravity acceleration determination exists which could provide satisfactory accuracy for some application but measurement of gravity acceleration is not too expensive and does not increase the price of projects significantly if high accurate is necessary).

Gravity acceleration is not constant value and it changes in time which means that calculation made on base of gravity in one moment of time do not have to be the same in other moment of time on the same location (i.e. on the same) point of earth surface. Variation of gravity which is resultant of gravitation and centrifugal forces depending on distribution of masses inside Earth as well as the Earth's position respective to Sun and Moon. Although the influence of Sun and Moon is relatively small it points out the fact that earths' gravity field is changeable with time and that could not be treated as constant. Continuous changes in earth crust and its' interior, distribution of masses continuously changes which affects the Earths' gravity field. Aforementioned reasons have a consequence that Earths' gravity field is not constant in space and time. This fact could be simply expressed by formulae:

$$g = g(x, y, z, t) \tag{1}$$

$$\frac{\partial g}{\partial x} \neq 0; \frac{\partial g}{\partial y} \neq 0 ; \frac{\partial g}{\partial z} \neq 0; \frac{\partial g}{\partial t} \neq 0 \tag{2}$$

where:

- g – gravity
- x – x – coordinate in Cartesian 3D World coordinate system;
- y – y – coordinate in Cartesian 3D World coordinate system;
- z – z – coordinate in Cartesian 3D World coordinate system and
- t – time.

Gravity is mostly the field of interest of two scientific disciplines, physical geodesy and geophysics [1]. The subject of physical geodesy is the study of gravity field and the figure of the earth [2]. Geophysics could be defined as application of physics to study the interior of Earth [3]. Earth's gravity field exploration has different function when is considered from aspects of two scientific disciplines. From the aspect of physical geodesy the Earths' gravity field is researched with aim to determine geoid (mathematical surface which describes planet Earth and whose every point is perpendicular to the direction of gravity force), while from the aspect of geophysics the main aim of gravity field determination is to find out the Earths' interior. The fact that, at least, two scientific disciplines have the gravity field as their subject, that significant resources are involved in those researches, that a number of scientific papers are devoted to those topics, that a number of technologies and methodologies (terrestrial as well as satellite) for gravity field determination and also practical results obtained by these researches imply the need to investigate the influence of gravity on hydraulic models of river flows.

The research of gravity influence on certain models will be performed by analysis of those models as a function of their arguments, whereby the function shall be linearized and after that the increment of function will be considered depending on the increment of its' arguments. In this paper only terms of first order will be considered.

2. Methodology

Hydraulics models of river flows and models which describe hydraulic structures in many cases are described by formulae based on model, numerical and empirical research, [11-13]. All these researches are based on measurements which contain unavoidable errors and whose influence is propagating through models and affects output quantities. Errors propagation through certain hydraulic model is depending on the form of formulae which describe observed hydraulic phenomenon.