DOCTORAL THESIS

Investigation of multilayer beds applied in water treatment filters

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Abstract

Rapid filtration is one of the key unit processes applied in water treatment plants. Appropriately functioning rapid filters require suitably selected filtration materials with optimal parameters, which include granulation, density, porosity as well as permeability.

Traditionally used single-layer quartz beds are increasingly being replaced by multi-layer beds, usually anthracite-quartz ones. The market also offers other granular materials that have potential for rapid filtration. These include expanded clay, crushed glass or garnet which can be utilised individually or in a multilayer form. The choice of these materials depends on their physico-chemical properties affecting the filtration and washing processes. An in-depth investigation of these properties is therefore essential for proper selection. In this thesis, granular materials were examined for their use in multilayer filters.

The thesis reviews the literature and analyses commercially available filter materials and verifies the solutions currently used in practice. Materials of different grain sizes such as quartz sand, anthracite, high and low specific density expanded clay, crushed glass filter media, AFM activated filter glass and garnet were selected for the study.

The materials were subjected to preliminary tests to determine physical parameters relevant to the fluidisation process such as density, porosity, grain size, free fall velocity and shape. The abrasiveness of each of the materials was established in order to assess their washing performance. To do this, the appropriate methodology was first developed in accordance with the existing standards.

For each material, curves were plotted for the dependence of expansion and pressure loss on fluidisation intensity at different temperatures. A significant effect of temperature on the magnitude of expansion and pressure loss at the same fluidisation intensity was revealed. The curves make it possible to assess the impact of the seasons on changes in the fluidisation process for individual materials and to estimate the economic benefits of adjusting the fluidisation intensity to individual periods.

Based on theoretical methods for selection of multilayer beds, minimum fluidisation velocity and density difference of mixtures at the layer interface, several multilayer beds were chosen. A traditional quartz-anthracite bed as well as other ones using low and high density expanded clay, crushed glass and garnet were selected. The new materials were applied in different configurations and grain sizes, with and without traditional materials.

This confirmed the effectiveness of the minimum fluidisation velocity method and the practicality of the density difference method for mixtures at layer interfaces. However, the latter requires an accurate description of the materials comprising the adjacent layers.

The study confirmed the validity of using new filtration materials such as expanded clay and crushed glass interchangeably for both or for one of the traditional layers: anthracite or quartz. Of the three-layer beds analysed, the bed composed of sand 0.4-0.8 and high specific density expanded clay (FILTRALITE® PURE HC 0.8-1.6) and low specific density expanded clay (FILTRALITE® PURE NC 1.5-2.5) proved to be the best in terms of fluidisation. This system had the lowest pressure drop and washing intensity during fluidisation, thus reducing the energy cost of washing and the amount of water used. During the tests, the dimensionless exponent n in the Richardson-Zaki equation was determined for all materials, allowing a complete mathematical description of the fluidisation process of the tested materials at any temperature and grain size.

Studies of garnet showed that it is impractical to utilise this material as the third bottom layer of the filter bed in typical applications because the material needs to be very homogeneous, which is difficult to achieve under technical conditions.

Keywords: multilayer beds, filter materials, washing, fluidisation, expansion, expanded clay, filter glass.

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