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Drinking water pellet softening: prediction the terminal settling velocity of natural particles

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Abstract: Natural particles are frequently applied in drinking water treatment in up-flow fluidisation processes. Additionally, sedimentation processes are applied to clarify water and to concentrate solids. To estimate the terminal settling velocity of single solid particles in a liquid system, a comprehensive collection of equations is available. For perfectly round spheres, settling velocity can be calculated accurately. For naturally imperfect particles, however, experimentally measured settling velocity shows considerable deviation compared to calculated values. This article discusses a number of experiments demonstrating this deviation and the applicability of commonly used drag-coefficient equation by Brown-Lawler.

Keywords: drinking water; terminal settling velocity; calcium carbonate pellets, pellet softening, garnet sand, grained calcite seeding material, drag coefficient

Introduction

To meet its sustainability goals, Waternet has modified its pellet softening processes in which garnet sand, used as a seeding material, has been replaced by calcite seeding particles that are based on re-used grained, dried and sieved calcium carbonate pellets[7]. Since these calcite particles have an irregular shape, their numerical prediction[11][10] is much more complex than would be the case for perfectly shaped particles. To address this matter, 1700 terminal settling experiments[4] were carried out and compared with the conventional drag force[9] coefficient equations proposed by Brown-Lawler[1] and Fair-Geyer[3]. In addition, the measured values were compared[2] with the modified Schiller[8] equation proposed by van Schagen[6] for garnet pellets.

Material and Methods

Individual terminal settling experiments for several materials were carried out in the Weesperkarspel drinking water pilot plant of Waternet, located in Amsterdam, the Netherlands. To compare the data from the experiments with the models, the normalised mean squared error (NRMSE) was applied. The set-up consisted of a 4-meter transparent PVC pipe with an inner diameter of 57 mm. Three of the most important parameters were varied: water temperature, water flow and grain size.

Results and Conclusions

The Brown-Lawler and Fair-Geyer equations are suitable instruments to accurately predict the terminal settling velocity of drinking water treatment particles. The values predicted by the van Schagen equation proved to be too high, making this equation unsuitable. The resulting deviation in estimated drag can be deduced from the naturally imperfect particle shape, rough surface and orientation. This means that there is no need for a new empirical model to predict terminal settling velocity. The Brown equation can be used in drinking water treatment processes for porosity prediction, for example Richardson-Zaki. In addition terminal settling experiments can also be used to determine the hydraulic diameter for modelling purposes.

Table 1.1 Normalised mean squared errors for terminal settling velocity.

Material	Experiments	Brown-Lawler	Fair-Geyer	van Schagen
All particles	N=1304	0.093	0.090	0.174
Calcite pellets	N=388	0.030	0.038	0.080
Garnet pellets	N=626	0.050	0.048	0.124
Glass pearls	N=101	0.037	0.033	0.067
Garnet	N=97	0.046	0.044	0.045
Calcite IT	N=45	0.026	0.021	0.029
Calcite UK	N=32	0.031	0.028	0.032
Crystal sand	N=15	0.008	0.005	0.011

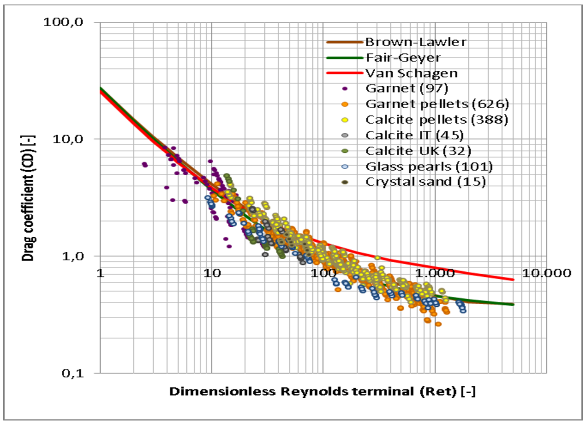

Figure 1.1 Experimental data (N=1304) and predicted terminal settling velocities.

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