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Hydrology and Earth System Sciences
Discussions

Interactive comment on "The referential grain size and effective porosity in the Kozeny–Carman model" *by* K. Urumović and K. Urumović Sr.

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RC:General comments: Determination of soils permeability on the basis of their grains size is definitely very interesting because it allows to predict the permeability from easily measured and routinely obtainable data. The article has a great value also because the investigations were carried out on a large number of samples. Although I do not agree with all conclusions I think that the article is worthy for publication.

AUTHOR'S ANSWER: We thank the reviewer for swift and prompt review. Also, we are glad to hear that reviewer 1 agrees with our opinion that this is an interesting and useful topic.

Specific comments: The question is if Kozeny-Carman equation also applies to clays or sands with a larger amount of clay minerals. For example: the studies of Carman

(1939) have shown that the KC equation is suitable for the evaluation of permeability for gravel and sand, whereas it is useless for clays. Such a conclusion was based on the studies of natural clays, which showed that the relationship between k and is not constant but decreasing function of porosity. Experimental investigations of Taylor (1948) have confirmed this claim, as well as measurements of fine grained natural materials, carried out by Michaels and Lin (1954). Al-Tabbaa and Wood (1987) have demonstrated that the coefficient of permeability for kaolinite is not linearly dependent on , which means that the KC equation does not apply. By the same conclusion also came Dolinar and Otonicar, 2007. They used pure clay minerals in their investigations. They concluded that KC equation is not suitable for clays in original form. They proposed a modified form of KC equation (Geologija, 2007, vol. 50, No. 2, str. 487-495). There is also the question how to properly measure the grain size of the fine-grained soils. With the use of hydometer method, which is commonly used method for engineering purposes, the results are not precise enough. It is well known that very small amount of clay minerals have a great influence to the permeability of soils. I believe that the assessment of the permeability of cohesive soils is, in the manner suggested by the authors, less reliable, while it is very good for non-cohesive soils.

AUTHOR'S ANSWER: This manuscript indicates that Kozeny-Carman model is suitable for calculating hydraulic conductivity within the limits of validity of Darcy's law. In both historic and recent scientific literature it was stated that Kozeny-Carman formula is only suitable for evaluation of hydraulic conductivity of gravel and sand. We do agree with this evaluation within the up to now-limitations of factors in KC formula. My impulse to thoroughly study this method was the fact that KC method is completely logical and theoretically correct. Therefore there must have been a way to apply it on natural sediments of various granulometric compounds. We have tried to optimize factors in KC equation. Then, while studying the porosity, we have come to the conclusion that real effective (flow) porosity is not the same as recently used specific yield. There is a small difference between two mentioned forms. Real effective porosity is associated with liquid flow velocity (relations of Darcy's and Hagen-Poiseuill's velocity) and therefore

presents a property of saturated media. Specific yield is a property describing desaturation of an aquifer, and is therefore time dependent of time. The other factor that was optimized was referential grain size. The idea to use geometric mean grain size was described in the manuscript (page 5, lines 27-35 and 6, lines 2-6). We believe that this optimization of factors in Kozeny-Carman formula led to a significant expanding of granulometric range that formula can be applied on. Range of applicability of KC formula was expanded on fine grained sediments up to referential grain size 0,003 mm. To summarize this thesis, the effect of change of porosity was expressed through porosity function, and value of porosity in relation with referential grain size was presented graphically in Figure 5. That, we believe, was the main scientific contribution of this manuscript. The studied samples of silty clay were undisturbed samples of natural deposits, from borehole core where quartz mineral was dominant. The impact of particular clay particles was not analyzed. It is beyond doubt that mineral composition of samples has a strong impact on hydraulic conductivity. And that is probably the reason why the correlation coefficient for cohesive (clayey) deposits is significantly lower than correlation coefficient of non-cohesive deposits. Further development of these research was planned in order to answer the above questions.

Technical corrections: Page 4, line 17: specific surface area based on the mass of solids Ms - OK, corrected Page 4, line 31: are efective porosity ne (not n) – OK, corrected

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