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Evaluation of empirical formulae for determination of hydraulic conductivity based on inverse augur hole method for Medak district, Telangana state

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Abstract
In the hydro geological study, hydraulic conductivity is one of the most important parameters, but also a difficult parameter to determine. In the present study, hydraulic conductivity in soils was determined by field method and by using 5 empirical formulae Brayer, Kozeny-Carman, Slitzer, Terzaghi and Hazen focusing on the different regions of Medak district, Telangana state and evaluated the empirical methods with field method. Samples had been taken from different locations namely Sangareddy, Siddipet, Narsapur, Zahirabad and Sadasivpet. These samples were tested to calculate hydraulic conductivity by empirical formulae and compared to each other. Results showed that the five empirical formulae estimated hydraulic conductivities of the various soil samples well within the known ranges. Hazen formula proved to be the best estimator of most samples analyzed and may be, even for a wide range of other soil types. However, some of the formulae underestimated or overestimated hydraulic conductivity; even of the same soils. Hydraulic conductivity of the Medak district soils can be estimated by the Hazan formula instead of using field method.

Keywords: Hydraulic conductivity, empirical formula, inverse augur hole method, brayer, Kozeny-Carman, Slitzer, Terzaghi and Hazen

1. Introduction
The hydraulic conductivity of a porous medium is a function of both the fluid properties of the liquid and the physical properties of the medium (Strangfeld, 2020; Kimberly 1994) [12, 7]. The fluid properties of the liquid that affect the hydraulic conductivity are viscosity and density (Teng *et al*., 2019) [13]. The physical properties of the porous medium that affect the hydraulic conductivity are particle shape, size, and size distribution, pore size and pore size distribution, fissures, joints, stratifications and other discontinuities (Li *et al*., 2020) [9].
It has long been recognized that hydraulic conductivity is related to the grain-size distribution of granular porous media (Freeze and Cherry, 1979) [3]. This interrelationship is very useful for the estimation of conductivity values where direct permeability data are sparse such as in the early stages of aquifer exploration (Hsu, 2021) [6].
Determining the K-value of soils can be done with correlation methods or with hydraulic methods. Hydraulic methods can be either laboratory methods or in-situ (or field) methods (Musa and Gupa, 2019; Nijland, 1994) [10-11]. Correlation methods are based on predetermined relationships between an easily determined soil property (e.g. texture) and the K-value. The advantage of the correlation methods is that an estimate of the K-value is often simpler and quicker than its direct determination
The average value of hydraulic conductivity which achieved from inverse auger hole method was 0.444 m/day and for constant head method was 0.563 m/day. This showed that soil has low infiltration (Babak and Sina, 2008) [1]. The comparison of outcomes from both methods indicated that constant head method evaluates hydraulic conductivity 21% more accurate than auger hole method.
The hydraulic conductivities estimated from the different equations indicate the hydraulic conductivities of clean sand to gravelly materials. USBR equation indicates moderate hydraulic conductivity and corresponds to hydraulic conductivity of fine sand (Gadzama, 2011) [16]. Terzaghi formula= 15.08 m/day, Kozeny-Carman formula= 2.871 m/day, Hazen formula= 2.133 m/day, Breyer formula= 1.869 m/day, Slitcher formula= 1.023 m/day. The method is based on only one size fraction, D_{10}, which represents the percentage of fine

material in a granular soil.

2. Materials and Methods

The Medak district is situated in the north-western part of Telangana bordering Karnataka state. It is located between 17°27' and 18° 18 ' North latitudes and 77°28 ' and 79° 10 ' East longitudes covering an area of 9,71,086 ha. Some of the areas selected in Medak were Patancheru, Sankarampet, Sangareddy, Siddipet, Sadasivapet, Narsapur and Zahirabad for determination of hydraulic conductivity by using inverse augur hole method (Field method) and by using different empirical formulae hydraulic conductivity with the same soil samples. Finally, hydraulic conductivity value obtained from empirical and inverse augur hole method was compared and which empirical formula is particularly suited for Medak district was concluded.

2.1 Estimation of hydraulic conductivity by empirical formulae

Soil samples were extracted from test holes during borehole drilling for finding the hydraulic conductivity by inverse augur hole method. Samples from the cuttings were collected in containers and taken to the laboratory for grain size analysis. From the laboratory, the samples were treated and tested for grain size distribution according to the standard procedure by the method of dry sieve analysis using a series of sorted BS sieves. Then using these values, empirical equations can be solved for obtaining the hydraulic conductivity values. Hydraulic conductivity (K) can be estimated by grain size analysis, using empirical equations relating either K to some size property of the sediment. Vukovic and Soro (1992) [15] summarized different empirical methods from former studies and presented a formula.

Hazan: $K=\frac{g}{v}\times 6\times 10^{-4}\left[1+10(n-0.26)\right]d_{10}^2$

Where,
K = hydraulic conductivity; g= acceleration due to gravity; v = kinematic viscosity; C= sorting coefficient; f(n) = porosity function, and de = effective grain diameter. The kinematic viscosity (v) is related to dynamic viscosity (µ) and the fluid (water) density.
Hazen formula was originally developed for the determination of hydraulic conductivity of uniformly graded sand but is also useful for fine sand to gravel range, provided the sediment has a uniformity coefficient less than 5 and effective grain size between and 3mm.

Kozeny-Carman: $K=\frac{g}{v}\times 8.3\times 10^{-3}\left[\frac{n^3}{(1-n)^2}\right]d_{10}^2$

The Kozeny-Carman equation is one of the most widely accepted and used derivations of permeability as a function of the characteristics of the soil medium. This equation was originally proposed by Kozeny (1927) [8] and was then modified by Carman (1937, 1956) [2] to become the Kozeny-Carman equation. It is not appropriate for either soil with an effective size above 3mm or for clayey soils.$n=0.255(1+0.85^u)$

Where
U is the coefficient of grain uniformity and is given by:

$$U=\frac{d_{60}}{d_{10}}$$

Here, d_{60} and d_{10}in the formula represents the grain diameter in (mm) for which 60% and 10% of the sample respectively.

Breyer: $K=\frac{g}{v}\times 6\times 10^{-4}\log\frac{500}{U}d_{10}^2$

This method does not consider porosity and therefore, porosity function takes on value 1. Breyer formula is often considered most useful for materials with heterogeneous distributions and poorly sorted grains with uniformity coefficient between 1 and 20, and effective grain size between 0.06mm and 0.6mm.

Slitcher: $K=\frac{g}{v}\times 1\times 10^{-2}n^{3.287}d_{10}^2$

This formula is mostly applicable for grain-size between 0.01mm and 5mm. The values of C, f(n) and de are dependent on the different methods used in the grain-size analysis. According to Vukovic and Soro (1992) [15], porosity (n) may be derived from the empirical relationship with the coefficient of grain uniformity (U) as follows: where U is the coefficient of grain uniformity and is given by:

Terzaghi: $K=\frac{g}{v}\times C_t\times\left(\frac{n-0.13}{\sqrt[3]{1-n}}\right)^2 d_{10}^2$

Where
The Ct = sorting coefficient and $6.1\times 10^{-3}< C_t<107\times 10^{-3}$. In this study, an average value of Ct is used. Terzaghi formula is mostly applicable for large-grain sand.

2.2 Estimation of hydraulic conductivity by in situ method

The inverse auger-hole method is based on the following principles. If one bores a hole into the soil, fills this hole with water until the soil below and around the hole is practically saturated, the infiltration rate will become more or less constant. The total infiltration Q will then be equal to v × A (where A is the surface area of infiltration). With v = K, we get:

Q = K × A.

After a hole was drilled completely vertically in order to not make any disturbance for water infiltration into the soil. Then fill water into the hole and wait for a few minutes till water penetrates into the soil and the soil becomes saturated. In the beginning, the amount of water level reduction is quick because the soil is dry, but by increasing soil moisture, water level depletion gradually decreases; then measure the value and note down all readings. The experiment continued till the water level depletion inside the hole came to zero. By using the same procedure, the experiment was done in the other area and readings were noted. The data (h + ½r vs t) are then plotted on semi-log paper.

$K=1.15r\left[\log(h_0+\frac{1}{2}r)-\log(h_t+\frac{1}{2}r)\right]/t-t_0$

$$K=1.15r\frac{\left[\log\left(h_o+\frac{1}{2}r\right)-\log\left(h_t+\frac{1}{2}r\right)\right]}{t-t_o}$$

Where
t = time since the start of measuring (s).
ht = the height of the water column in the hole at time t (cm).
h0 = ht at time t = 0.

The values of ht are obtained from
ht = D' – Ht

Where
D' = the depth of the hole below reference level (cm)
Ht = the depth of the water level in the hole below reference level (cm)
When H and t are measured at appropriate intervals, on semi-log paper, plotting ht + ½r on the log axis and t on the linear axis produces a straight line with a slope:
Tan α= [log (h +½r) – log (h+½r)]/t – t0
The calculation of K with the above Equation can be done with the value of tan α. Hence:
Hydraulic conductivity (K) = 1.15 r tan α

3. Results
The different values of hydraulic conductivity obtained from different empirical formulae and field method are tabulated and provided in table1 and are analysed for the best suitability with the field method.

Table 1: Hydraulic conductivity values of field and empirical methods, in m/day

Location	Hazen	Kozeny-carman	Breyer	Slitcher	Terzaghi	Inverse auger hole method
Shankarampet	00.50	03.50	01.20	02.29	00.33	00.36
Sadasivpet	05.66	01.34	03.50	07.86	01.45	01.05
Sangareddy	01.56	00.40	02.70	03.56	00.78	00.60
Siddipet	03.34	05.20	05.30	04.23	02.45	00.92
Patancheru	02.40	06.93	03.46	02.10	01.99	00.80
Zaheerabad	07.13	08.16	05.66	05.10	05.13	00.95
Narasapur	16.42	14.50	10.96	10.00	11.12	01.65

From Table.1, it can conclude that, the Narasapur had the greatest hydraulic conductivity values both in field method and all empirical formulae followed by Zaheerabad. Where the Shankarampet and Sangareddy areas have relatively low values of hydraulic conductivity in both field method and empirical formulae models. Then the remaining areas have their hydraulic conductivity values between the above area values and those values are fluctuating because of the hardness of soil.

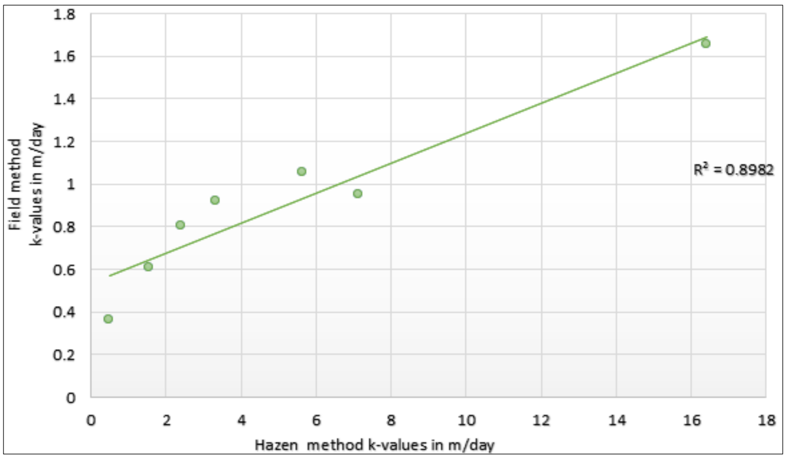

Fig 1: Graph plotted between K-values of Hazen and field method

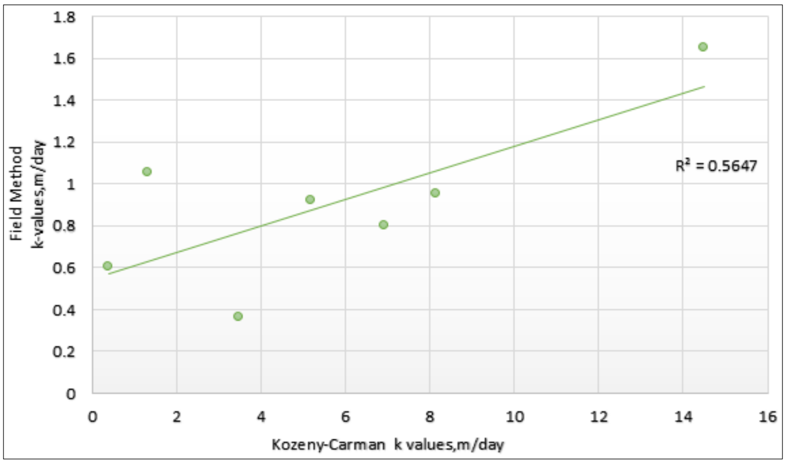

Fig 2: Graph plotted between Kozey-Carman and field method K-values

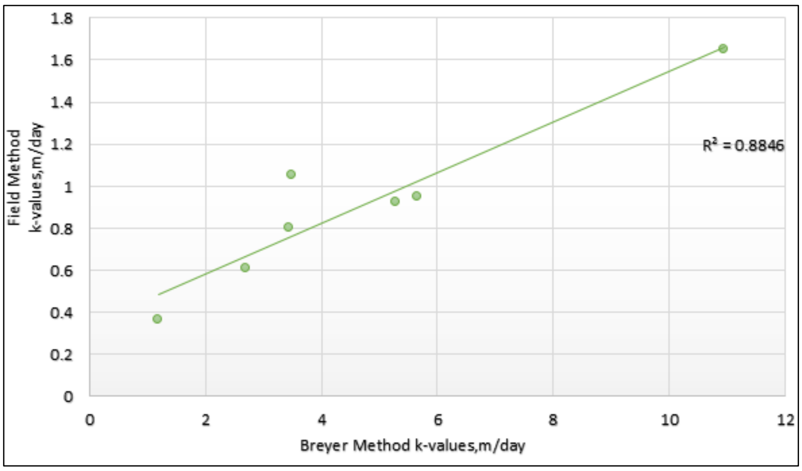

Fig 3: Graph plotted between Breyer and field method K-values

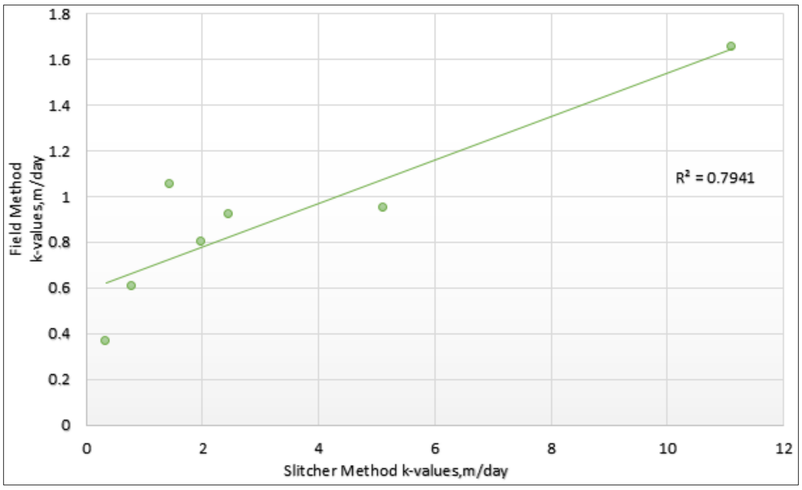

Fig 4: Graph plotted between Slitcher and field method K-values

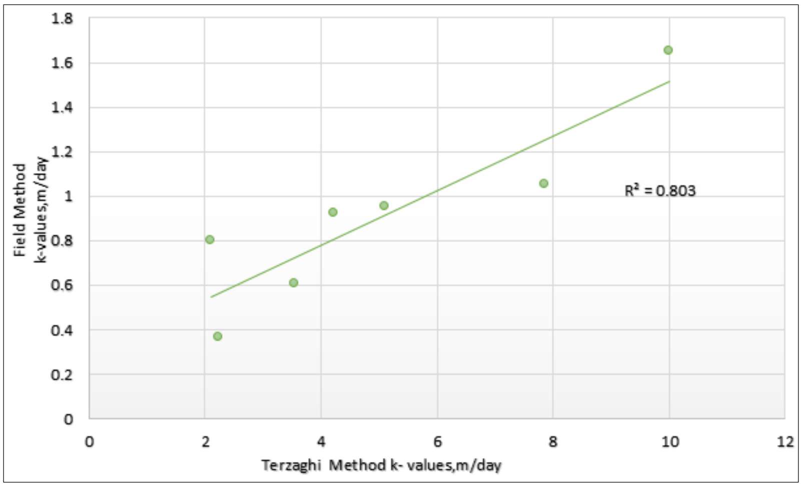

Fig 5: Graph plotted between Terzaghi and field method K-values

Fig. 1 to Fig. 5 showed the graphs plotted between field method on Y-axis and different empirical formulae on X - axis. From the Fig. 1, it can be seen that the regression coefficient of Hazen formula obtained was 0.899 which is the maximum of all empirical formulae. We can conclude that Hazen formula was suitable for calculating hydraulic conductivity instead of other empirical formulae. It can be seen that regression coefficient of all the empirical formulae was greater than 0.5. This is due to the fact that the most suitability of all individual empirical formula with their limited advantage applications.

4. Conclusion

Estimating the hydraulic conductivity of soils in terms of grading characteristics can relatively lead to underestimation or overestimation unless the appropriate method is used. For the studied samples, and consequently may be for a wide range of soil type, the best overall estimation of permeability is reached based on Kozeny-Carman's formula followed by Hazen's formula. Then coming to the evaluation of five empirical formulae for seven identified sites, obtained results concluding that the Hazen's formula is preferable for determination of hydraulic conductivity in Medak District, followed by Breyer formula.

5. References

1. Babak, Sina. Comparing hydraulic conductivity through both inverted auger hole and constant head methods. State of California business, transportation and housing agency; c2008. p. 231-242.
2. Carman PC. The flow of Gases through Porous Media. Butterworths Scientific Publications, London; c1956.
3. Freeze RA, Cherry JA. Groundwater. Prentice Hall Inc., Englewood Cliffs, New Jersey; c1979.
4. EW G, UK. Evaluation of empirical formulae for the determination of hydraulic conductivity based on grain-size analysis. Journal of geology and mining research. 2011;3(4):105-113.
5. Hazen A. Some Physical Properties of Sands and Gravels, with Special Reference to their Use in Filtration. 24th Annual Report, Massachusetts State Board of Health, Pub. Doc. 1892;34:539-556
6. Hsu SM. Quantifying the hydraulic properties of fractured rock masses along a borehole using composite geological indices: A case study in the mid and upper Choshui River Basin in Central Taiwan. Engineering Geology. 2021;284:105924.
7. Kimberly. Determination of the hydraulic conductivity of the Alachua country southwest landfill. C. Gallageetal. Soils and Foundations; c1994. p. 417-430.
8. Kozeny J. Uber Kapillare Leitung Des Wassers in Boden. Sitzungsber Akad. Wiss. Wien Math. Naturwiss. Kl., Abt. 2a, (In German). 1927;136:271-306.
9. Li Y, Liu Z, Liu G, Xiong K, Cai L. Dynamic variations in soil moisture in an epikarst fissure in the karst rocky desertification area. Journal of Hydrology. 2020;591:125587.
10. Musa JJ, Gupa YU. An Overview of Methods Used in the Determination of Soil Hydraulic Conductivity; c2019.
11. Nijland. Determining the saturated hydraulic conductivity, international institute for land reclamation and improvement (ILRI). Publication 16, second revised edition, Wageningen, the Netherlands; c1994. ISBN 90 70754 3 39.
12. Strangfeld C. Determination of the diffusion coefficient and the hydraulic conductivity of porous media based on embedded humidity sensors. Construction and Building Materials. 2020;263:120092.
13. Teng J, Kou J, Zhang S, Sheng D. Evaluating the influence of specimen preparation on saturated hydraulic conductivity using nuclear magnetic resonance technology. Vadose Zone Journal. 2019;18(1):1-7.
14. Terzaghi K, Peck RB. Soil Mechanics in Engineering Practice. Wiley, New York; c1964.
15. Vukovic M, Soro A. Determination of Hydraulic Conductivity of Porous Media from Grain-Size Composition. Water Resources Publications, Littleton, Colorado; c1992.
16. Gadzama IM, Mondo NJ. Assessment of the influence of limnological factors on the malacofauna of two major manmade lakes in Zaria, Nigeria. International Journal of Biological and Chemical Sciences. 2011;5(5):1898-906.