

A CRITICAL REVIEW OF THE INFLUENCE OF PARTICLE MORPHOLOGY AND POROSITY ON SOIL THERMAL CONDUCTIVITY

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Abstract

Introduction. This critical review underscores the importance of examining key factors such as particle morphology and porosity in the extensive body of literature on soil studies. A deeper understanding of how these elements influence soil thermal conductivity is essential for advancing knowledge in geotechnical and environmental research. **Methods.** By synthesising findings from a wide range of studies, this review highlights the complex nature of soil thermal conductivity and stresses the need to thoroughly investigate these parameters. Each factor plays a crucial role in determining heat transfer behaviour in soils. Through an in-depth analysis of existing research, this paper emphasises the necessity of systematically studying these variables to resolve inconsistencies, fill knowledge gaps, and enhance predictive models for geotechnical and environmental applications. **Conclusions.** Recently developed multi-variable functions offer a robust framework for predicting soil thermal conductivity by integrating these influential parameters. By providing a comprehensive perspective that connects theory with practical application, this review serves as a vital resource, supporting both scientific exploration and engineering practice.

Keywords: thermal conductivity, granular soils, factors, critical review, proposed models.

Introduction

Thermal conductivity is a crucial physical characteristic of soils that gauges their heat conduction capacity. It represents the rate at which heat traverses a unit area under a unit temperature gradient — essentially the quantity of heat passing through soil per unit area and time, divided by the temperature difference across the soil layer (Zhang et al., 2017; Kashani et al., 2017). The thermal conductivity of soils, particularly sands, has long captivated researchers and engineers due to its significance in geotechnical and environmental engineering applications. Understanding its origin and historical aspects is imperative for accurate behaviour prediction (Yun and Santamarina, 2008; Chen et al., 2014; Liu et al., 2020). Thermal conductivity serves as a crucial parameter for understanding soil thermal characteristics and environmental interactions. It plays indispensable roles in geothermal energy, building energy efficiency, and underground construction. Research efforts have focused on understanding influencing factors and developing precise predictive models across various soil types and conditions (Johansen, 1977; Lu et al., 2007; Zhang et al., 2015). Studies have also explored the influence of soil texture and mineralogy (Barry-Macaulay et al., 2013). Accurate measurement is essential for geothermal energy, building efficiency, and underground construction applications (Adam and Markiewicz, 2009; Loveridge and Powrie, 2013; Wang et al., 2016). Influential factors on granular soil

thermal conductivity include particle shape and size, porosity, rubber content, soil composition, moisture content, soil type, temperature, compaction, packing density, saturation, freeze-thaw cycles, polymers, and bio-cementation methods. Each factor significantly impacts thermal conductivity, requiring detailed study. Fig. 1 incorporates these influential parameters, with their soil impacts depicted in Fig. 2.

Literature Review

The literature on soil thermal conductivity contains apparent contradictions due to varying research perspectives. Numerous researchers have examined the thermal characteristics of sand, silt, and clay soils (Cai et al., 2015; Zhang et al., 2017). Cai et al. (2015) investigated the thermal conductivity of clay, silt, fine sand, and coarse sand in China's Nanjing region. Wang et al. (2017) showed that sand had higher thermal conductivity (1.44 W/m·K) than clay (0.69 W/m·K) and sandy loam (1.17 W/m·K). Alrtimi et al. (2016) reported that thermal conductivity increased with the degree of saturation. Liu et al. (2020) used forty data points correlating soil thermal conductivity with saturation (5–40 % water content). They observed a swift initial rise in mucky silty clay thermal conductivity with increased saturation, followed by stabilisation. The relationship showed exponential growth ($R^2 > 0.95$). Yang et al. (2022) found that the thermal conductivity increase sequence was: sand > composite of scrap tyre rubber and sand > shredded tyres. They explained that the particle arrangement transitioned

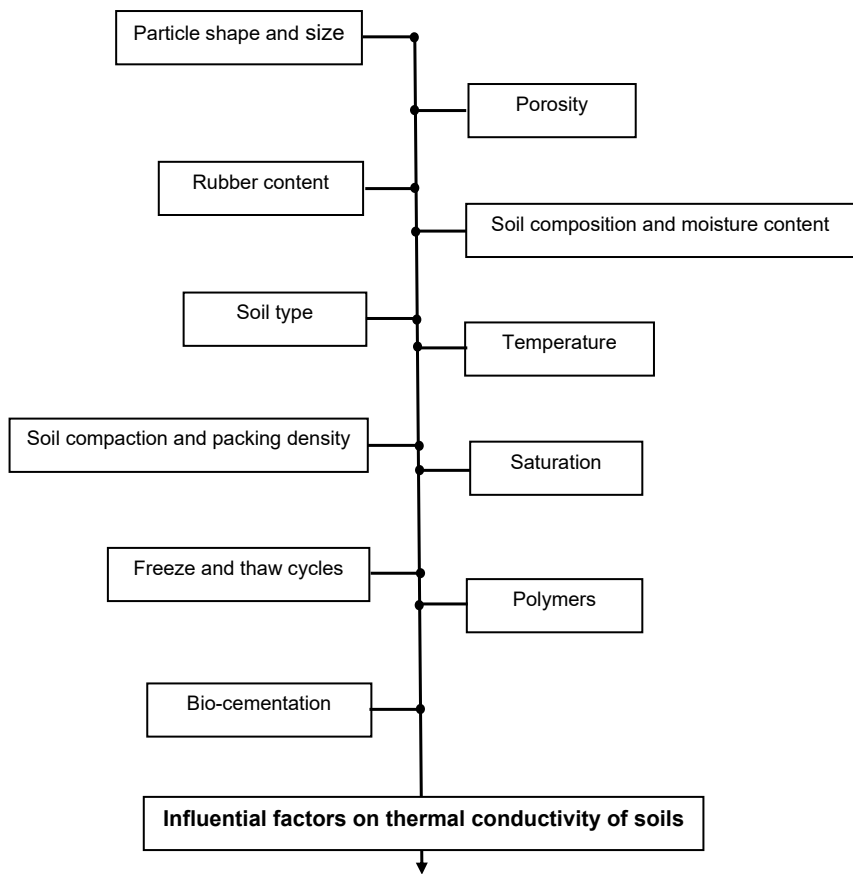


Fig. 1. Influential factors on the thermal conductivity of granular soils

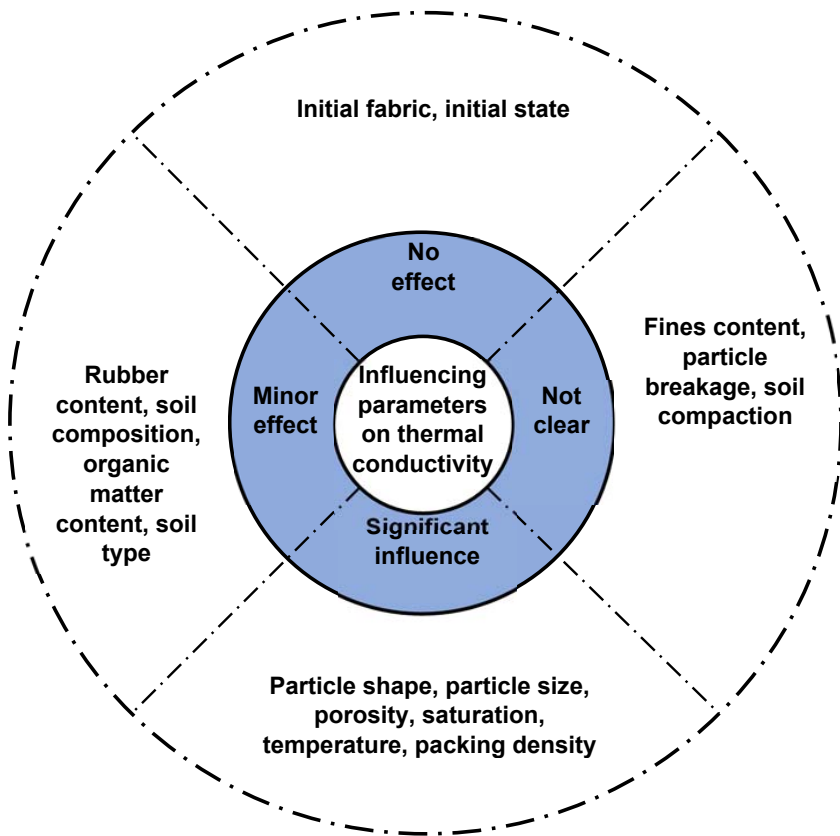


Fig. 2. Influencing parameter on the thermal conductivity of soils

from a ‘rubber-connected insulation layer’ to a ‘sand-encompassed conduction path’ as the sand-to-tyre ratio increased. Tang et al. (2008) studied the effects of dry density, water content, and saturation on American MX80 bentonite thermal conductivity, proposing a linear correlation with pore gas volume. Xu et al. (2016) explored bentonite-sand mixtures, while Liu et al. (2019) investigated bentonite-sand-graphite-fibre mixtures. Liu et al. (2020) reported an exponential relationship between water content and thermal conductivity in mucky silty clay at varying dry densities. Water addition forms thin films around particles, creating bridges between air gaps and particles, increasing the effective contact area and enhancing heat transfer. Beyond a specific water content threshold, thermal conductivity showed minimal variation across densities. Thermal conductivity is influenced by the effective contact area between particles (Brigaud and Vasseur, 1989; Cai et al., 2015). Studies have investigated the correlation between thermal conductivity and soil porosity (Tong et al., 2009; Wang et al., 2008). Liu et al. (2020) demonstrated that the thermal conductivity of mucky silty clay decreased exponentially with increasing porosity ($R^2 > 0.96$). Rubber addition decreases thermal conductivity, with important geotechnical implications. Lee and Shang (2013) found that rubber particle size and shredded tyre proportion significantly influenced thermal conductivity and anisotropy. Yang et al. (2022) demonstrated that shredded tyres significantly decrease sand thermal conductivity, suggesting applications in insulation layers. Particle shape affects thermal conductivity through arrangement effects (Gan et al., 2017; Fei et al., 2019). Xiao et al. (2020) reported that thermal conductivity increased with relative density for given particle shape parameters. Particle size has important effects on soil behaviour (Azaiez et al., 2022; Cherif Taiba et al., 2022; Mahmoudi et al., 2024) and, specifically, it significantly affects thermal conductivity; smaller particles generally have higher thermal conductivity due to increased contact facilitating heat transfer. Xiao et al. (2018) showed that thermal conductivity increased with the uniformity coefficient within the range $2.0 < Cu \leq 4.7$,

then increased gradually beyond $Cu > 4.7$. He et al. (2022) confirmed a good correlation between thermal conductivity and mean grain size of carbonate sand. Numerous predictive models have been developed (Lu et al., 2007). Johansen (1977) introduced the concept of normalised thermal conductivity, exploring the impacts of porosity and saturation. Côté and Konrad (2005) proposed novel relationships, while Chen (2014) developed empirical equations from 80 needle-probe tests. Alrtimi et al. (2016) showed that thermal conductivity fluctuations could be represented by logarithmic functions. Most prediction models yielded accurate results at lower porosity levels and high saturation ratios. Design parameters crucial for soil heat transfer include particle morphology, degree of saturation, and porosity. Additionally, this study moves well beyond a traditional literature review by combining a critical examination of the physical origins and governing mechanisms of soil thermal conductivity with the development of new semi-empirical predictive models. These models explicitly integrate the coupled effects of key soil parameters, specifically particle morphology, porosity, degree of saturation, and relative index. Built upon a rigorous synthesis of experimental data from published laboratory studies, the article uses this curated dataset to formulate quantitative relationships that reflect the interdependence of these variables. In doing so, it also identifies, clarifies, and reconciles discrepancies and inconsistencies present in the existing body of research. The paper is driven by real-world engineering demands in geotechnical, geoenvironmental, and geothermal applications, where reliable estimation of thermal properties is crucial. By merging in-depth critical analysis with original, data-informed modelling, this manuscript serves as both a scholarly synthesis and a practical tool, offering researchers and practitioners an enhanced framework for understanding and predicting the thermal behaviour of diverse soil types. Tables 1 and 2 present a summary of the key studies and the advantages and limitations of soil thermal conductivity research in the published literature.

Table 1. Summary of key studies on soil thermal conductivity

References	Soil Types	Key Parameters
Cai et al. (2015)	Clay, silt, fine sand, coarse sand	Particle size, soil type
Wang et al. (2017)	Sand, clay, sandy loam	Soil type, saturation
Yang et al. (2022)	Sand, tyre-sand mixtures	Tyre content, particle arrangement
Tang et al. (2008)	MX80 bentonite	Dry density, water content, saturation
Xu et al. (2016); Liu et al. (2019)	Bentonite-sand-graphite fibres	Additive effects
Côté and Konrad (2005)	Silica sands	Porosity, particle size
Johansen (1977)	Theoretical	Porosity, saturation
Chen (2014)	Various (80 tests)	Saturation, porosity

Table 2. Advantages and limitations of key thermal conductivity studies in the published literature

References	Advantages	Limitations / Gaps
Cai et al. (2015)	Real field soils; comparative analysis across soil types	Limited control over fabric; no quantitative model proposed
Wang et al. (2017)	Clear comparative data; practical relevance	Small dataset; no porosity or density control reported
Yang et al. (2022)	Novel application (recycled materials)	Non-natural material; limited to insulation context
Tang et al. (2008)	Relevant for nuclear waste disposal	Only bentonite; narrow applicability
Xu et al. (2016); Liu et al. (2019)	Tailored for barrier design	Complex mixtures; not representative of natural soils
Côté and Konrad (2005)	High-precision lab setup; temperature control	Excludes fines; no saturation >80 % tested
Johansen (1977)	Foundational model; widely used	Empirical; less accurate at low saturation
Chen (2014)	Large dataset; practical correlations	Limited mechanistic insight; model not universal

Proposal of Novel Predictive Models Based on Data from a Literature Review

All the data incorporated in this review were drawn exclusively from controlled laboratory experiments reported by the original authors, each employing distinct but well-established techniques to measure soil thermal conductivity under carefully regulated conditions. Côté et al. (2011) conducted their experiments in a temperature-controlled cold room using a custom-built thermal conductivity cell: dry soil was compacted into thin cylindrical PVC molds (10.1 cm in diameter and 7.5 cm in height) and placed between two 3-cm-thick Pyrex glass disks functioning as heat flux meters; high-precision thermistors were embedded at the center of each disk face, positioned within fractions of a millimeter from the soil-disk interfaces, to accurately capture the steady-state temperature gradient across the specimen. Alrtimi et al. (2016) utilised a steady-state divided-bar apparatus grounded in Fourier's law of heat conduction, where a uniform one-dimensional heat flux was applied through two identical, vertically stacked soil samples, enabling the determination of thermal conductivity across a range of saturation levels by measuring the resulting temperature drop along the heat flow path. Xiao et al. (2020) adopted a transient approach using a vertically oriented thermal needle probe system; their samples were prepared via the under-compaction method, a layer-by-layer compaction technique that minimises density gradients and ensures uniform fabric, allowing precise control over initial dry density, porosity, and degree of saturation during testing. Finally, Liu et al. (2020) and He et al. (2022) both employed a multifunctional thermal needle probe system based on the transient line heat source method, in which a short-duration electrical pulse heats a needle embedded in the soil, and the resulting temperature rise over time is recorded to calculate thermal conductivity; this technique is particularly effective

for capturing the influence of moisture content, density, and soil structure under near-instantaneous, minimally invasive conditions. While these studies vary in their methodological details, ranging from steady-state to transient techniques and differing sample preparation protocols, all were conducted under controlled laboratory settings, ensuring high data quality and reproducibility, which forms a robust foundation for the comparative analysis and model development presented in this review. In addition, all the experimental data used in this study were obtained from studies in which the original researchers employed cohesionless soils and are valid only within the following experimentally covered ranges summarised in Table 3.

Thermal Conductivity as a Function of Porosity, Degree of Saturation and Effective Diameter

To formulate multi-variable equations connecting thermal conductivity (λ) with porosity (n), degree of saturation (S_r), and effective diameter (D_{10}), we utilised data from Liu et al. (2020) and Alrtimi et al. (2016). This enabled the prediction of thermal conductivity as a function of porosity and saturation. Additionally, we examined Côté et al. (2011) data to assess the relationship between thermal conductivity, porosity, and effective diameter. Fig. 3 confirms that thermal conductivity rises with decreasing porosity and increasing effective diameter. The 3D plots illustrate that thermal conductivity increases with elevated saturation and reduced porosity in both studies. Figs. 4 and 5 demonstrate robust correlations between thermal conductivity, porosity, and saturation in compiled data from Liu et al. (2020) and Alrtimi et al. (2016), with high determination coefficients ($R^2 = 0.95$ and 0.84).

However, the correlation between thermal conductivity, porosity, and effective diameter in Côté et al. (2011) yields a lower determination coefficient ($R^2 = 0.62$) compared to Liu et al. (2020) and Alrtimi

Table 3. Boundary conditions of the proposed thermal conductivity models

Parameter	Symbol	Range	Source Studies
Effective grain size	D_{10} (mm)	0.087 – 2.70	Côté et al. (2011)
Mean grain size	D_{10} (mm)	0.16 – 3.16	He et al. (2022)
Porosity	n	0.327 – 0.640	Liu et al. (2020); Alrtimi et al. (2016)
Degree of saturation	S_r	1.5 % – 100 %	Liu et al. (2020); Alrtimi et al. (2016)
Relative index	I_d	0 – 1	He et al. (2022); Xiao et al. (2020)
Sphericity	S	0.48 – 0.60	He et al. (2022)
Overall regularity	OR	0.822 – 0.960	Xiao et al. (2020)
Aspect ratio	AR	0.715 – 0.969	Xiao et al. (2020)
Convexity	C_x	0.950 – 0.995	Xiao et al. (2020)
Thermal conductivity	λ (W/m·K)	0.094 – 2.475	All sources

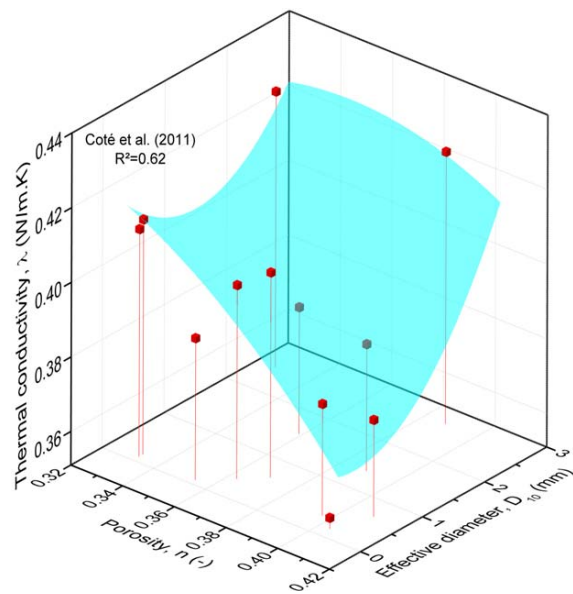


Fig. 3. Thermal conductivity versus porosity and effective diameter

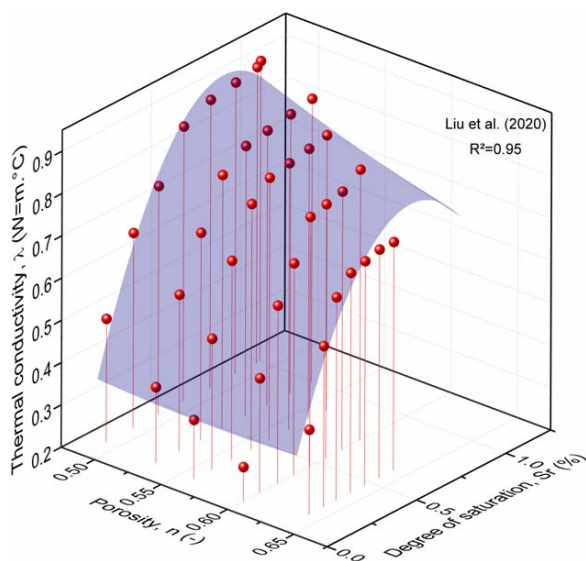


Fig. 4. Thermal conductivity versus porosity and degree of saturation

et al. (2016). This underscores the significant impact of coupled porosity and saturation effects on thermal conductivity, emphasising their greater influence compared to the combined effects of porosity and effective diameter. Understanding coupled porosity and saturation effects is crucial for accurately predicting thermal conductivity variations. When porosity and saturation are considered together, their combined effects exhibit a synergistic impact on thermal conductivity. Simultaneous variation in both parameters results in more pronounced thermal conductivity changes compared to single-factor consideration. The proposed multi-variable equations for thermal conductivity as functions of porosity (n), degree of saturation (S_r), and effective diameter (D_{10}) from three literature studies are as follows:

$$\lambda = 1.4 \times (n)^2 - 1.15 \times (S_r)^2 - 1.51 \times (n) + 2.35 \times (S_r) - 1.09 \times (n) \times (S_r) + 0.60; \quad (1)$$

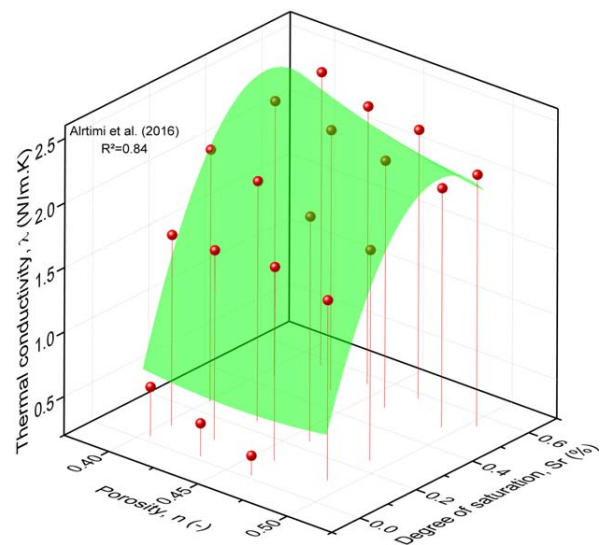


Fig. 5. Thermal conductivity as function of porosity and degree of saturation

$$\lambda = 19.67 \times (n)^2 - 9.85 \times (Sr)^2 - 17.66 \times (n) + 11.52 \times (Sr) - 6.86 \times (n) \times (Sr) + 4.51; \quad (2)$$

$$\lambda = -3.39 \times (n)^2 + 0.009 \times (D_{10})^2 + 1.86 \times (n) - 0.08 \times (D_{10}) + 0.19 \times (n) \times (D_{10}) + 0.17. \quad (3)$$

Thermal Conductivity as a Function of Relative Index and Particle Size

In this section, we present a multi-variable function in which thermal conductivity (λ) serves as the dependent variable, while the independent predictor variables are the relative index (I_d) and particle size represented by the mean diameter (D_{50}). To assess the accuracy and effectiveness of using thermal conductivity as the dependent variable, we performed a multi-variable analysis using compiled data extracted from the research of He et al. (2022). The 3D plots show that as the relative index of the materials increases, there is an enhancement in their thermal conductivity (Fig. 6). Additionally, when the mean diameter of the materials decreases, this is associated with an increase in thermal conductivity. This can be interpreted as greater efficiency in heat transfer within the materials, likely due to improved contact between particles or a reduction in the mean free path for heat carriers, ultimately leading to higher thermal conductivity values. Through this analysis, we evaluate the connection between thermal conductivity, relative index, and mean diameter, providing valuable insights into the accuracy and effectiveness of the proposed multi-variable function. A polynomial function was chosen as the mathematical representation for the investigated relationship. The results highlight the suitability

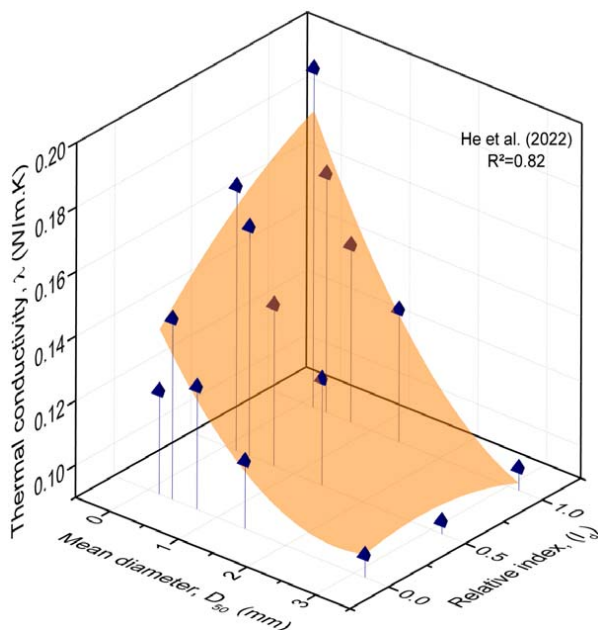


Fig. 6. Thermal conductivity versus mean diameter and relative index

of including the relative index and mean diameter when studying the thermal conductivity of the tested materials, yielding a coefficient of determination of $R^2 = 0.82$. The proposed multi-variable equation for thermal conductivity (λ) in terms of mean diameter (D_{50}) and relative index (I_d) for the tested soils is expressed as follows:

$$\lambda = -0.007 \times (D_{50})^2 - 0.017 \times (I_d)^2 - 0.04 \times (D_{50}) + 0.06 \times (I_d) + 0.015 \times (D_{50}) \times (I_d) + 0.15. \quad (4)$$

Thermal Conductivity as a Function of Relative Index and Particle Shape

The objective was to create multi-variable equations that establish a correlation between thermal conductivity (λ), relative index (I_d), and particle shape characteristics, specifically sphericity and regularity (S and ρ), using data collected from the study of He et al. (2022). The results indicate a strong correlation between thermal conductivity and both the relative index and particle shape properties (S and ρ). The observed increase in thermal conductivity with rising relative index and favourable particle shape characteristics can be attributed to improved heat transfer efficiency within the materials. A higher relative index suggests a more efficient transfer of thermal energy, and favourable particle shapes, such as increased sphericity and regularity, likely contribute to enhanced contact and conductivity pathways between particles. These factors collectively result in a higher thermal conductivity, indicating a more effective transmission of heat through the material (Fig. 7).

The use of an exponential function for regularity and a polynomial equation for sphericity as mathematical representations of the studied relationship was driven by their suitability in capturing complex, non-linear interactions among variables. This choice enables the modelling of intricate behaviours observed in thermal conductivity concerning both relative index and particle shape characteristics. The results obtained underscore the significance of incorporating both relative index and particle shape properties, specifically sphericity and regularity, when examining the thermal conductivity of the tested materials. In particular, when focusing on sphericity and regularity, the coefficients of determination (R^2) reached notable values of 0.86 and 0.87, respectively. These high R^2 values indicate strong correlations, suggesting that the proposed multi-variable functions effectively capture the underlying patterns in the data. The multi-variable equations proposed for thermal conductivity (λ), expressed as functions of relative index and particle shape properties (S and ρ) for the tested soils, provide quantitative representations of the relationship. These equations serve as valuable tools for predicting thermal conductivity based on the specified variables, contributing to a more nuanced

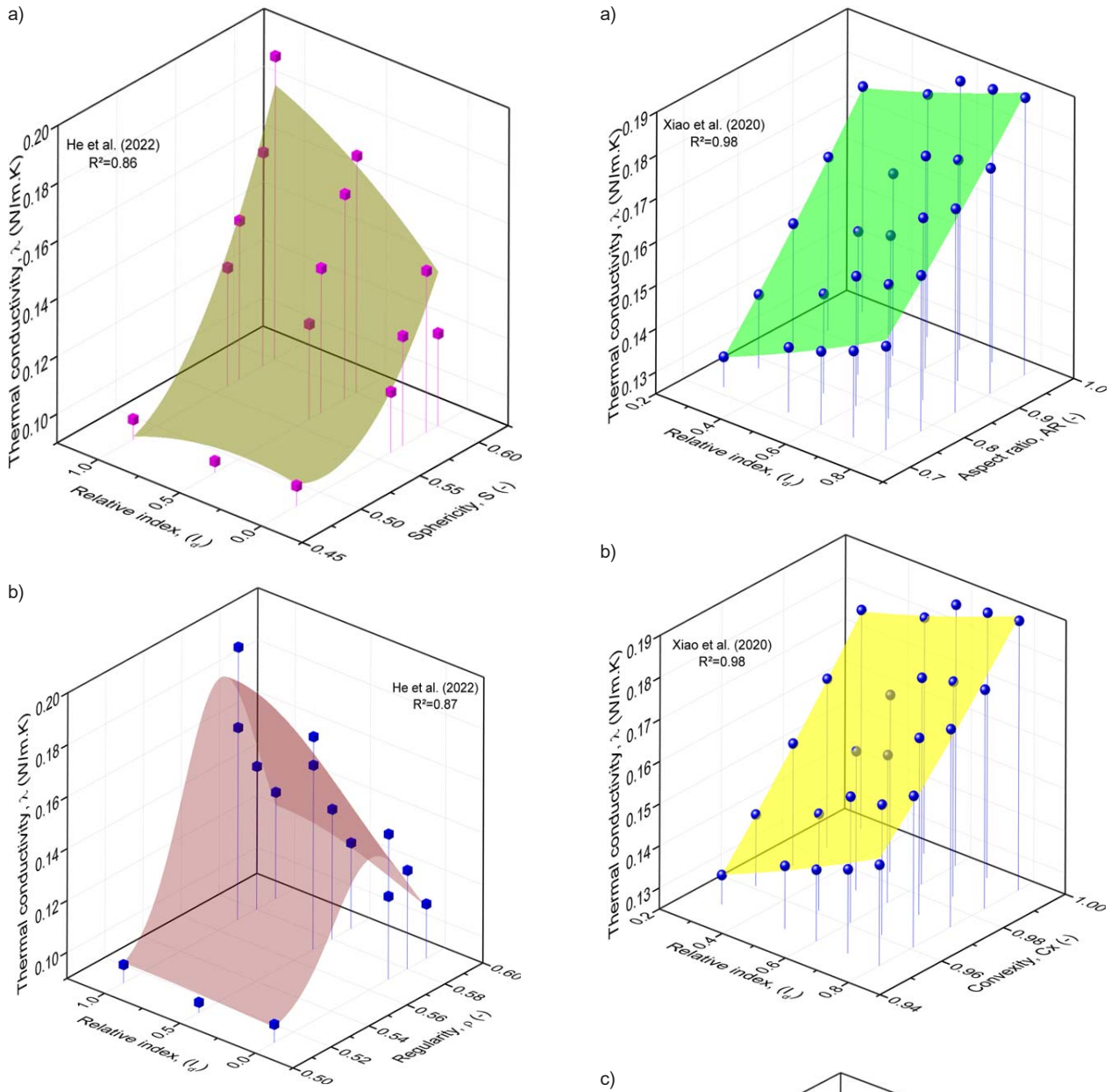


Fig. 7. Thermal conductivity versus relative index and particle shape characteristics: Sphericity; (b) regularity

understanding of the intricate processes occurring within the soils:

$$\lambda = 5.2 \times (S)^2 - 0.017 \times (I_d)^2 - 5.26 \times (S) - 0.18 \times (I_d) + 0.40 \times (I_d) \times (S) + 1.41; \quad (5)$$

$$\lambda = 0.09 \times e^{(-0.5 \times (\rho - 0.56)^2) - (0.5 \times (I_d - 0.96)^2)} + 0.094. \quad (6)$$

Moreover, Fig. 8 depicts correlations between thermal conductivity (λ) and relative index (I_d) with three particle shape properties: aspect ratio (AR), convexity (Cx), and overall regularity (OR) using data from Xiao et al. (2020). Results show that an increase in relative index and favourable particle shape characteristics substantially increases thermal conductivity. Increased thermal conductivity with

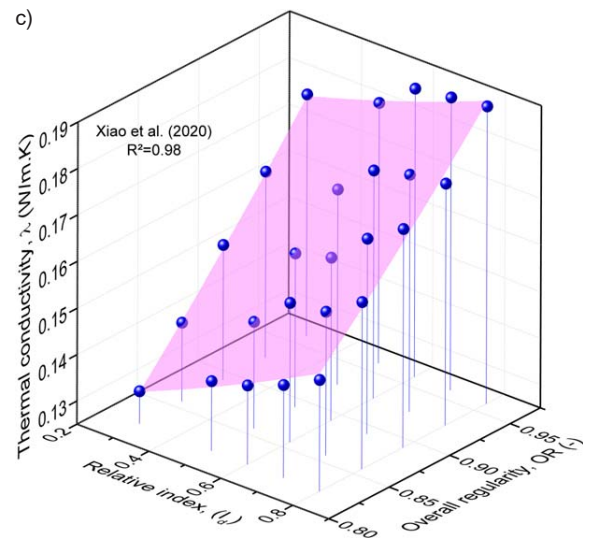


Fig. 8. Thermal conductivity versus relative index and particle shape characteristics: aspect ratio; (b) convexity; (c) overall regularity

higher relative index and favourable particle shape characteristics results from improved heat transfer efficiency. Higher relative index indicates more effective thermal energy transfer, meaning better heat conduction and higher overall thermal conductivity. Improved particle shape characteristics — higher aspect ratio, increased convexity, and overall regularity — contribute to better particle contact and alignment. Enhanced contact creates more efficient heat conduction pathways, increasing thermal conductivity. This analysis assesses relationships between thermal conductivity (λ) and independent variables (I_d , AR , C_x , OR), providing valuable insights into the multi-variable equation precision and effectiveness. Polynomial functions were selected as the mathematical representation for the explored correlations. Results underscore the appropriateness of incorporating (I_d , AR , C_x , OR) when investigating thermal conductivity, yielding high determination coefficients (R^2) of 0.98 for (AR , C_x , OR). The proposed multi-variable equations for thermal conductivity (λ), expressed in terms of particle shape properties (AR , C_x , OR) and relative index (I_d) for the tested soils, are as follows:

$$\lambda = 0.009 \times (I_d)^2 + 0.22 \times (OR)^2 + 0.09 \times (I_d) - 0.04 \times (OR) - 0.07 \times (I_d) \times (OR) + 0.01; \quad (7)$$

$$\lambda = 0.009 \times (I_d)^2 + 0.06 \times (AR)^2 + 0.05 \times (I_d) + 0.0 \times (AR) - 0.04 \times (I_d) \times (AR) + 0.03; \quad (8)$$

$$\lambda = 0.009 \times (I_d)^2 + 2.46 \times (C_x)^2 + 0.23 \times (I_d) - 3.72 \times (C_x) - 0.22 \times (I_d) \times (C_x) + 1.44. \quad (9)$$

Validation of the Newly Proposed Models

The validation procedure for the multi-variable equations linking predicted to measured thermal conductivity values from literature involved a thorough analysis. Three distinct models were collected directly from the original published studies cited in this review article. All data points plotted on the x-axis correspond to the actual measured thermal conductivity values reported in these peer-reviewed sources. The y-axis, in contrast, shows the values predicted by the new models proposed in this study, enabling a direct validation of model performance against independent experimental data. Mean Absolute Error (MAE) is determined by computing the absolute errors, summing them, and dividing by the total number of observations. For equations (1)–(9), the calculated MAE values are 0.003, 0.009, 0.001, 0.001, 0.009, 0.002, 0.006, 0.009, and 0.0003, respectively. MAE indicates the average magnitude of discrepancies between predicted and actual values, providing insights into equation accuracy. Root Mean Square Error (RMSE) is computed by summing squared errors, dividing by the total number of observations, and taking the square root. RMSE values for the equations are

0.02, 0.04, 0.005, 0.003, 0.03, 0.009, 0.03, 0.04, and 0.001, respectively. RMSE measures the standard deviation of differences between predicted and actual values, reflecting the overall error magnitude. Lower RMSE indicates better agreement between predicted and observed data. The coefficient of determination (R^2) was calculated for each equation, yielding values ranging from 0.98 to 0.99 for Equations (1)–(9), as depicted in Figs. 9, 10, and 11. R^2 indicates the proportion of the variance in thermal conductivity that is explained by the independent variables (particle morphology, porosity, degree of saturation, and relative index). The obtained R^2 values affirm a substantial correlation between thermal conductivity and the evaluated parameters (particle shape properties, n , S_r , I_d , and particle size), aligning with the predictions. These validation outcomes underscore the dependability and efficacy of the proposed multi-variable equations. Small MAE and RMSE values signify high precision in predicting thermal conductivity based on the studied independent variables. High R^2 values suggest that the equations elucidate significant portions of variation in thermal conductivity. This validation study provides comprehensive insights into the intricate relationships between thermal conductivity and the factors affecting soil heat transfer paths, contributing to a deeper understanding of these systems and their practical applications.

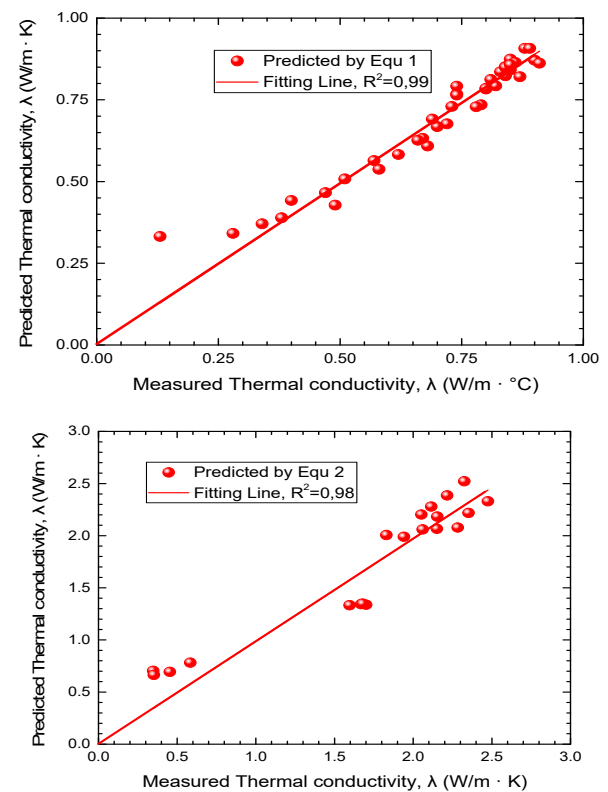


Fig. 9. Predicted thermal conductivity (Equations (1)–(3)) plotted against measured thermal conductivity

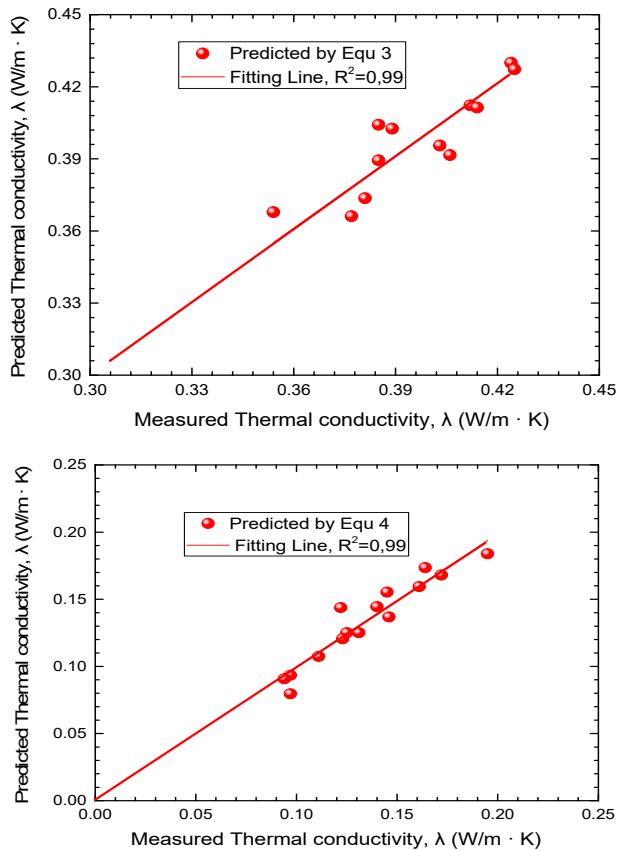


Fig. 10. Predicted thermal conductivity (Equations (4)–(6)) plotted against measured thermal conductivity

Conclusion

Studying the factors affecting the thermal conductivity of granular soils is crucial in geotechnical engineering, environmental science, and geothermal energy systems. Understanding how particle morphology, porosity, degree of saturation, and relative index affect thermal conductivity helps in designing efficient geothermal systems and predicting soil heat transfer. Engineers can develop more effective systems by considering the unique thermal behaviour of granular soils. This paper has presented innovative formulations for estimating soil thermal conductivity that serve as valuable predictive tools. The proposed multi-variable functions provide comprehensive approaches for accurately determining thermal conductivity. Assessing the accuracy of the proposed equations via performance evaluation is crucial, involving error computation and

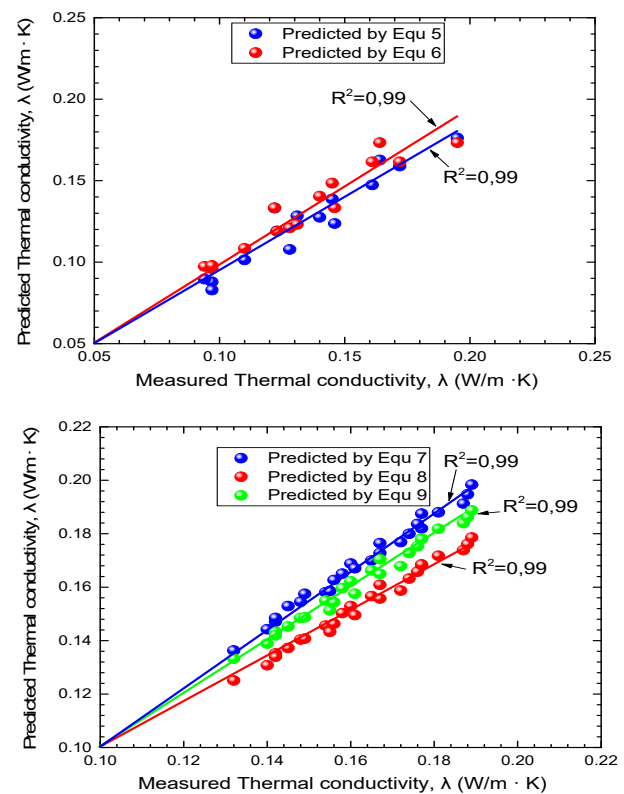


Fig. 11. Predicted thermal conductivity (Equations (7)–(9)) plotted against measured thermal conductivity

metrics such as MAE and RMSE to ascertain their reliability. The validation study offers insights into the relationships between thermal conductivity and the independent variables (particle morphology, porosity, degree of saturation, and relative index), enhancing understanding and highlighting practical implications. This review serves as a valuable resource connecting theory with application for scientific inquiry and engineering practice. Continued research into other influential parameters affecting granular soil thermal conductivity is essential for advancing knowledge and promoting practical applications.

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КРИТИЧЕСКИЙ ОБЗОР ВЛИЯНИЯ МОРФОЛОГИИ ЧАСТИЦ И ПОРИСТОСТИ НА ТЕПЛОПРОВОДНОСТЬ ПОЧВЫ

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Аннотация

Введение. Данный критический обзор подчеркивает важность исследования в обширном корпусе литературы по изучению грунтов таких ключевых факторов, как морфология частиц и пористость. Углубленное понимание влияния этих элементов на теплопроводность грунта играет важную роль в развитии геотехнических и экологических областей знаний. **Методы.** Данный обзор обобщает результаты широкого спектра исследований и подчеркивает сложную природу теплопроводности грунтов, а также необходимость тщательного изучения этих параметров. Каждый фактор играет решающую роль в определении поведения теплопередачи в грунтах. На основе углубленного анализа существующих исследований данная статья подчеркивает необходимость систематического изучения этих переменных для разрешения противоречий, восполнения пробелов в знаниях и совершенствования прогностических моделей для применения в геотехнических и экологических исследованиях. **Заключение.** Недавно разработанные многомерные функции предлагают надежную основу для прогнозирования теплопроводности грунтов путем интеграции этих значимых параметров. Данный всесторонний обзор, связывающий теорию с практическим применением, служит важным ресурсом, поддерживающим как научные исследования, так и инженерную практику.

Ключевые слова: теплопроводность, зернистые грунты, факторы, критический обзор, предлагаемые модели.