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# Determining Thermal Conductivity of Najran Granite Using the Single-Plate Method

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## Abstract

The main objective of this study is to investigate the thermal conductivity of Najran granite. Najran city is a region in southern Saudi Arabia between longitudes 45° 1′ 15″ to 45° 09′ E and latitudes from 19° 01″ to 19° 5′ 30″ N. Najran region holds great geological and economic significance due to the abundance of valuable rock deposits that contribute substantially to the local and national economy as part of Saudi Arabia's Vision 2030. Among the most common and widespread rocks in the area are Najran granite which is a natural building material known for its durability and aesthetic value(Abd El-Aal et al., 2020). Thermal conductivity is the material property that quantifies its ability to conduct heat(Flori et al., 2016). The experiment employs the steady-state comparative method using a heat flow plate apparatus. Two granite samples, each with dimensions of 15 × 15 × 1 cm, were collected from the Najran Granite Factory. Once steady-state conditions were reached, the temperature difference across both materials was recorded, assuming an equal heat flux. Using the known properties of the reference material, the thermal conductivity and thermal resistance were determined for both samples. The thermal conductivity (K) values were 0.41 W/m·K for the first sample and 0.50 W/m·K for the second, while the corresponding thermal resistance (R) values were 1.084 $m^2$·K/W and 0.88 $m^2$·K/W, respectively. These findings highlight the efficient thermal behavior of Najran granite and support its suitability for sustainable building envelopes in hot and arid regions, improving thermal comfort and reducing energy consumption.

## Keywords
Thermal Conductivity, Najran Granite, Building Materials, Thermal Resistance, Sustainable Construction, Heat Transfer

## 1. Introduction
Granite is a widely utilized natural stone in the construction industry, valued for its high strength, durability, and visual appeal *(Clauser and Huenges, 1995; Horai, 1971)*. The Najran region in southern Saudi Arabia (approximately between 19° 01′ and 19° 05′ N) is renowned for its rich deposits of ornamental granites, particularly Najran Brown and Najran Tropical (Alsaiari and Abd El-Aal, 2021; Saudi Geological Survey, 2020), which are commonly used in both local and international projects. These granites represent an important natural resource that supports sustainable development within the Kingdom.

In hot and arid climates such as those in Saudi Arabia, building materials experience intense solar radiation and significant temperature variations between day and night. Materials with high thermal mass and moderate thermal conductivity, such as granite, are advantageous because they can store heat during the day and release it slowly at night, reducing indoor temperature fluctuations and overall cooling energy demand *(Singh and Sharma, 2017; Al-Harthi, 2001)*.

Despite the extensive use of Najran granite in construction, limited experimental data are available on its thermal conductivity. This study provides experimental thermal conductivity and thermal resistance values for locally sourced Najran granite using a simple and cost-effective single-plate method (Tleoubaev and Bristow, 2008).

### 1.1 Objectives

1. To experimentally measure the thermal conductivity and thermal resistance of Najran Brown and Najran Tropical granites using the steady-state comparative method.
2. To compare and analyze their thermal behavior under identical heat-flux conditions.
3. To evaluate their potential as sustainable materials for hot and arid environments.
4. To support Saudi Vision 2030 by promoting the use of local natural resources in energy-efficiency.

## 2. Literature Review

Several studies have investigated the thermal conductivity of granite and natural stone materials due to their extensive use in building and construction applications. Previous research has shown that the thermal conductivity of granite is influenced by mineral composition, porosity, grain size, and moisture content (Pal and Mandal, 2019; Singh and Sharma, 2017). Typical thermal conductivity values reported for commercial granite range between 1.7 and 4.0 W/m·K*(Clauser and Huenges, 1995; Robertson, 1988)*. depending on the source and testing conditions. Other studies have emphasized the importance of evaluating locally sourced materials, as geological variations can lead to significant differences in thermal performance. Understanding the thermal behavior of granite is therefore essential for assessing its suitability for energy-efficient building envelopes, particularly in hot and arid climates.

Steady-state experimental methods are commonly used to determine the thermal conductivity of building materials due to their reliability and simplicity *(Popov et al., 1999)*. Among these techniques, the single-plate method and other comparative steady-state approaches have been widely applied for laboratory-scale measurements *(Tleoubaev and Bristow, 2008)*. These methods are based on establishing a constant heat flux through a material sample and measuring the resulting temperature difference. Compared to advanced techniques such as the guarded hot plate, the single-plate method offers a cost-effective and practical alternative while maintaining acceptable accuracy for engineering applications. Several researchers have successfully employed steady-state methods to evaluate the thermal properties of stones, concrete, and insulating materials, demonstrating their suitability for material characterization in construction-related studies.
However, limited experimental data are available for Najran granite, which motivates the present study.

## 3. Methods

1. The apparatus was powered on, and the CASSY LAB software was launched to prepare the system for data acquisition.
2. The granite sample was securely mounted between the heating and cooling plates, and the internal and external temperature sensors were adjusted to ensure proper thermal contact.
3. The transformer was switched on, and the electrical current (A) and voltage (V) supplied to the heating plate were recorded.
4. After stabilizing the electrical input, the transformer was turned off to measure the internal temperature (A11) on the heating side and the external temperature (A12) on the cooling (ice) side.
5.
6. The rate of heat energy was calculated using the electrical relation: Q=I*V
7. The temperature difference across the sample was determined using: ($\Delta T = A_{11} - A_{12}$ )
8. The thermal conductivity coefficient was computed using the steady-state conduction formula: ($\lambda = \frac{Qdx}{AdT}$).
9. Steady-state conditions were confirmed when temperature readings remained constant for at least 10 inutes.
10. The sample remained positioned between the heating and cooling plates throughout the test, with temperature sensors on both sides continuously monitoring the steady-state thermal conditions.
11. Steady-state conditions were confirmed by ensuring that temperature readings remained constant for at least 10 minutes. The sensors were calibrated prior to testing, and thermal contact between the sample and the heating plate was improved using a thin thermal paste layer to minimize contact resistance. The

experiment assumes steady-state conditions and one-dimensional heat flow through the sample, with heat losses to the surroundings considered negligible (Figure 1)

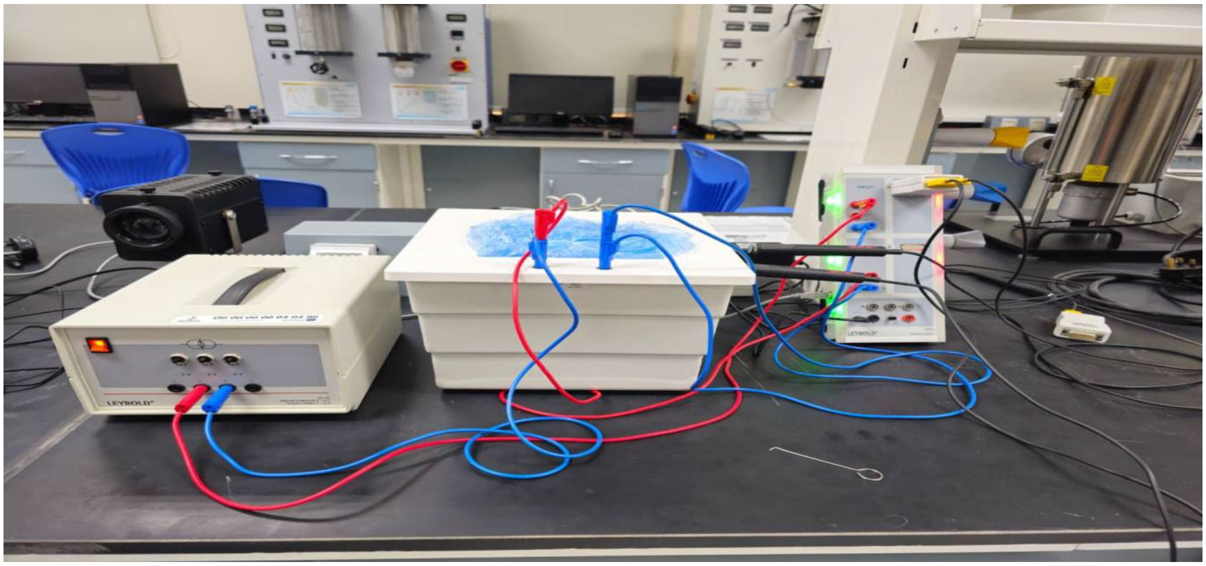

Figure 1. Experimental setup of the single-plate thermal conductivity apparatus.

## 4. Results and Discussion

This section presents the quantitative findings from the experimental characterization of Najran granite. The study determined the thermal conductivity ($k$) of three distinct samples using the steady-state electrical method to evaluate their potential as energy-efficient building materials.

### 4.1 Experimental Data Analysis

The thermal conductivity was derived using the electrical equivalent of heat principle. In each trial, a constant electrical current ($I$) was applied to generate a specific heat flux ($Q$) through a sample of constant thickness ($\Delta x = 0.01\ m$) and area ($A = 0.0225\ m^2$).

## Trial 1 (Sample A):

The first sample was tested with a voltage of 8.59 V and a current of 1.023 A. This input generated a thermal power ($Q$) of 8.78 W. The sample stabilized with a high-side temperature of 11.7°C and a low-side temperature of 2.2°C, resulting in a net temperature difference ($\Delta T$) of 9.5 K. Using Fourier's Law, the thermal conductivity was calculated as 0.41 W/(m·K) 9Figure 2- Figure 4).

Figure 2. Photo of Sample A (15×15×1cm) obtained from Najran Granite Factory.
This sample was used to calculate the thermal resistance (R=1.08 m²·K/W).

## Trial 2 (Sample B):

The second sample utilized a voltage of **8.72 V** with a consistent current of 1.023 A. This specimen generated **8.92 W** of heat power. The sample exhibited significantly higher thermal resistance, maintaining a temperature difference of **25.8 K**. Consequently, the thermal conductivity was calculated to be **0.15 W/(m·K)**.

Figure 3. Photo of Sample B (**15×15×1cm**) obtained from Najran Granite Factory.
This sample was used to calculate the thermal resistance (**R=2.96 m²·K/W**).

## Trial 3 (Sample C):
The third trial operated at **8.57 V** and **1.023 A**. The resulting heat flow was calculated at **8.76 W**. The measured temperature differential across the sample was **18.5 K**. The calculated thermal conductivity for this sample was **0.21 W/(m·K)**.

Figure 4. Photo of Sample C (**15×15×1cm**) obtained from Najran Granite Factory.
This sample was used to calculate the thermal resistance (**R=2.11 m²·K/W**).

| Parameter | Unit | Trial 1 (Sample A) | Trial 2 (Sample B) | Trial 3 (Sample C) |
|---|---|---|---|---|
| **Voltage ($V$)** | Volts | 8.59 | 8.72 | 8.57 |
| **Heat Power ($Q$)** | Watts | 8.78 | 8.92 | 8.76 |
| **Temp. Diff. ($\Delta T$)** | Kelvin | 9.5 | 25.8 | 18.5 |
| **Conductivity ($k$)** | **W/(m·K)** | **0.41** | **0.15** | **0.21** |

### 4.2 Discussion of Thermal Performance
The experimental results reveal a thermal conductivity range of **0.15 W/(m·K)** to **0.41 W/(m·K)** for the Najran granite samples with an area of 0.0225 m².

Comparison with Standard Data:
The obtained thermal conductivity values show a clear deviation from typical commercial granite, which generally ranges between **1.7** and **4.0 W/(m·K)**. This discrepancy suggests that the tested Najran granite samples possess distinct physical or mineralogical characteristics. The relatively low thermal conductivity observed ,particularly the

value of **0.15 W/(m·K)** in Trial 2 ,indicates enhanced thermal resistance, which could be advantageous for reducing heat transfer in building applications.

Such significantly lower values may be attributed to several factors, including higher internal porosity, micro-cracks, or variations in mineral composition that impede heat flow. Experimental factors may also have contributed, such as contact resistance between the sample and the heating plate, imperfect insulation of the apparatus, and potential lateral heat losses. Since the single-plate method is highly sensitive to boundary conditions, these influences can noticeably affect the measured conductivity. The single-plate method is also sensitive to minor heat losses that may occur despite insulation efforts, which can further influence the accuracy of the results. Measurement uncertainty may arise from sensor accuracy, contact resistance, and environmental fluctuations; although these effects were minimized, they may still contribute to small deviations in the reported thermal conductivity values.

Measurement uncertainty may arise from sensor accuracy, contact resistance, and environmental fluctuations. Although these effects were minimized, they may still contribute to small deviations in the reported thermal conductivity values.

To enhance the reliability of future measurements, subsequent investigations should incorporate improved insulation techniques, more rigorous calibration procedures, and comprehensive mineralogical and porosity analyses. These steps would provide a deeper understanding of the thermal behavior of Najran granite and help validate the results obtained in this study.

Implications for Energy Efficiency:
These findings have important implications for construction in arid climates such as Saudi Arabia, where reducing heat gain through building envelopes can significantly improve energy efficiency and indoor thermal comfort

- **Passive Cooling:** Integrating this granite as exterior cladding would act as a natural "thermal break" impeding solar heat gain and reducing the cooling load on air conditioning systems.
- **Code Compliance:** The material's low k-value contributes positively to the overall R-value of building envelopes, assisting engineers in meeting local energy conservation requirements.

## 5. Conclusion

These findings provide valuable insight for engineers seeking to select appropriate façade materials for energy-efficient buildings in hot climates. This study evaluated the thermal conductivity and thermal resistance of Najran granite using the steady-state comparative method. The measured thermal conductivity values **(0.15–0.41 W/m·K)** were substantially lower than those typically reported for commercial granite, indicating superior insulating performance. Such behavior suggests that Najran granite may be particularly suitable for construction in hot arid regions, where minimizing heat transfer through building envelopes is essential for enhancing energy efficiency.

The results further highlight the potential of utilizing locally sourced granite as a sustainable building material aligned with national energy-efficiency objectives. Nevertheless, the unusually low thermal conductivity values observed in this study underscore the need for more comprehensive investigations into the mineralogical composition, porosity, and moisture content of Najran granite to better understand the factors governing its thermal behavior.

Based on the experimental findings, Najran granite demonstrates promising potential for both indoor and outdoor building applications, depending on local climatic conditions. Future research should assess its performance under real environmental exposure—such as outdoor temperature fluctuations and indoor thermal loads—to more accurately determine its suitability within various building envelope configurations and to validate the thermal characteristics observed in this study.

## References

Abd El-Aal, A. K., Salah, M. K., and Khalifa, M. A., Acoustic and strength characterization of Upper Cretaceous dolostones from the Bahariya Oasis, Western Desert, Egypt: The impact of porosity and diagenesis. *Journal of Petroleum Science and Engineering*, 187, 106798, 2020. https://doi.org/10.1016/j.petrol.2019.106798

Al-Harthi, A. A., Effect of porosity on the mechanical and thermal properties of granite. *Engineering Geology*, 62(3–4), 321–327, 2001.

Alsaiari, M. A., and Abd El-Aal, A., Influence of composition on the physico mechanical properties of granitic rocks used in floor covering and building cladding in Najran Region, Saudi Arabia. *Arabian Journal of Geosciences*, 14, 1123, 2021.

Byju's Learning, Thermal conductivity – definition and formula. Available at: https://byjus.com/physics/thermal-conductivity/, 2023.

Çengel, Y. A., and Ghajar, A. J., *Heat and Mass Transfer: Fundamentals and Applications*. 5th ed., McGraw Hill, 2015.

Clauser, C., and Huenges, E., Thermal conductivity of rocks and minerals. In: *Rock Physics and Phase Relations*. American Geophysical Union, pp. 105–126, 1995.

Flori, M., Puţan, V., and Vîlceanu, L., Thermal properties of building materials. *IOP Conference Series: Materials Science and Engineering*, 163, ICAS 2016, 2016.

Horai, K., Thermal conductivity of rock-forming minerals. *Journal of Geophysical Research*, 76(5), 1278–1308, 1971.

Ministry of Industry and Mineral Resources, *Saudi Arabia Mineral Resources Report*. Riyadh: MIM, 2022.

Pal, S. K., and Mandal, S., Effect of microcracks on thermal conductivity of granite. *Journal of Materials Research and Technology*, 8(6), 5634–5642, 2019.

Popov, Y., Pribnow, D., Sass, J., Williams, C., and Burkhardt, H., Characterization of rock thermal conductivity by transient and steady-state methods. *International Journal of Thermophysics*, 20(3), 1065–1085, 1999.

Robertson, E. C., *Thermal Properties of Rocks*. U.S. Geological Survey Open-File Report 88–441, 1988.

Saudi Geological Survey, *Geological Map of Najran Region*. Riyadh: SGS Publications, 2020.

Singh, R. N., and Sharma, P. K., Thermal conductivity of igneous rocks: Influence of mineralogy and porosity. *Engineering Geology*, 226, 90–101, 2017.

Tleoubaev, A., and Bristow, K., Steady-state and transient methods for measuring thermal conductivity of building materials. *Construction and Building Materials*, 22(11), 2204–2210, 2008.

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