Perlite: The Most Sustainable Insulation Solution for Buildings

Perlite is one of the most overlooked insulating materials, especially as it offers numerous advantages over other organic and inorganic insulation materials.

In an era of growing concern for the impact that building materials and products have on the environment, the choice of which materials to use is increasingly informed by relative performance and sustainability metrics. An extensive review of international literature and comparative technical studies finds that perlite is very much seen as a sustainable, natural and user-friendly alternative to competing organic and inorganic insulating materials, like PUR-foam and EPS coming from non-replenishable sources and mineral wools. Global academic research and official technical reviews from certified national bodies argue decisively in favor of perlite as having a minimal Global Warming Potential (GWP) and that perlite-based insulation offers consistent thermal performance over the application lifecycle while at the same time protecting structures from fire. The information presented here relies on data compiled from a range of independent international bibliographies focusing on the performance of various insulation materials over time, the efficient use of raw materials and waste generated, and their relative fire-resistant qualities.

Introduction

Perlite is a naturally occurring, siliceous volcanic mineral that expands when heated to form a froth of tiny glass bubbles of entrapped air. The resultant
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Aging/Drop of Thermal Insulation Performance of Expanded Polystyrene/Polyurethane

- Thermal resistance of expanded polystyrene decreases by up to 43% (from 2.485 m²·K/W to 1.424 m²·K/W) after roughly 5,000 days from production.[2]
- Thermal resistance of rigid polyurethane falls by up to 27.5% (from 2.579 m²·K/W to 1.897 m²·K/W) after 5,000 days.[2] The same trend has been identified for polyurethane (PU) foam insulation in refrigerator panels.[3]

By contrast, perlite is dimensional, stable and keeps its insulating performance 100%. It maintains its structural integrity and retains stable thermal conductivity for the entire lifetime of the building.

Figure 1 • Relative thermal resistance of cellular plastic foams with three different thicknesses after scaling factor was applied.[4]

ultra-lightweight material, referred to simply as expanded perlite, is durable, non-combustible (Class A1 / DIN 4102), inorganic, and ultra-lightweight with a bulk density range of between 40 Kg/m³ and 140 Kg/m³ (2.5 – 9.0 lb./ft³). Expanded perlite has low thermal conductivity at 0.044 W/mK (0.023 BTU/hr·ft²°F) at ambient conditions, with an R-value of approximately 3.0 – 3.5 per inch at a mean temperature of 40 deg F (4 deg C) for product 4.1 – 7.4 lb/ft³ (66 – 118 kg/m³). It is resistant to chemical attack, odorless, pH neutral and can be produced to comply with ASTM C332[4] and ASTM C549. Construction grade expanded perlite replaces chemical insulators and products such as expanded (EPS), extruded polystyrene (XPS), and polyurethane foam. Such chemical products are highly combustible, contain Volatile Organic Compounds (VOCs), are organic and deteriorate with time.

For example, the performance of cellular plastic foams as insulating materials is not stable over the long-term (see Figure 1). Both EPS and XPS deteriorate with time in two main stages.[1] In the primary stage (under 5 years), air from the outside penetrates the insulating material and replaces the insulating gas inside each enclosed cell. In the secondary stage (5 years and up), the gases that penetrated the internal air bubbles are slowly lost to the outside without being replaced, resulting in gradual shrinking of volume. The morphological change and the replacement of low conductivity gas with air causes an overall decrease in thermal resistance of the foam-based insulation.

Perlite: The Safe and Fully Natural Material

Both unexpanded and expanded forms of perlite are fully natural, inert, mineral-based materials. No long-term health effects have been linked to perlite mining, processing, or application and installation activities, provided that the prescribed occupational exposure limits (OEL) and means of using Personal Protective Equipment are observed. For more information, see the relevant information published by the Perlite Institute[3].

Embodied Energy and Embodied Carbon

Embodied energy (EE) and embodied carbon (EC) constitute two important metrics for examining the relative amount of energy involved in manufacturing a product. Embodied energy accounts for the energy used for extracting and processing of raw materials,
Global academic research and official technical non-replenishable sources and mineral wools. Technical studies that perlite is very much seen as materials to use is increasingly informed by relative amount of energy involved in manufacturing, transportation, and final construction or assembly. Embodied carbon is the sum of fuel-related carbon emissions (i.e. embodied energy that is combusted, but not feedstock energy retained within the material) and process-related carbon emissions (i.e. non-fuel related emissions that may arise, for example, from chemical reactions). A cradle-to-gate approach for both factors is followed in this document, which considers the impact of the product from the extraction of the raw materials up to the distribution of the final product.

Figure 2 and Figure 3 present embodied energy and embodied carbon, respectively, under the cradle-to-gate boundaries, for perlite and other insulating materials.

Expanded Perlite has minimal embodied energy and embodied carbon compared to all other organic and inorganic alternatives. The embodied energy of raw perlite is 0.66 MJ/kg and 0.03 kg CO₂/kgr.
Global Warming Potential and Applications

Global Warming Potential (GWP) is the appraisal of a material's relative contribution to greenhouse gas emissions, such as CO₂, methane, and ozone O₃. GWP is calculated at the manufacture (Stage A), use (Stage B), and end-of-life stage (Stage C), and it is calculated as the sum of emissions of the greenhouse gases (CO₂, N₂O, CH₄ and VOCs) multiplied by their respective GWP impact factors.

GWP of expanded perlite and other insulating materials calculated on volume and mass basis is presented in Figure 4 and Figure 5, respectively. Table 1 presents critical environmental metrics for the raw material extraction (Stage A1), the transportation to the processing facility (Stage A2) and the final manufacturing (Stage A3). These stages account for the primary 'cradle-to-gate' processes involved in the manufacture of most materials and services used for construction. The rules for determining their impact and aspects are defined in EN 15804®.

As shown in Figure 4, expanded perlite offers an extremely favorable GWP when compared on a volume-to-volume basis to similar alternatives such as mineral wool, EPS, fiberglass, extruded polystyrene and polyurethane foam. It accounts for only 0.52 kg CO₂ equivalent, which is five times lower compared to polystyrene at 2.70 kg CO₂ equivalent.

A similar observation (Figure 5) can be made when GWP values are compared on a weight basis.
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<tr>
<th>ENVIRONMENTAL METRICS OF INSULATING MATERIALS</th>
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<td>PROPERTIES</td>
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<td>COMMON INSULATING MATERIALS</td>
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<td>Density (kg/m³)</td>
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<tr>
<td>----------</td>
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<tr>
<td>Expanded Perlite [6]</td>
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<tr>
<td>Mineral Wool [6] (Stone/Rock Wool)</td>
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<tr>
<td>EPS Insulation Graphite 80 [7]</td>
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<td>Fiberglass Insulation [6]</td>
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<td>XPS Insulation [6]</td>
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Ozone Depletion Potential (ODP) measures the potential of emissions of chloroaurahydrocarbons (CFCs) and chlorinated hydrocarbons (HCls) for depleting the ozone layer. The aforementioned are major contributors to the greenhouse effect. Photochemical Ozone Creation Potential (POCP) scale quantifies the relative abilities of volatile organic compounds (VOCs) to produce ground-level ozone. Eutrophication Potential (EP) covers the impact on terrestrial and aquatic environments due to over-fertilization or excess supply of nutrients, particularly focusing on the most important substances nitrogen (N) and phosphorus (P). Acidification Potential (AP) measures the contributions of SO₂, NOₓ, HCl, NH₃, and HF to the potential acid deposition, i.e., on their potential to form H⁺ ions.

Table 1 • Environmental metrics for perlite and other alternative building insulation materials, per mass and per volume [6]–[8].

Per kilogram of material. In that case, fiberglass presents the least impact with 12.8 kg CO₂ equivalent per Kg of material, while perlite comes in third at 60.1 kg CO₂ equivalent. The reason behind this is the extremely low densities of both EPS and fiberglass in comparison to that of expanded perlite considered (Table 1).

Ozone Depletion Potential (ODP), Photochemical Ozone Depletion Potential (POCP), Eutrophication Potential (EP), and Acidification Potential (AP) are also important metrics relating to the impact of construction products. (Definitions for these metrics can be found in the Table 1 footnotes.) Table 1 presents a convenient comparison. Among all the commonly used building insulation materials described, expanded perlite has the least ODP, POCP, EP and AP values calculated on either a mass or volume basis, and the least environmental impact overall. Marginally lower values for POCP of fiberglass and EP of EPS are identified when calculated on volume basis due to their extremely low density.

### Mining, Expansion and Transportation

The global perlite industry actively mines a total of less than 8 square km (3 sq miles) annually, as noted in a relevant Perlite Institute brochure. Perlite mining and processing takes place close to the surface with minor quantities of overburden and waste produced. According to the 2021 USGS report, annual worldwide perlite extraction is approximately 3.1 mil. metric tons and known reserves are estimated to be in excess of 350 mil. metric tons; annuals. Other building products such as thermal insulating plastors, acoustic materials, and lightweight concrete are used for landscape applications.

![Perlite Ore](image1.png)

**Figure 6:** Dense perlite ore is delivered to local processors where it is expanded (typically) to 12 times its original volume.

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almost every country worldwide. Local distribution of expanded perlite is viable and LEED compliant when the distance from the manufacturing plant is less than 500 Km (310 miles). Transportation is carried out via road, rail, and ocean-going vessels.

**Selected Applications**

**PERLITE LOOSE-FILL WALL INSULATION**
Expanded perlite offers very favorable environmental attributes combined with optimum thermal performance. Low U-values (thermal transmittance values), offer easy pathways to compliance with increasingly stringent building performance requirements. The U-values achieved are maintained over the lifecycle of the building. Construction grade perlite easily lasts for the typical lifetime of a building (usually 50 years) and will continue to offer the same U-value for many years beyond, which is not the case for petroleum-based insulators which experience degradation over time and a decrease of their U-value. Additionally, and in contrast to perlite which is non-combustible, they are a high fire hazard threat. Optionally, expanded perlite may be coated to render it hydrophobic and reduce the moisture absorption which burdens its insulating performance.

**PERLITE LIGHTWEIGHT INSULATING CONCRETE**
Perlite lightweight insulating concrete consists of a mix of construction grade expanded perlite aggregate, cement and optionally sand. Perlite lightweight insulating concrete reduces building dead loads; hence structural requirements (beams, columns). It further displaces the total volume of concrete (a known contributor to greenhouse gas emissions), as well as reinforcement, which further saves on natural resources. Perlite lightweight insulating concrete is the most widely available thermal insulating concrete with a very low thermal conductivity value of \( k = 0.07 - 0.08 \) W/mK (0.04 - 0.046 BTU/hr-ft.°F). Perlite lightweight insulating concrete roofing offers higher thermal insulation performance coupled with the durability and strength of concrete.
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OTHER BUILDING PRODUCTS
Construction perlite is used by numerous building material manufacturers to produce sustainable products, such as thermal insulating plastors, acoustic products, fire-resistant plastors, lightweight construction products (mortar, glue, paint, adhesive, etc.).

PERLITE FOR BUILDING LANDSCAPE APPLICATIONS
Fine grade perlite is used for landscape applications as an inorganic, pH neutral, fully natural water-retaining soil additive to reduce overall irrigation demand by 50% in sandy soils, as proven in a Perlite Institute study. This reduces the demand for irrigation water and encourages larger beautification areas.

Coarse grade perlite is used as a lightweight soil conditioner to reduce dead load on building planters or roof gardens. This allows for bigger, deeper and greener podiums and raised bed landscaping. Due to its grain size coarse perlite improves the soil structure, adding more “loft” and “texture” to keep the soil well aerated and loose.

Summary
- Construction perlite sustainability improves the technical properties of a structure: perlite is a sustainable mineral for use in building insulation systems and products, with minimal Global Warming Potential, as well as embodied energy and embodied carbon factors calculated on a volume basis.
- Perlite presents a considerably low environmental footprint and minimum Ozone Depletion, Photochemical Ozone Depletion, Eutrophication Potential, and Acidification Potential in comparison to other competing organic and inorganic building insulation materials.
- Perlite offers thermal insulation and stable U-value performance that lasts for the entire design life of the building.
- Perlite lightweight concrete is ultra-lightweight, which allows for the reduction of structural building elements during the design/construction phase.
- Perlite is non-combustible and fire-resistant.
- Perlite products do not pose health risks commonly associated with other construction products (i.e. silicosis and VOCs).
- There are reduced transportation emissions because perlite is either locally or regionally available.
- There are significantly fewer natural resources consumed per volume of finished product.

BIBLIOGRAPHY