NANO-INSULATING vs LEED

Monday 02 January 2023 Issue | 01

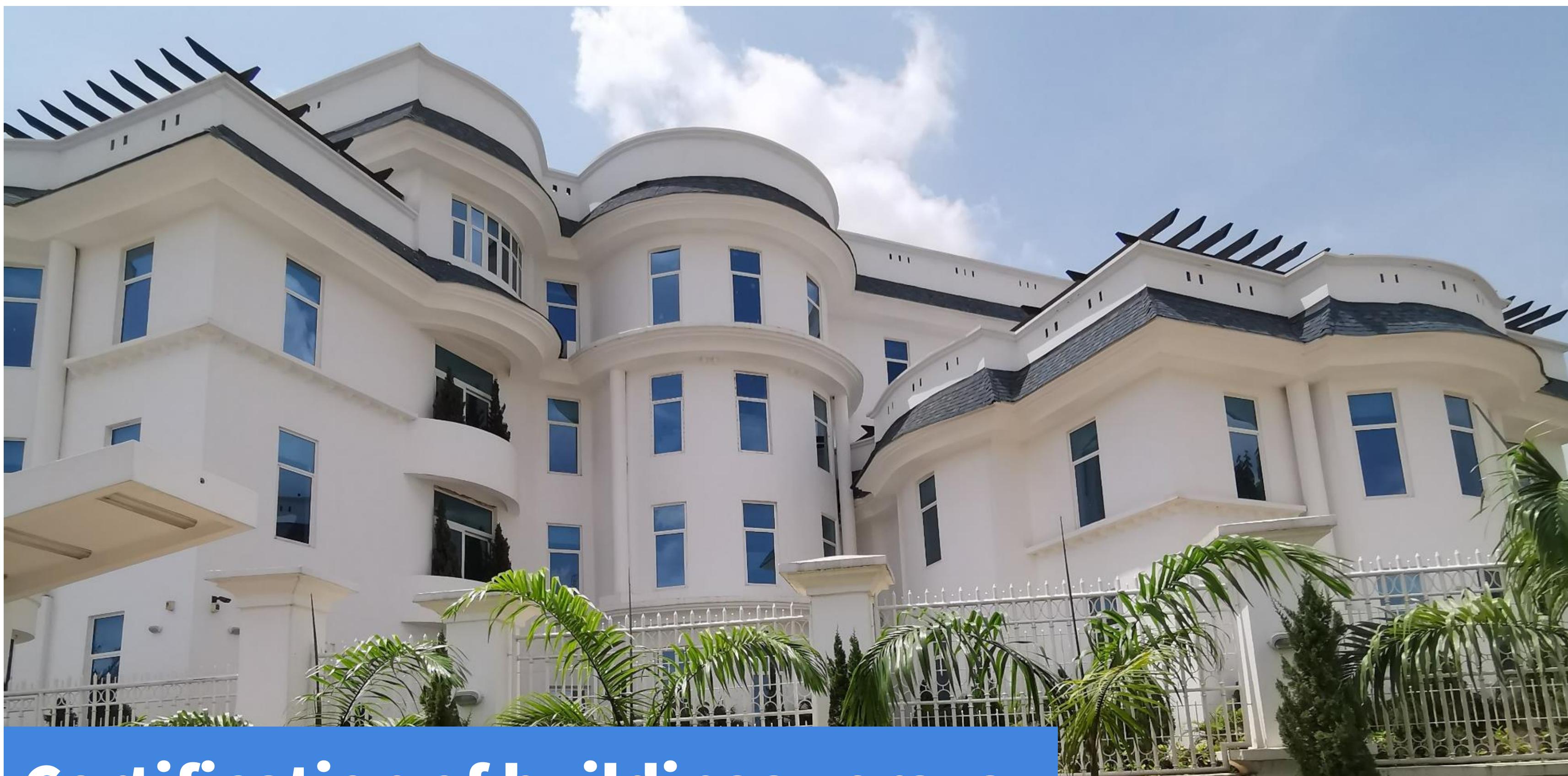

Foto: Rafael Jaworski, Nigeria, Abudża, 2019.

Certification of buildings versus energy efficiency in nanothermal insulation

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Worldwide energy consumption has increased significantly over the last few years. It is caused, among others, by population growth and rapid technological development. The development of civilization introduces many innovations, but it also raises the standard of living faster and faster, increases the comfort of using material goods. A new house, apartment, comfortable study conditions or ideal working conditions in a new building increase the demand for energy. By increasing our standard of living, as well as that of other real estate users, we consume more and more energy, interfering with the climate and environmental protection. Heating in winter, cooling in summer increases CO2 emissions, negatively affecting the climate; poorly selected insulating materials affect energy losses but also have a negative impact on the environment and our health. A large amount of energy is wasted during cooling and heating in buildings. However, with the help of thermal heating management, you can minimize costs, heat consumption and create a thermal insulation management system for buildings. This concept is implemented through various methods. Based on analyzes and studies, there is evidence of energy consumption before and after testing and the use of design solutions for heating management in building units.

This article is about assessing the impact of external coatings on energy consumption versus international certification standards. Coatings are considered one of the smart and effective solutions available for energy efficiency.

Various reflective technologies (also known as cool materials) were studied to monitor the heat exposure of buildings and the impact of thermal insulation materials on buildings. In recent years, cool building materials have become more and more popular due to their excellent energy efficiency. Cool materials are the right way to mitigate urban heat islands and reduce CO2 emissions and thermal discomfort in cities.[1]

The 2030 Agenda for Sustainable Development adopted by UN leaders on 25 September 2015 sets out an ambitious plan to improve the lives of people everywhere in the world. This agenda has a universal, inclusive one and indivisible, and constitutes a call to action addressed to all countries, regardless of their level of development. Like other OECD countries [2], Poland is currently looking for ways to best implement the Agenda and achieve the Sustainable Development Goals by 2030. [3]It sets the course for the social, economic and environmental transformation of the world by 2030. Cities are a key issue in this transformation: population growth and intense anthropogenic activities make them centers with a strong environmental impact. For example, cities have become Urban Heat Islands (UHI) [4]due to significant increases in temperatures caused by pollution and heat generated by human activities. The urgent need to make cities sustainable from the ecological point of view prompts the search for innovative solutions to counteract this phenomenon.[5]

Urban heat island (UHI)

One such solution is thermal insulation emulsions and reflective paints, because they absorb less heat and stay cooler than traditional materials, and are considered an effective technique to mitigate UHI. Coatings reflecting the sun's rays (thermal insulation emulsions and reflective paints) were tested. To achieve the goal, thermal insulation emulsions and reflective paints with a high solar reflectance (SR) have been incorporated into many scientific, commercial and certification projects to reduce CO2 emissions. Increasingly urbanized and industrialized cities are the heroes of strong socio-economic progress, generating many economic, social and environmental problems.

Fig. 1. Agenda for sustainable development 2030: towards successful implementation in Poland, https://apps.who.int/iris/handle/10665/345721

Co_2 emissions and reflective coatings

Foto: Shutterstock

The uncontrolled use of non-renewable resources and the release of large amounts of CO_2 into the environment causes air pollution and global warming, as well as a drastic reduction of available natural resources. The desire to consume increases, and nature and the environment are threatened with irreversible devastation, threatening their ability to sustain life on the planet.[[10]]

UN 2030 Agenda for Sustainable Development, transforming our world: 2030 Agenda for Sustainable Development (Resolution A/RES/70/1 adopted by the General Assembly on September 25, 2015 by 193 nation states) through 17 goals (SDGs - Sustainable Development) Goals) and 169 goals is a document that defines the path to "transforming our world" by 2030, following the path of sustainable development, which is balanced in three dimensions: economic, social and environmental, defined as "development that meets the needs of the present without compromising the ability to meet needs of future generations."[[11]] This is the perspective that the signatory countries of the 2030 Agenda work with: This is the perspective that the countries signatory to the 2030 Agenda work with: in particular, Goal 11 focuses on the topic of "sustainable cities and communities" with the aim of making cities and human settlements inclusive , safe and sustainable.[[7]] From an environmental perspective, today's cities do not represent a sustainable context as their continued expansion and increase in anthropogenic activities have led to the need for more infrastructure and buildings made of high absorbency (concrete and asphalt), which causes a rapid increase in temperature. Due to their characteristics, cities have become Urban Heat Islands (UHI), [8]a microclimatic anomaly where temperatures are much higher than those of the surrounding suburbs and rural areas. UHI is mainly due to urbanization: as cities grow, the natural vegetation is reduced and the highly absorbent surface area increases, making cities hotter and more unpleasant than rural areas. In addition, the demand for energy for air conditioning has increased by 13% over the last few years, contributing to rising temperatures in cities and thermal discomfort. Thus, the urgent need to make cities sustainable places and reduce their per capita environmental impact (Goal 11, Targets 11.3 and 11.6)[[9]] has spurred research into solutions to mitigate UHI.

Urban heat island (UHI)

For example, the use of vegetative covers, reflective coatings, water-retaining materials, or heat-trapping devices in urban areas are effective UHI mitigation strategies. In between such strategies, reflective surfaces have the advantage that their manufacture uses the industrial processes currently used to produce conventional building materials. Solar reflective surfaces are materials designed to maintain a high solar reflectance (SR) and high infrared emissivity (ε). SR, or albedo, is the ratio of the solar energy globally reflected from the surface to the total incident solar energy. When a surface reflects all incident radiation, its SR value is 1, and becomes 0 if the surface instead absorbs all incident radiation. Emissivity is the ability of thermal radiation to return to the atmosphere most of the absorbed solar radiation. The most common urban surfaces have an SR of 0.2, which means that they reflect only 20% of the sunlight while absorbing 80%, contributing to urban heating.[[6]] To calculate the SRI for a given material, it is necessary to obtain a reflectance value and emittance for this material. The SRI is calculated according to ASTM E 1980. This is standard practice for solar reflectance calculations for horizontal and slightly inclined opaque surfaces with an emissivity greater than 0.1.

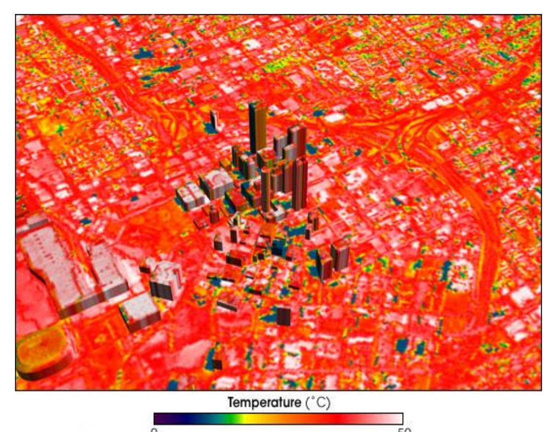

Photo: https://en.wikipedia.org/wiki/Urban_heat_island, photo of Atlanta, Georgia showing temperature distribution. The blue areas represent cold temperatures, the red areas are warm and the white areas are hot.

Energy efficiency and the reflectivity of the coatings

Foto: Canstockphoto

Most industry experts agree that reflectance has a greater impact than emissivity on a roof's energy performance in hot weather. If most of the initial solar radiation is reflected, then less is left for infrared emission. Coating products for cool roofs with a reflectance of 75 to 90% are increasingly being introduced, meaning that only 10 to 25% of the sun's energy is absorbed by the roof. According to **Lawrence Berkeley National laboratory** (www.lbl.gov), at an ambient temperature of 98 degrees, a change in the roof emissivity coefficient from 0.75 to 0.90 while maintaining a constant coefficient reflectivity lowers the surface temperature by two degrees. Conversely, increasing the roof's reflectance from 0.25 to 0.40 while keeping emissivity constant results in a 13°C reduction in surface temperature, which is a significant difference. Still, the combination of high reflectivity and high emissivity during the hot summer months results in surface temperatures sometimes 60ºC to 70°C lower than a non- reflective roof . Reducing the consumption of thermal energy means less need for air conditioning and lower energy costs.[12]

Foto: Wallpaper stock

LEED - STANDARDS AND SCORING
(Leadership in Energy and Environmental Design)

Reflectance is calculated in accordance with one of three ASTM standards - ASTM E 903, ASTM E 1918 or ASTM C 1549. Emittance is calculated in accordance with ASTM E 408 or ASTM C 1371. The Environmental Protection Agency's Energy Star Thermal Insulating, Reflective Coatings Programme (www.energystar.gov) includes measurement methods, tests.[13]

Seal and Insulate with ENERGY STAR
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The role of thermal insulation and reflective coatings (RRC) in the LEED certification process

We focused on acrylic roof and façade coatings. Other chemicals include polyurethane, silicone, lead, asbestos, fluoropolymer and ethylbutylene styrene, which are harmful to health and the environment. These materials have a valuable role to play not only in the 2030 Agenda for Sustainable Development[ ] but are also recognised in LEED[ ] rating systems for several reasons. The most important of these are their ability to reduce the urban heat island effect, their contribution to energy conservation with accompanying carbon reduction benefits, and their ability to extend the life of roof systems and existing buildings in general. Reflective coatings have both a direct and indirect role to play in the LEED certification process. Before, as well as during, LEED certification, it is important to raise awareness of how '[...] building materials can contribute to certain credits commonly associated directly with construction and renovation work, as well as the important role they play in optimising energy efficiency, reducing the construction waste stream and contributing to an effective daylighting strategy, among others. among others, in order to fully understand the role of RRCs (reflective roof coatings) in LEED and whether they contribute directly or indirectly to the achievement of prerequisites or credits, we must first address the building type and LEED assessment. In addition, it must be determined whether the project can be classified as new or existing construction, or a combination of both. LEED uses the "40/60 Rule" to provide decision-making guidance when several rating systems appear to be appropriate for a project. This is important when considering which credits are directly attributable to the use of reflective coatings and which are indirectly attributable, as opportunities vary by rating system. To apply this principle, the LEED team must "assign" a rating system to each square foot of the building based on the guidelines in this document. The correct grading system depends on the percentages obtained. The entire gross area of a LEED project must be certified under one rating system. It is subject to all preconditions and scoring attempts under this rating system, regardless of the type of mixed construction or space use."[14] The purpose of the credit is to minimize impacts on the microclimate and habitats of humans and wildlife. The conditions for obtaining this credit are based on the use of roof surfaces with a sufficiently high solar reflectance index (SRI) on at least 75% of the roof area.

LEED (Leadership in Energy and Environmental Design) is an American rating system construction created by the USGBC (US Green Building Council). During the LEED v4.1 certification process, all elements of sustainable construction are taken into account, including [15]:

- It ensures that all building stakeholders – developer, property manager, tenant and community benefit from sustainable design, construction, operation and performance.
- It supports projects to implement sustainable and healthy building practices to achieve environmental, economic, social and societal benefits for decades to come.
- It emphasizes integrative design to ensure better design, translate design into high-quality construction, optimize operations, and build high performance.
- It helps buildings deliver higher quality beyond market practice by incorporating innovative design, technology, construction and material selection strategies.
- It focuses on both sustainable strategies and results-oriented outcomes.
- It helps buildings use fewer resources, lower operating costs, add value and create a safer and healthier environment for their occupants.
- Helps buildings reduce greenhouse gas/carbon emissions.
- It helps buildings use toxin-free materials to deliver cleaner indoor air, improving occupant productivity, focus and reducing respiratory illness.
- It prioritizes sustainable materials by helping manufacturers design, manufacture and supply building materials that reduce the environmental impact of a building. LEED v4.1 also helps manufacturers reduce energy consumption, water consumption, waste during production, carbon footprint during distribution and transportation, and overall carbon footprint throughout the production lifecycle.[16]

Figure 2. LEED credit categories, https://www.igbc.ie/certification/leed/

LEED certification
LEED v4 scoring

These categories are divided into scores for which the project can obtain a given number of points. Credits can be divided into those whose fulfillment is necessary to obtain a certificate and those whose choice is voluntary. After the certification process, the project receives LEED certification at one of four levels depending on the number of points obtained:[[17]]

- Certified
- Silver
- Gold
- Platinum

LEED certification can be applied to existing, newly built and renovated buildings. LEED v4 is divided into several systems depending on the type of certified facility. Among other things, it is certified office, industrial, commercial, hotel and school spaces, common areas.[[18]] Certificates in most schemes are one-time and indefinite, the exception is EB O+M for buildings existing and functioning for at least a few months, which must be renewed min. every five years. An optional pre-certification can be used for each scheme (based on an advanced design) - thanks to this, the image potential of certification can be used at a very early stage.[[19]]

PRODUCT CONFORMITY

According to the definition and guidelines of the LEED credit interpretation (CIR) procedure, only 75% of the roof surface must have an emissivity of 0.90; the remaining 25% can be covered with anything. There are many regulations on the interpretation of LEED Credit , which allow lower emissivity or solar reflectance - but neither - when 100% of the roof surface is covered with a single material. This means that any pre-painted metal covering 100% of the roof that meets the Energy Star solar reflectance specification and has a thermal emissivity of 0.70 or higher meets or exceeds the LEED 7.2 credit criteria. [20]This Credit Interpretation Request (CIR) information can be critical when planning a LEED compliant building.

How do coating and roofing manufacturers achieve
LEED compliance? It should be clarified that the US Green Building The Council does not certify products, only buildings in the LEED program. However, products and their manufacturers may meet standards to be labeled Energy Star or LEED compliant. For example, a product may validate claims that it can contribute to LEED credits in a particular category.

COLORS AND ENERGY EFFICIENCY

According to the EnergyStar programme (www.energystar.gov), tests have shown that during a day with an ambient temperature of 32°C, the surface temperature of a white roof is only 43°C, while that of a black roof is 87°C. However, building material manufacturers are creating further innovations so that they are not limited to white, despite the energy savings. Accordingly, roofing manufacturers are developing cool roof coatings that increase thermal reflectance and reduce emissivity without sacrificing colour choice. Studies show that most cool coatings currently available have too many problems in meeting reflectance standards for LEED and Energy Star programmes.[[21]]

Some manufacturers would not be able to meet the emissivity requirements if the entire roof area required it when scoring LEED standards.

A cool roof is made of a material or has a coating that can lower the temperature of the roof surface, reducing the amount of heat transferred to the building. Traditional roofs absorb sunlight during the day, warming the building and the surrounding air. Roofs that are lighter in color or reflective stay cooler than roofs that absorb sunlight. The same basic principles apply to cool walls as to cool roofs.[[22]]

In the case of Energy Star and LEED, a specialist laboratory can determine the coefficients required by the program. Therefore, both third-party and manufacturer laboratories can be used to provide EPA data.

However, European law requires test reports from EU-accredited laboratories, similarly to Cool Roof Rating Council (CRRC), a non-profit independent trade association.[[23]] The testing laboratory must be listed as an independent, accredited company to perform reflectance
and emissivity tests.

Rys. 3. Refleksyjność powłok. Opracowanie własne.

Fig. 4. Coating reflectivity. Own study.

INCREASED ENERGY DEMAND versus cool reflective coatings

The role of thermal insulation and reflective coatings (RRC) in the LEED certification process cont.

Another interesting source states that "… electricity demand for cooling increases by 1.5–2.0% for every 0.6°C increase in air temperature, starting from 20 to 25°C. This suggests that 5–10% of a community's electricity needs are used to compensate for the heat island effect. Urban heat islands increase the overall demand for electricity, such as urban heat islands increase the overall demand for electricity as well as the peak demand that usually occurs on hot summer afternoons in temperate microclimates and for most of the year in more tropical zones. During extreme heat, which is exacerbated by urban heat zones, the resulting cooling demand can overload energy supply systems. In the worst case, this can cause the utility to initiate controlled phased power outages or blackouts to avoid power outages. Electricity companies typically rely on fossil fuel power plants to meet peak demand, which in turn leads to increased air pollution and greenhouse gas emissions. The main pollutants from power plants include sulfur dioxide (SO2), nitrous oxide (PM) particulate matter, carbon monoxide (CO) and mercury (Hg).

These pollutants are harmful to human health and contribute to complex air quality problems such as ground-level ozone formation, fine particulate matter and acid rain. The increased use of fossil fuel power plants also increases emissions of greenhouse gases such as carbon dioxide (CO2), which contribute to global climate change. To earn LEED credits, a minimum SRI of 78 on roof slopes equal to or less than 2:12 (16.6%) and an SRI of 29 on slopes greater than 2:12 are required to meet this credit requirement. All acrylic roof coatings meet these criteria, including all undyed and tinted coatings. Again, assessments must cover a minimum of 75% of the roof area. Other incompatible materials can be used for the remaining 25%. Achieving this credit is largely a matter of documenting the physical surface of the roof and the properties of the RRC surface material. There are no additional energy calculation requirements for this Credit. The role of RRC in energy conscious architecture is well documented and directly contributes to the achievement of Energy and Atmosphere EAC 2: Minimum Energy Performance and Energy and Atmosphere 1: Energy Performance Optimization. Brightly colored roofing is commonly used in hot, sunny climates, especially in buildings with predominant internal loads, where cooling and dehumidification are the main space conditioning loads. Roofs experience significant solar heat gains depending on their pitch and resulting direct exposure to the sun. Typical flat roof surface materials such as modified bitumen, tar and gravel, with an albedo of 0.10 to 0.20, can absorb more than 70 percent of the solar radiation that directly hits them and can reach temperatures as high as 77°C up to 93°C. This increases the cooling load on the building and shortens the life of the roof.

Brightly colored RRC roofs can reflect a significant percentage of incident solar energy. The measure of reflection and absorption is albedo (photometric parameter determining the ability to reflect rays by a given surface). The higher the surface albedo, the less energy it absorbs and the cooler it stays. High-performance reflective coating systems contain significant amounts of UV-blocking ingredients that reduce the impact of incident radiation on the roof surface. This ensures a corresponding reduction in cooling demand. A cool-coat roof does not experience as much daily temperature variation, so it helps reduce the tendency to trigger peak charges. Because the roof is subject to less thermal fatigue, reflective roof coatings are usually marketed as maintenance products as they extend the life of the roof. When a dark single-layer roof is covered with a white reflective coating, the albedo can increase from 0.2 to 0.65-0.85, and the surface temperature will remain below 55 degrees Celsius in sunny weather. With a lightly insulated roof in cold climates **, heat reflective coatings can save more than 40 percent of the building's cooling energy and have a lifespan of 10–15 years.** The life of the roof will be extended due to lowered temperatures. Numerous studies confirm that RRC can lower surface temperatures by 10-40 degrees Celsius and save significant amounts of cooling energy during the summer months. Roof coverings that increase the albedo coefficient by 40 to 60 percentage points can **significantly reduce cooling energy consumption by 25-70%** , regardless of the amount of roof insulation used. Savings vary depending on building type and roof area to floor area ratio.

The purpose of Energy and Atmosphere EAC 2: Minimum energy performance is to establish a minimum level of energy efficiency for the proposed building and systems in order to reduce the environmental and economic impacts associated with excessive energy consumption. The primary standard is ANSI/ASHRAE/IESNA 90.1, 2007."[[24]] In the commissioning of entire buildings, there is a tendency to take a very comprehensive view of the performance of the building envelope. This includes the use of thermal imaging and moisture migration and infiltration testing.

Reflective and thermal insulation coatings

Reflective and thermally insulating coatings are an energy-saving material with a high sunlight reflectance factor. In contrast, thermal insulation coatings also have extremely low thermal conductivity for buildings. Research is often carried out on the dynamic thermal performance and energy efficiency of reflective and thermal insulation coatings. A simplified model of the thermal resistance and heat capacity of the exterior wall of a building has been developed to predict thermal performance. Dynamic temperature and heat flow through the wall are predicted to reduce heat loss through the inner wall surface compared to a conventional coating. The effect of thermal conductivity and solar reflectance of the coating minimizes heat loss through the wall. Studies show that a thermal insulation coating is more effective at adapting to outdoor climate change than a reflective coating. Compared to cement, it reduces the maximum temperature of the outer wall surface by at least 7.45°C, and the heat loss through the inner wall surface by at least 38%.

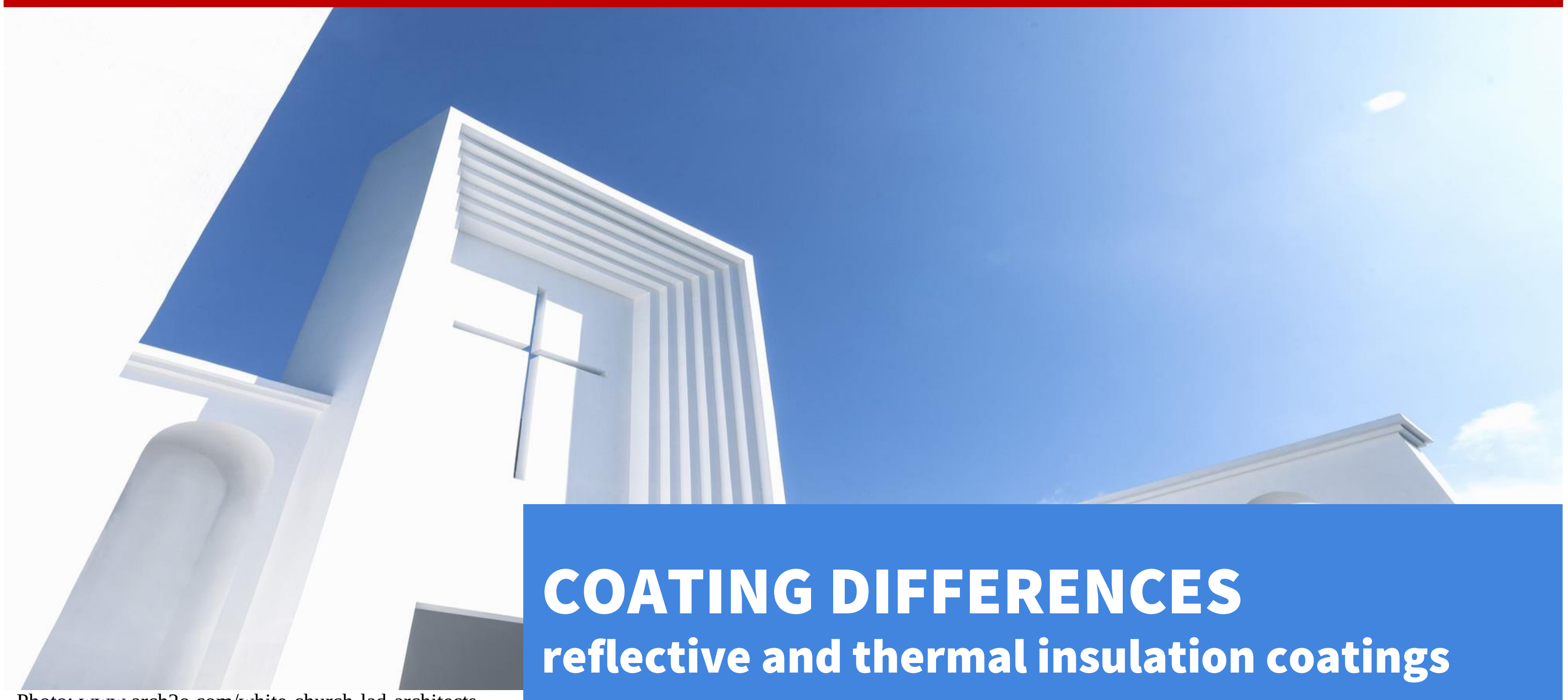


Photo: www.arch2o.com/white-church-lad-architects

COATING DIFFERENCES

reflective and thermal insulation coatings

Reflective and thermal insulation coatings

Heat loss decreases as sunlight reflectance increases and thermal conductivity decreases. The results can provide a useful reference and guidance for the use of reflective and thermal insulation coatings on the exterior walls of buildings to promote their energy-efficient use on the building envelope.[[25]] According to the theory of heat transfer, solar radiation is transferred to the object mainly in the form of heat, so when the surface of the object absorbs sunlight, heat can transfer from the surface to the interior of the object. As a result, the temperature of the object increases accordingly. But if an object can be covered with heat insulating coatings on its surface, most of the extra heat from sunlight can be insulated before it transfers to the surface of the object.[[26]]

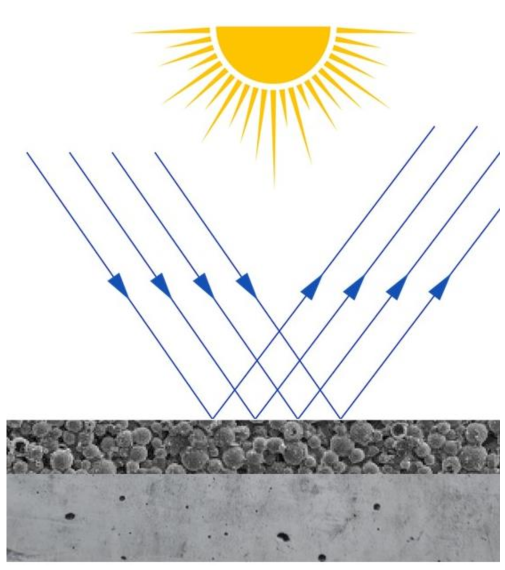


Figure 5. Schematic diagram of the thermo-reflective insulation mechanism .

Heat transfer is usually a combination of heat conduction, heat convection and heat radiation. On their basis, three different modes of thermal insulation are distinguished: obstructive, reflective and radiative. Therefore, together with the appropriate fillers, thermal insulation coatings can be divided into four different types: barrier, reflective, radiation and composite thermal insulation coatings.[[27]]

Reflective coatings

Reflective paints reflect the sun's energy instead of absorbing or resisting it. Normally, we can use the Total Solar Reflectance (TSR) to evaluate the reflectance of a material. TSR is the ratio of solar energy reflected from a specific surface of a material, usually expressed as a percentage. Theoretically, any material can more or less reflect solar energy. Since the wavelength of solar radiation energy is mainly concentrated in the 200–2500 nm range , specifically about 50% is in the visible spectrum (400 to 720 nm) and 43% in the near infrared spectrum (400 to 720 nm). 720 to 2500 nm). Because higher reflectivity means better thermal insulation in the elbow in the 400–2500 nm range , the first rule of thumb for choosing reflective coatings is that the material should have a high reflectivity in the visible and near infrared spectrum. Studies show that these fillers can improve the thermal insulation properties of coatings , of course, compared to traditional thermal insulation materials.[[28], [29]] On this basis, white is the best infrared reflecting color because white fillers can reflect almost the entire spectrum in the visible bands. The influence of different colors on the internal temperature of a building has been studied not only theoretically, but also experimentally[[30], [31], [32], [33]] ; [34]a test in various conditions confirmed that white coatings show better thermal insulation than coatings in other colors, especially black. Due to their high reflectivity, the coatings can reflect sunlight directly back into the atmosphere, instead of first absorbing and emitting the emission as a thermally conductive coating[[35]]. It is worth noting that reducing the surface roughness of the coating is also conducive to improving the heat reflectivity of the coating . As a result, reflective thermal insulation coatings have already been researched and widely used . For example, covered with a heat-reflective coating reflective on the exterior walls of a building in Hangzhou, China, a typical hot summer and cold winter zone, the surface temperature of the wall can be reduced to 10°C. By calculating, it was found that the annual air conditioning electricity savings with heat-reflective insulation coating on external walls is about 5.8 kWh/(m2 months), which indicated that the energy-saving effect of the thermal insulation coating is obvious[[36]]. It is the most widely used reflective coating used in improving the energy efficiency of buildings.

Thermal insulation coatings

Since heat transfer through an object is a combination of heat conduction, convection and radiation, an ideal thermal insulation coating can resist heat transfer, reflect and actively radiate solar energy. Although the above-mentioned reflective coatings have their advantages in thermal insulation, the thermal insulation performance by only one mechanism cannot meet the need for comprehensive thermal insulation; so against this background, smart thermal insulation nanocoatings aim to achieve synergistic thermal insulation with obstacles, glare and radiation[[37], [38], [39]]. The data shows that thermal insulation can effectively counteract heat transfer, reflect most of the sun's energy, and can actively cool the substrate by radiating the absorbed energy. The multi -thermal insulation system with fillers, reflective and radiation compatible with the acrylic substrate, shows better thermal insulation than the one with a reflective coating[[40], [41], [42]]. Thus, intelligent thermal insulation coatings have now become the main direction of research on these coatings. Covering with a thermal insulation coating is one of the most effective methods of energy saving. As discussed above, the thermal insulation performance of coatings is mainly affected functional fillers, but the suitability of coatings is mainly influenced by the substrate. So when a coating is designed for a specific application, both thermal insulation properties and comprehensive protective, decorative and other special needs (anti-corrosion, waterproofing, fire retardant, anti-fouling, anti-fungal, etc.) must be considered at the same time.[[43]] In this situation, multi-functional coatings with thermal insulation and other special functions can meet the market demand more. Take, for example, the energy saving of a building, to achieve the overall effects of thermal insulation, a variety of thermal insulation coatings have been produced for the exterior and interior walls of buildings. Based on the practical application, the development trend is multifunctional coatings with thermal insulation and other special functions for thermal insulation coatings. Since thermal conductivity due to molecular vibration and convection will completely disappear in a vacuum, the thermal insulation properties of the coating will be excellent if the coating can form a vacuum or a vacuum-like structure. In the 1970s, experts in the United States obtained a high-quality thermal insulation coating with airgel as a filler;

Aerogels and energy efficiency

The airgel was prepared by filling spherical hollow ceramic microbubbles with an inert latex (water) binder using NASA spacecraft insulation materials technology. The airgel then creates a vacuum layer in the shell that can not only block but also effectively reflect solar energy. Tests have shown that it is enough to apply a thin layer of coating to the surface of buildings, so that the temperature in the room increases in winter and decreases in summer[[44]]. In addition, the data shows that the coating can achieve thermal insulation of up to 95% and, as a result, reduce energy consumption by up to 30-60% when applied to buildings. This means that vacuum thermal insulation coatings are excellent in terms of both thermal insulation and versatile performance due to their special structure[[45], [46]]. And it is considered one of the most efficient energy-saving materials with a promising future. As mentioned above, vacuum airgel exhibits ideal thermal insulation properties when used as a filler. But in many situations it is not easy to achieve a complete vacuum state. In this situation, the scientists tried to use the airgel itself as a filler.

Airgel basically consists of ultrafine particles and a gaseous dispersion medium. Normally, the particles are filled in the pores of the lattice structure of the medium. It was found that when the pores in the network are smaller than 50 nm , the airgel can show a very good thermal insulation effect. In fact, the ideal value of thermal conductivity of fillers can even approach zero. Thus, it is completely possible to obtain a coating with a lower thermal conductivity than static air (0.023 $W\ m^{-1}\ K^{-1}$) with fillers with a nanoporous structure [[47]], which is of great importance for the thermal insulation properties of the coating. Thus, fillers with a nanoporous structure gave unprecedented possibilities and opportunities for the development of thermal insulation coatings. Aerogels are low-density solid materials with a nanoporous network structure. The aperture of airgel is about 2–50 nm , and the hole rate is high up to 99.8%, and the thermal conductivity value of airgel is 0.008–0.018 $W\ m^{-1}\ K^{-1}$ at room temperature, which is much less than 0.023 $W\ m^{-1}\ K^{-1}$. Thus, airgel is considered one of the materials with the lowest thermal conductivity in the field of thermal insulation. Thermal insulation properties were also prepared and tested airgel composites . For example, an airgel composed of ceramic fibers was studied. As discussed, airgel itself has a very low thermal conductivity value for both gas and solid due to its special structure; meanwhile, ceramic fibers can significantly reduce the value of radioactive thermal conductivity of the composite. Thanks to this, airgel composites show excellent thermal insulation properties.[[48]] The interest in thermal insulation coatings is becoming more and more popular in the world, due to their multifunctional properties and application possibilities. Heat-insulating coating based on aerogels and fillers is a material usually with the consistency of a thick emulsion, which is applied to various surfaces depending on its properties: concrete, ceramics, metal, wood and even plasterboard in order to improve the energy efficiency of buildings and protect the surface against UV. One of the very interesting thermal insulation products is SFEROLIT® produced in Poland. Its physico-chemical properties stand out among the competition and it can certainly be said that it can compete with the best products in the world.

SFEROLIT® - NANO THERMAL INSULATION

Liquid ceramic coating with thermal insulation properties and waterproofing properties. Micro-ceramic ceramic and glass beads form the filler, integrated into a blend of acrylic copolymers. It is used as a lightweight, anti-fungal, anti-corrosive, heat-insulating coating for internal and external surfaces of buildings, heating systems, window and door frames, walls, ceilings and door reveals, walls, ceilings and roofs. The insulating propertiesof this material are based on the ability of the vacuum to maintain the set temperature, limiting the penetration of cooled or heated air particles from the outside.

The basis of SFEROLIT are millions of vacuum empty particles which, after application and drying, form a tight membrane. Particle diameter from 20 to 120 microns. As a result of polymerization, liquid thermal insulation becomes a durable and lightweight cover, reducing heat loss by up to 70%, impervious to water, while allowing the surface to breathe freely. Vapor permeability , thanks to which intensive air exchange takes place and protects against the development of fungi, mold, corrosion and other negative effects of the environment. SFEROLIT® emulsion is tested in accredited laboratories, according to ISO and ASTM standards, and its physical and technical parameters exceed the normative requirements regarding: thermal conductivity, SRI, TSR, emissivity

and resistance to weather conditions.

SFEROLIT®
nanoThermal insulation vs LEED v4

While the information below is part of US accreditation systems, it represents SFEROLIT®'s high international standards and recognition in leading environmental and energy efficient certifications. Construction Council Ecological USA - LEED PROGRAM (Leadership in Environmental and Energy Design). Green building rating system. Points offered for the use of SFEROLIT® technology in each of the following categories: LEED v4.1 standard - all elements of sustainable construction are taken into account, including [49] **what are the benefits of using SFEROLIT® technology and to what extent does it comply with the standard LEED?**

- SFEROLIT® exceeds the test requirements of ASTM E903 reflectance and ASTMC 1371 emittance. The SRI (sunlight reflectance index) required a minimum percentage of 0.75 (SFEROLIT® - 0.98, which far exceeds LEED standards). SFEROLIT®: TSR 89.43%, Emissivity 0.98, SRI 114.
- SFEROLIT® thermal conductivity coefficient λ 0.0012 W/ mK improves resistance parameters for various building partitions.
- Adhesion ensuring strong, durable and long-term adhesion min. for concrete, stone, ceramics, metals, plasterboard and wood.
- Ecological product - does not contain ingredients harmful to health. Environmentally friendly.
- Light, does not burden the building structure, increases the volume of the building, replacing traditional thick thermal insulation inside the building.
- It increases the comfort of using the property, because it absorbs noise and vibrations, the coating is nice and warm to the touch.
- Increases the life cycle of buildings by at least 10-15 years.
- It increases the energy efficiency of the building up to 40%, eliminates 100% of thermal bridges, helps buildings reduce greenhouse gas/carbon emissions.
- Product innovation.
  SFEROLIT® during production is low-emission, harmless to the environment, animals, insects and does not significantly affect climate change. It also helps during production to reduce energy consumption, water consumption, waste volume, carbon footprint during distribution and transportation, and overall carbon footprint throughout the production lifecycle.
- SFEROLIT® waste is degradable , harmless to health, environment and climate.

TSR and SRI coefficient designations

According to the test report No. GL.4130.64.2021 of December 1, 2021, carried out at the Łukasiewicz Research Network - Institute of Engineering of Polymer Materials and Dyes, it shows that SFEROLIT® significantly exceeds LEED standards, being in line with the certification of buildings and meeting high international standards.

TSR is determined in accordance with ISO 22969-2019-7. The spectral characteristics of the coatings were determined in the solar radiation range of 300-2500 nm using a double-beam UV/VIS/NIR V-670 spectrophotometer with an integrating sphere, Jasco . Total Solar Radiation Ratio (TSR) was calculated on the basis of ASTM E903 using the developed calculation program. The given result is the average of 3 measurements.

The emissivity coefficient was determined using a FLIR thermal imaging camera with the E60 symbol, based on own methodology. The given result is the average of 3 measurements. SRI calculated from ASTM E1980-11(2019) Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque surfaces .

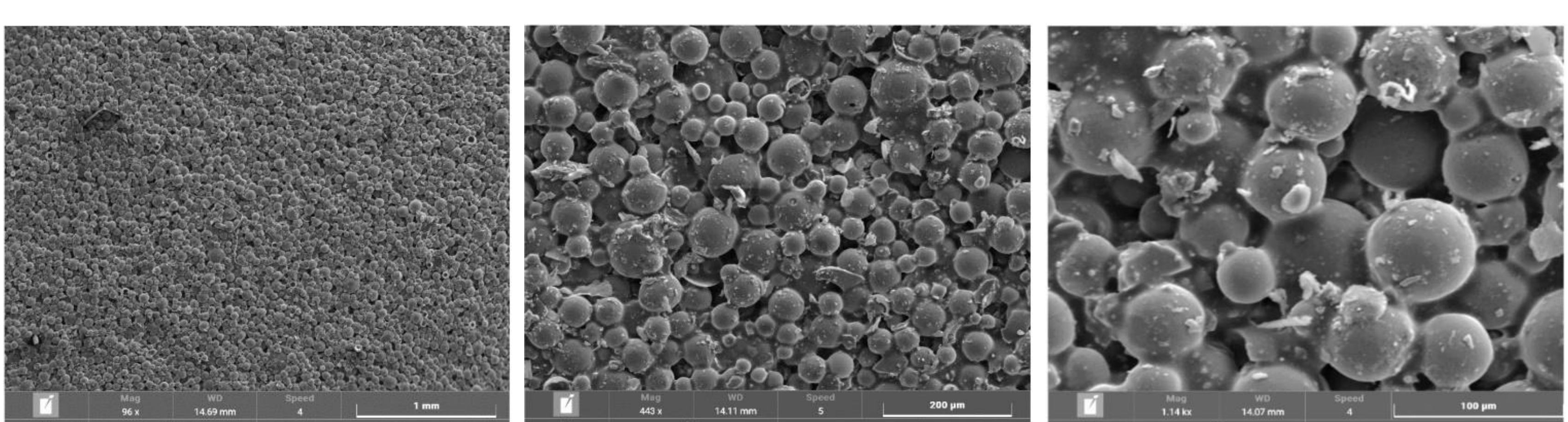
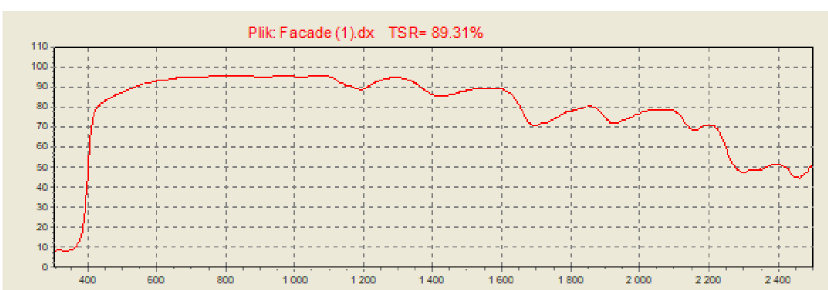


Fig. 6. The surface of the SFEROLIT® coating applied to a black sheet and magnified 96, 443 and 1140 times.

The tests were carried out by scanning electron microscopy using the TESCAN VEGA 4 microscope (Fig. 1). The tests consisted in the impact of a scanning, focused and concentrated electron beam of a specific energy on the analyzed area of the surface of the test sample. The electron beam penetrated the surface layer of the material, inducing in it various signals coming from the tested layer. The excited signal of secondary electrons (SE) allowed the topography of the observed surface to be imaged.

SFEROLIT® - Thermal insulation properties and use in construction



The results of the TSR and emissivity determinations are the average values from the 3 measurements. Results of **TSR = 89.43%, emissivity = 0.98 and SRI= 114**

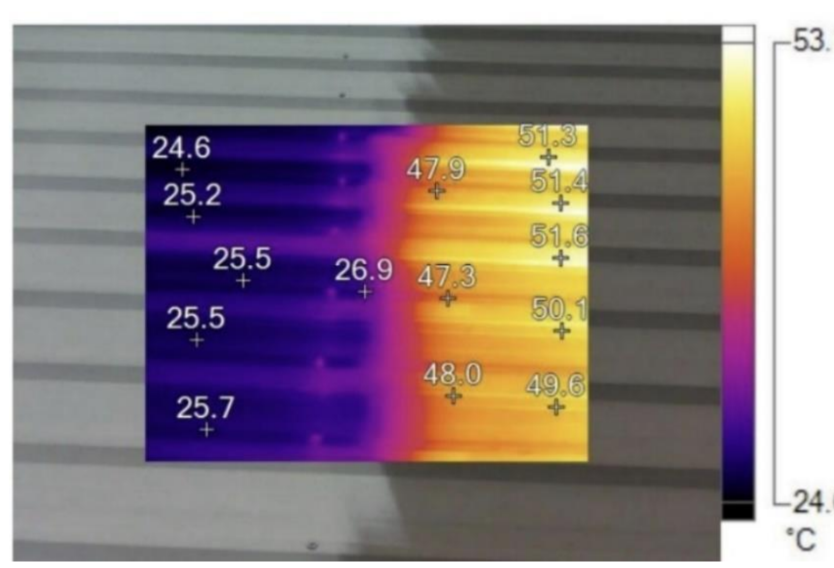
Fig. 7. Solar radiation spectrum for the SFEROLIT® APM Facade coating

SFREROLIT® - is not only a nano -coating with excellent thermal insulation properties, but also has multi -properties as a protection of the building surface:

- Dew point - eliminates the effects of condensation in partitions and on the surface of walls, ceilings and roofs;
- Operates at operating temperatures from -60°C to +120°C;
- The thermal conductivity is λc 0.0012 W/ mK ;
- metal elements of the building structure protect against water and corrosion;
- Increases energy efficiency, reduces energy consumption costs;
- Application on the external surfaces of the building and inside on the surfaces, including escape routes due to its flammability class Bs1d0;
- High adhesion ensures durable and safe operation of coatings on various surfaces: concrete, ceramics, silk , stone, steel, aluminum, wood, plasterboards;
- It is vapor permeable, which ensures the safety of partitions in terms of moisture;
- The composition of the emulsion is ecological, ensuring the safety of health and the natural environment;
- The emulsion is water-based - safe, ecological, not subject to ADR during storage and transport;
- Protects against mold and fungus;
- Protects against damage caused by weather conditions;
- Significantly absorbs noise and vibration;
- The emulsion is flexible and durable during operation
- Eliminates microcracks on wall and ceiling surfaces;


- During application, it does not harm health and only basic health and safety regulations are required;
- A negligible amount of waste when removing thermal insulation, because the coating is only a few mm;
- Waste is degradable and does not harm the environment or health;
- SFEROLIT® production is low-emission and does not harm insects.

SFEROLIT® emulsion can be applied manually (brush, roller, trowel) and mechanically (spray). However, a thick emulsion, depending on the method, leaves behind different textures. On the other hand, efficient and even guarantees spray painting. **SFEROLIT® thermal insulation is not a reflective paint, but a thick emulsion with excellent reflective properties and U parameters of conductivity and thermal transmittance.**



CONCLUSIONS and RECOMMENDATIONS nanothermal insulation SFEROLIT®

Foto::Own study

Reflective coatings influence the overall LEED building evaluation process and play a key role in many LEED prerequisites and credits. On the other hand, thin-layer thermal insulation nanocoatings are the future in the construction industry .

Their properties in terms of reducing energy consumption, improving the efficiency of partitions, comfort and extending the life of existing buildings are increasingly known around the world. Each of them is a basic principle of US Green Building Council , Green Building Certification Institute , Energy Star, and many others who support the high-efficiency green building movement. SFEROLIT® is such a product. In addition, the properties of the SFEROLIT® nanocoating exceed the standards set by LEED, ensuring high-quality protection of buildings. Its properties perfectly complement the deficiencies in the efficiency of buildings, and sometimes even completely replace traditional thermal insulation technologies such as mineral wool, polystyrene, PUR foams, multipor blocks or lagging of the technical infrastructure of the building. In many cases, SFEROLIT® is the only technology that can be used to improve the energy efficiency of a building. Historic properties under the care of a monument conservator are an example where traditional thermal insulation technology cannot be used because it changes the architecture, while SFEROLIT® is its opposite.

The thermal insulation emulsion does not change the architecture, and with precise painting, you can even cover stucco with complicated ornaments with small details inside and outside the building. High reflectivity protects against UV, and vapor permeability and excellent thermal transmittance parameters protect partitions against energy loss and against moisture, which significantly extends the life cycle of the building.

Advances in building energy system modeling, building forensics, commissioning, and ongoing measurement and verification of building performance will increase the demand for thin-film thermal insulation nano- coatings in green and passive high-efficiency building and LEED US Green Building projects council .[50]

The multi -properties of the thin-layer coating give a wide range of applications, ranging from residential, commercial and industrial construction, to public, sacral, historic or military facilities and special purposes, such as bunkers, tunnels or pressure towers. ATENA NANO, as a manufacturer of SFEROLIT® nanocoatings, strives to continuously improve nanocoatings , being one of the world's leading manufacturers. SFEROLIT® is not just a product, but a whole range of nano -products, from construction to the industrial, energy, petrochemical and transport sectors (all branches of transport).

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