The Graphene Council

Graphene for Concrete and Cement

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Source: First Graphene

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About Graphene

Graphene is a nanomaterial that is made from pure carbon. It is often described as a two-dimensional (2D) material because it is only a few carbon atoms thick and therefore is almost entirely surface area.

Graphene can also be considered a “family” of materials because it comes in many forms and types including graphene oxide, reduced graphene oxide, graphene sheets, graphene flakes and other versions of this amazing material.

The most common way to describe different types of graphene is to count the number of layers of carbon. Graphene can be a single layer of carbon atoms up to and including 10 atomic layers according to ISO Standard definitions.

The number of carbon layers has a significant impact on how the material will perform in a given application. Other important characteristics include the lateral size (how “wide” the particles are) and if the material has been “functionalized” by the addition of other helpful elements or molecules.

Graphene in all its forms derives unique properties from its 2D characteristics and dimensions. These 2D properties make graphene one of the strongest and most electrically and thermally conductive materials ever measured. These attributes make it an extremely interesting material to make other materials better, lighter, stronger, more durable and more recyclable.

Why is Graphene Used in Concrete and Cement?

Cement-based concrete represents the most heavily used material in the construction industry owing to its low-cost and excellent compressive strength. However, cement and concrete are responsible for as much as 8% of all CO_2 emissions globally.

Graphene as an additive offers attractive properties to address some of the issues facing cement-based concrete. For example, adding graphene in a concrete formulation can reduce the amount of cement needed by as much as almost 50%, reducing the main source of embedded CO_2.

Graphene can also contribute to the rapid setting of concrete, thus, allowing the manufacturer to remove formwork in a reduced time. The increased strength delivered by adding graphene may lead to less steel reinforcement used which will save costs and additional CO_2.

Graphene can enable the following benefits in cement and concrete:

- More rapid cure rate
- Increased load strength
- Reduced water permeation
- Reduced micro-cracking and fractures
- Requires less cement and concrete to achieve the same engineering performance, resulting in a reduction of CO_2 emissions

Graphene's attractive properties in concrete and cement:

High surface area: Graphene is capable of mechanically interlocking with calcium - silicate – hydrate crystals that are responsible for concrete's hardening properties and mechanical properties. It is able to achieve this interlocking with these crystals because of its significant surface area and its nano dimensions. During this process, the nanomaterial interacts with the crystals adding strength and accelerating the rate of cure.

The high aspect ratio of graphene also has the ability to arrest the crack propagation (by controlling the nano-sized cracks before they form micro-sized cracks) and hence greatly improve peak toughness, making them more effective than even conventional steel bar or fiber reinforcements.

Graphene's large surface area makes it very effective as catalyst. This means they can speed up the curing of cement and concrete.

Mechanical strength: Graphene has an extremely high Young modulus, which is a mechanical property that measures the stiffness of a solid material. In fact, graphene is the strongest material ever tested in this measurement with graphene five times stronger than structural steel. Because of graphene's inherent strength properties, it can increase concrete's overall durability and resistance to cracking.

On average the addition of just 0.03 per cent of graphene powder increase the strength of concrete by a conservative average of 25 per cent.

Impermeability: As the thinnest material, graphene is composed of carbon atoms linked to one another in a 2D honeycomb lattice with high electron-density in the aromatic rings, which blocks-off all molecules. This translates to a material that is impermeable against water, oxygen, and ions diffusion. In cement and concrete applications this translates to a reduction in water permeability and thereby, the corrosion of reinforcing steel. Also, the reduction in water permeability enables a reduction of freeze/thaw damage.

Flexibility: Flexural strength in concrete is quite poor. Graphene is a flexible crystal. Typically, increased strength of a material includes increased brittleness. Graphene not only has increased strength but it is also flexible with up to a 20% bend radius and elongation, something not available in other high-strength materials.

Graphene is a possible candidate as an additive to offer significant improvements with both flexural and compressive strength even with loadings of 0.05% by weight of cement.

Graphene has been shown to increase the flexural strength of ordinary Portland cement matrix by from between 41% to 59% and the compressive strength increased between 15% and 33%. Graphene achieves the same or higher compressive and flexural pounds per square inch (psi) in 7 days as Portland Cement achieves in 28 days.

Thermal Conductivity: Graphene in concrete can prevent early age thermal cracking by improving the thermal diffusivity of hydrated cement. As graphene is highly thermally conductive, when sufficient amounts of the material are added to cement paste it improves the thermal diffusivity of the cementitious composite. When 5% graphene is added for instance, the thermal diffusivity is improved by 25% at 25˚C and about 30% at 400˚C compared to pure cement paste.

Electrical Conductivity: Since graphene is electrically conductive, at high enough loadings, uniformly distributed graphene can create a continuous electrical network inside the cementitious composites. Cement composites with electrical conductivity and sensitive piezoresistivity, makes it a reliable and competent structural composite for the use of strain/damage sensing for civil infrastructure providing warning signals if the structural integrity is close to failure.

Homogeneously dispersed graphene in cementitious composites can promote electromagnetic interference (EMI) shielding, which could be used to decrease the electromagnetic emission problems on human health, enhance the privacy of building occupants or provide protection for military applications.

Affinity for Other Materials: Graphene's well-defined pores can be readily engineered to work with various forms of cement.

Applications

Source: Versarien

Pre-Cast Concrete

Various structural elements can be made and cast in a factory environment which boosts quality, volume output, extends life cycle and durability of the concrete elements, and of course increases productivity and quality of delivery by using less labor on site.

The factory conditions are also favorable for precise admixture dosing, curing time and environment, as well as controlling the hydration and setting of concrete at a constant temperature. This factory-based environment is a perfect setting for using graphene additives where all the mixing variables can be carefully controlled.

Dispersion of graphene in the cement mix is challenging if performed on the construction site at large scale if it involves complex procedures such as sonication or high-shear mixing. Therefore, pre-fabricated stable graphene dispersions that can be directly added to the cement mix, provide an industrially attractive option control systems.

Graphene's ability to prevent early age thermal cracking by improving the thermal diffusivity of hydrated cement is particularly relevant to pre-cast concrete production since the concrete blocks are baked in an autoclave at high temperature and the large size of the blocks can lead to a temperature gradient when cooling that can cause cracking. By focusing on these relatively higher priced concrete products, with graphene used not only as a reinforcing filler but also to provide property enhancements which are particular to solving an industry challenge or goal, graphene could find success in a variety of cement and concrete market segments.

Graphene has been used commercially in this application in the production of fire pits by a US-based manufacturer of pre-cast concrete products.

Marine Concrete

Graphene serves as a nucleus between the cement crystals at nano- and micro-level, which, when properly dispersed while mixing (or spray-coated as a separate thin layer), can increase the water permeability of concrete by a significant factor.

Studies have demonstrated a fourfold decrease in water absorption, thanks to the inherent hydrophobic nature of the nanomaterial, coupled with decreased porosity of the composite material. Although this market segment is more niched, most of the marine concrete is precast which creates a huge opportunity for adding graphene for floating concrete structures, such as houses, ships, pontoons etc.

Self-Consolidated Concrete

This type of concrete has an extremely high slump (a property which demonstrates how fluid the mix is) and consequently has a high workability. It can be used in areas where there is thick reinforcement required or the formwork has a very complex shape.

Surfactant-stabilized graphene dispersions are preferred for this type of concrete as the surfactant molecules can act as an “lubricant” and add to the fluidity properties. This represents a relatively small market as compared to the precast or marine ones.

Ultra-high-performance Concrete

Ultra-high-performance concretes have increasingly been gaining traction. These are frequently reinforced with steel fibers and can achieve compressive strengths approaching 250Mpa. Ultra-High-Performance Concrete (UHPC) and Ultra-High Strength Concrete (UHSC) operates at such a high-performance level that it competes with steel rather than regular concrete grades. Advantages are lower lead times compared to steel.

UHPC and UHSC are key markets for graphene. The additional cost of graphene compare to other cement additives can be more easily absorbed in these high value markets.

Graphene oxide nanosheets improve the flexural and compressive strengths of cement mortar and UHSC. In particular, the compressive strength of UHSC incorporating 0.01% (by weight of cement) of graphene oxide nanosheets, after curing for 28 days, increased by 7.82% than that of UHSC without graphene oxide.

The unit cost per compressive strength for UHSC is much higher than for normal concrete. Based on this 7.82% strength improvement, we can determine that graphene is much more commercially attractive target for graphene reinforcement.

Thermally Conductive Screeds

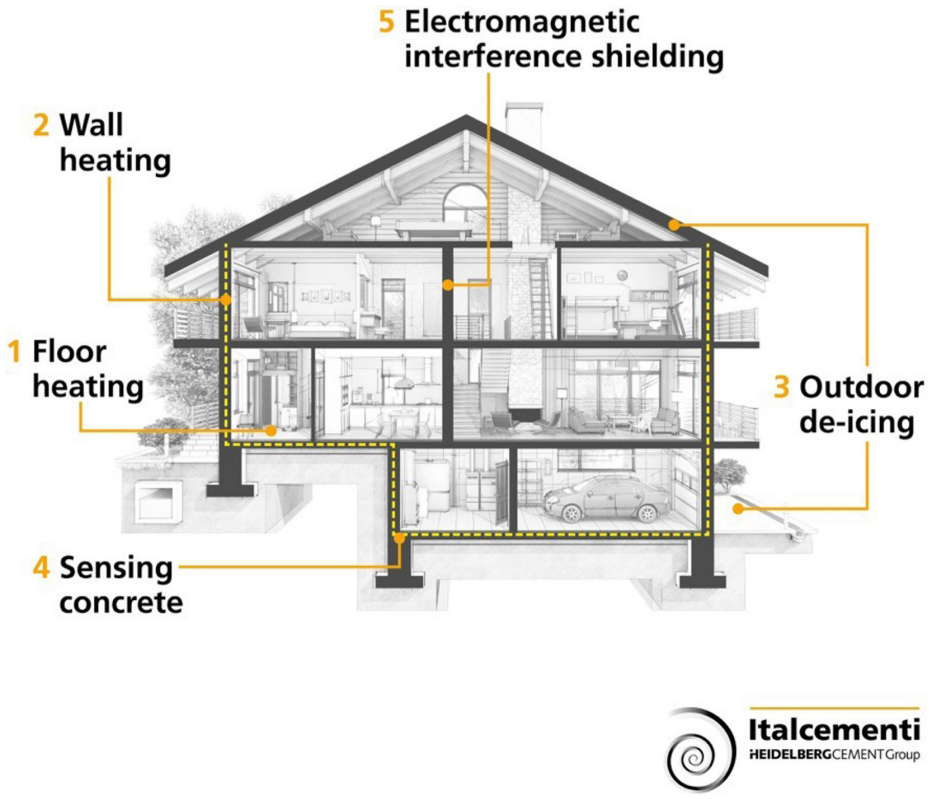
A screed is a thin, top layer of material (sand and cement, magnesite or calcium sulfate), poured on site on top of the structural concrete or insulation, on top of which other finishing materials can be applied, or the structural material can be left bare to achieve a raw effect.

A growing market in this area is what’s known as thermally conductive screeds. Graphene because of its electrical and thermal conductivity looks to be ideally suited for this application.

The applications that these graphene-enabled screeds would see use include in electricity distribution, under-floor heating, domestic geothermal well, and ice-free road-bridge-tarmac areas.

Smart Structures

Another area in which graphene will impact construction markets is in so-called “Smart Structures”. These Smart Structures leverage advanced building materials to provide multifunctional smart features such as asset management tracking, self-powering and self-sensing for structural health monitoring applications. Graphene’s electrical conductivity enables these electrical and electronic capabilities.



Source: Italcementi

Summary

Graphene currently is starting to develop commercial applications in cement and concrete applications. These are not lab curiosities, but real-world products integrating graphene.

It is important to note that there are many types of graphene and it is therefore critical to match the correct variety of graphene to a particular application.

Unfortunately, in this relatively new market, not everyone who claims to be selling graphene is in fact selling bona fide graphene material. This is why The Graphene Council recommends sourcing your material from one of our member companies and Verified Graphene Producers. In this way you know from the start you are working with qualified suppliers.

Successful application developers work with qualified graphene producers. Working with a reputable supplier will help to identify the appropriate type of graphene for your and optimize its effectiveness in your products.

About The Graphene Council

The Graphene Council was founded in 2013 with a mission to serve the global community of graphene professionals. Today, The Graphene Council is the largest community in the world for graphene researchers, academics, producers, developers, investors, nanotechnologists, regulatory agencies, research institutes, material science specialists and end-users.

The mission of The Graphene Council is to support the adoption of graphene to solve critical applications and engineering challenges. We do this through the establishment of internationally recognized standards, rigorous material testing, education and disseminating the latest research and development news, and connecting customers with qualified supply chain partners.

We connect the entire ecosystem, from university-based researchers to innovative graphene producers, to established end-user industry companies looking for the next advancement in materials.

The result is a single resource that can support your product development needs from concept to execution.

The Graphene Council

www.thegraphenecouncil.org

Leading the Adoption of Graphene

The Graphene Council

Our Services

The Graphene Council provides a wide range of services and resources to support and promote the interests of all graphene sector stakeholders including users of graphene, producers, researchers, regulators and investors.

Information & Publications:

- **The Graphene Report:** Covers all aspects of graphene production, applications, standards and a review of more than 200 commercial producers of graphene. Based on primary research and industry-specific data, it is the most comprehensive and up-to-date report on the graphene sector available.
- **Weekly Intelligence:** Weekly Graphene Intelligence Briefing brings you the very latest graphene application, corporate, patent and research news from around the world.
- **Research Journal:** Partnered with Springer Nature to produce the peer-reviewed 'Graphene and 2D Materials' journal, covering the nexus of research and commercial application.

Verification Programs

A rigorous in-person inspection and verification of graphene production facilities, evaluating producers, products, and material functionalization to ensure credibility, authenticity, and compliance with industry standards.

Materials Testing

Collaborating with world-class testing facilities, The Graphene Council offers comprehensive testing and characterization services, ensuring adherence to the latest international standards and best practices. This includes the provision of Technical Data Sheets and Safety Data Sheets aligned with the Graphene Classification Framework for your material's compliance needs.

Networking

Through webinars, conferences, and trade shows, we foster connections among graphene industry professionals. We facilitate partnerships between companies and verified graphene producers and partners for supply chain and application development.

Market Assessment and Supply Chain Validation

Thorough market assessments provide valuable insights to businesses entering the graphene industry. Robust supply chain validation services help ensure reliability and adherence to industry standards for graphene-related materials and products.

Standards Development

Developing global standards for graphene through key collaborations with ISO, ASTM, BSI, IEC, IUPAC, and others, creates transparency and trust in the sector. Volunteer driven standards, such as the Graphene Classification Framework (GCF), are widely used in the industry.

Regulatory Compliance

Providing crucial EPA/TSCA registration services for materials in the US helps with regulatory compliance. Global workplace exposure monitoring services help to mitigate Health, Safety, and Environmental (HSE) related risks for companies.

Due Diligence

Comprehensive technical assessments for potential investments or acquisitions in the graphene sector, covering both technical and market-related aspects, supporting informed decision-making.

Consulting Services

Helping companies with more effective market development, application testing, and seamless product integration by leveraging a vast global network of commercial, technical and academic experts.

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