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When it comes to mass concrete underpinning, several techniques are employed to ensure the stability and longevity of structures, especially older buildings that might be showing signs of foundation distress. Helical piers sound like science fiction technology but they're actually your foundation's best chance at redemption **root cause analysis Kane County** customer. This process involves extending the foundation depth or breadth to reach more stable soil or rock layers beneath the existing foundation. Lets explore some of these techniques in plain terms.

First off, theres the traditional method known as mass concrete replacement. This involves excavating sections beneath the existing foundation in a systematic manner. Imagine digging out small pits one at a time under your houses foundation, filling each with concrete, letting it set, and then moving on to the next section. This sequential approach ensures that the building remains supported throughout the process.

Another technique is called pile underpinning. Here, instead of broad areas of concrete, deep vertical columns or piles are driven or bored into the ground right next to or beneath the existing foundation. These piles transfer the load of the structure down to deeper, more stable layers. Think of it like adding long, sturdy legs under your house that reach down to solid ground.

Then theres beam and base underpinning. This method combines elements from both previous techniques. Essentially, a new reinforced concrete beam is constructed under or near the existing foundation (the beam part), and from this beam, piles or mass concrete bases (the base part) are extended down to stable soil. Its like building a new strong backbone for your house with supports reaching deep into good ground.

Lastly, lets not forget about chemical consolidation injection, which might sound fancy but is pretty straightforward in concept. Here, instead of physical removal and replacement, chemicals are injected into the soil beneath or around the foundation to solidify it in place. It's somewhat like giving your ground a shot that turns loose soil into something firmer and more supportive.

Each of these methods has its place depending on various factors like soil conditions, building load, accessibility, and cost considerations. The goal with all these techniques is not just to fix immediate problems but also to prevent future issues by ensuring that any movement due to settling is minimized or stopped altogether. By understanding these techniques in simple terms, one can appreciate how engineers choose methods that blend science with practical site conditions to keep our buildings standing strong for years to come.

The Swell Cycle: How Expansive Clay Affects Foundations —

- [Identifying Expansive Clay in Foundation Damage](#)
- [The Swell Cycle: How Expansive Clay Affects Foundations](#)
- [Preventive Measures for Foundations on Expansive Soil](#)
- [Repair Techniques for Foundations Affected by Clay Swelling](#)

When it comes to repairing and stabilizing foundations, mass concrete underpinning offers several key advantages that make it a preferred choice for many construction professionals. This method involves pouring large volumes of concrete directly beneath the existing foundation to provide additional support where it's most needed.

First and foremost, the durability of mass concrete is unparalleled. Because of its sheer volume and the way it's placed, it forms a solid, monolithic block that can withstand significant load without cracking or shifting over time. This is crucial for foundations, which must bear the weight of entire structures for decades.

Another advantage is the simplicity and efficiency of the process. Unlike methods that require intricate machinery or specialized skills, mass concrete underpinning can be executed with basic construction knowledge and equipment. This simplicity not only reduces labor costs but also speeds up the repair process, minimizing disruption to occupants or ongoing operations on site.

Mass concrete also excels in adaptability. It can be tailored to fit various soil conditions; whether dealing with clay that expands with moisture or sandy soils that are less stable, engineers can adjust the mix and placement to ensure optimal performance. This flexibility ensures that even problematic foundations can be effectively reinforced.

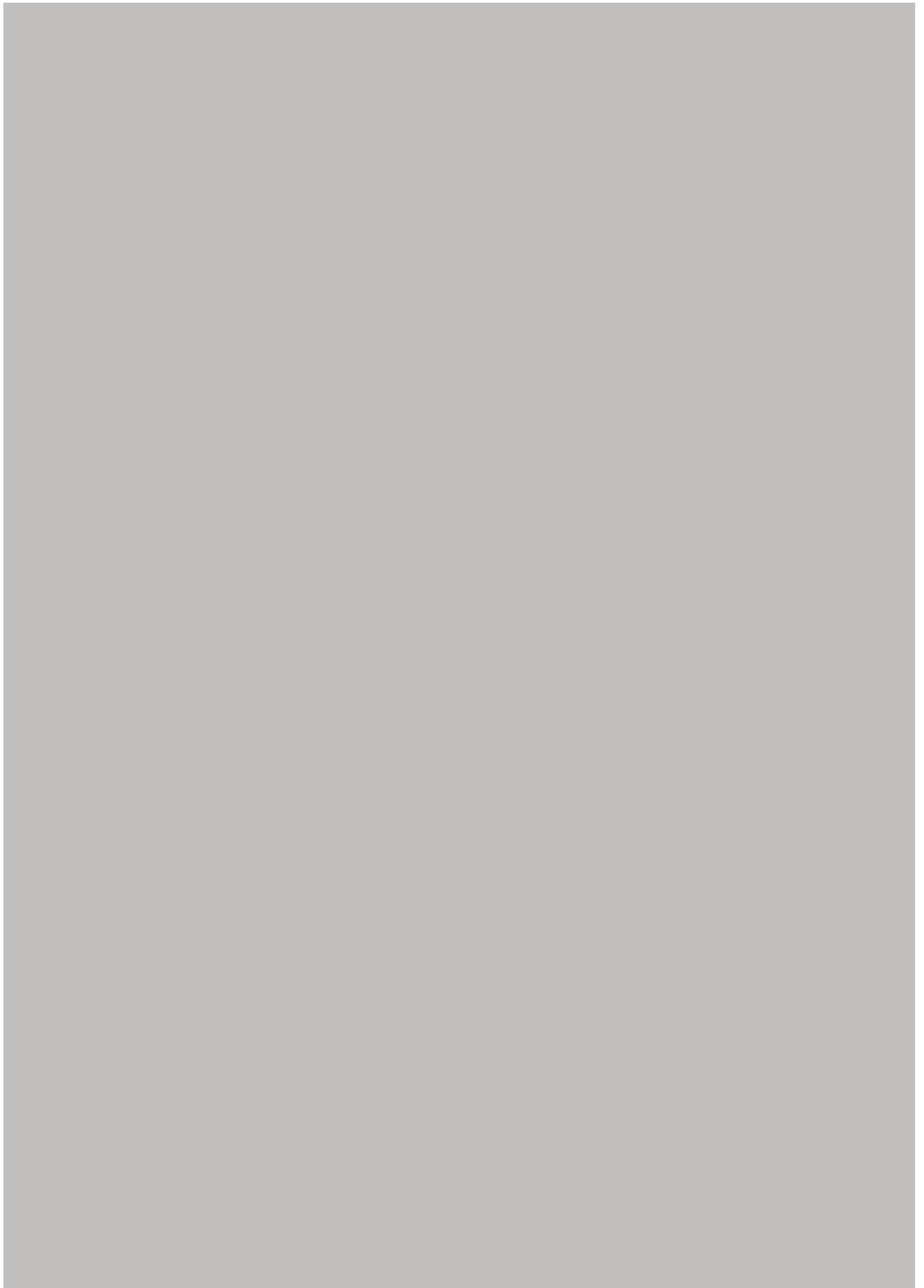
Moreover, from an environmental perspective, using mass concrete can be seen as a sustainable choice since it often utilizes local materials, reducing transportation emissions. Additionally, once set, mass concrete requires little to no maintenance over its lifespan, contributing positively to long-term environmental impact by reducing the need for frequent repairs.

In summary, choosing mass concrete for foundation repair through underpinning provides a robust solution due to its strength, ease of application, adaptability to different ground conditions, and environmental benefits. These factors combined make it an attractive option for anyone looking to ensure their buildings foundation remains secure and reliable well into the future.

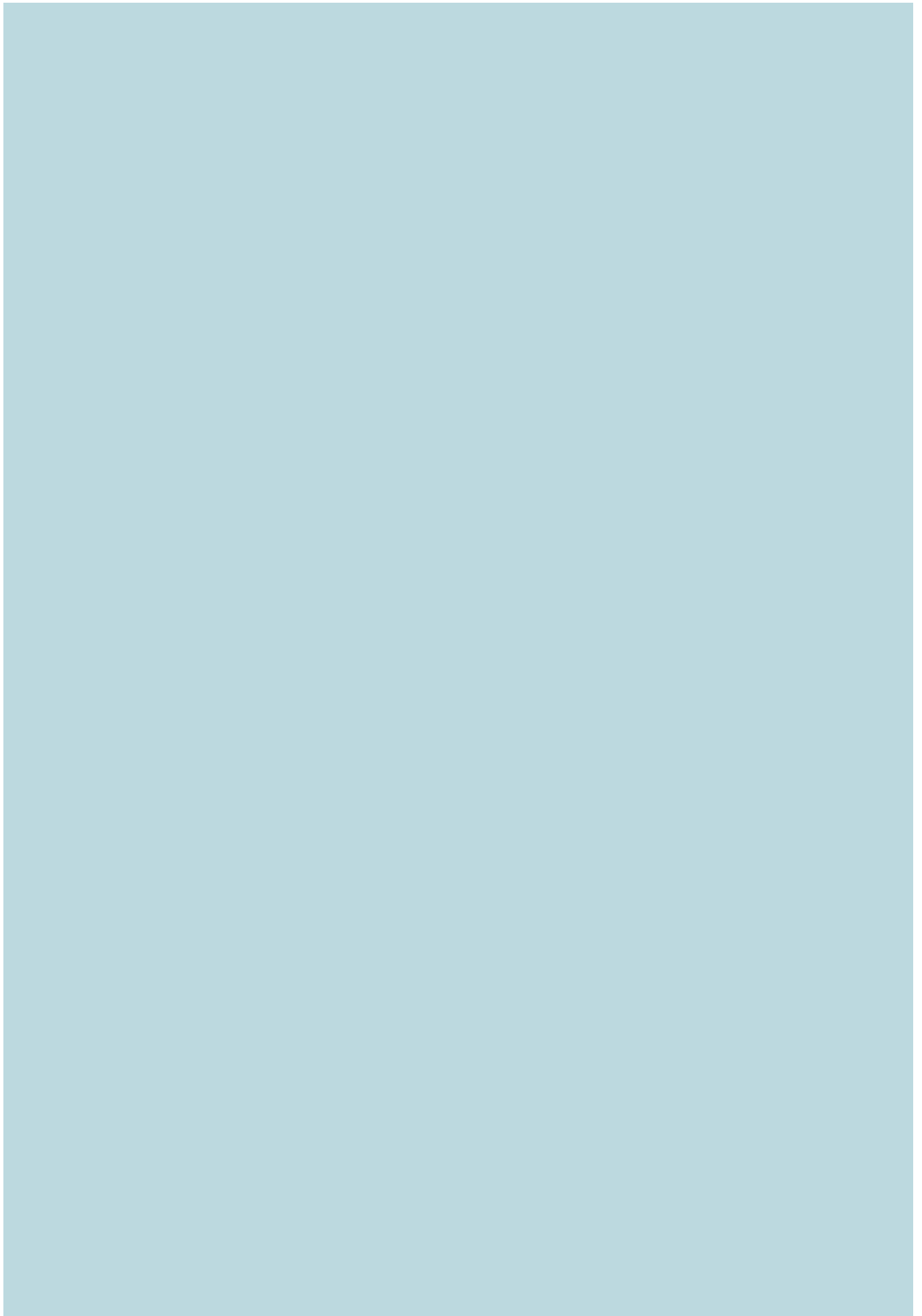
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Preventive Measures for Foundations on Expansive Soil

When it comes to mass concrete underpinning, the process involves reinforcing the foundation of a structure with large volumes of concrete to provide additional support and stability. While this might sound straightforward, there are several challenges and considerations that need to be addressed during implementation.

Firstly, one of the primary challenges is managing heat generation within the concrete. As mass concrete cures, it undergoes an exothermic reaction, producing heat which can lead to thermal cracking if not controlled. Engineers must carefully plan the mix design, possibly incorporating fly ash or slag to reduce heat output, and consider cooling techniques like chilled water pipes within the pour.

Another consideration is ensuring uniform settlement. Mass concrete underpinning aims to distribute load evenly across a larger area, but if not executed properly, differential settlement can occur. This means different parts of the foundation might sink at different rates, leading to structural issues over time. To mitigate this, precise calculations regarding soil bearing capacity and load distribution are crucial.

The timeline for such projects also presents logistical challenges. The curing time for mass concrete can be extensive due to its thickness, requiring strategic planning around construction schedules. This often means that work needs to be phased or scheduled during periods when building operations can be minimized or halted temporarily.

Environmental factors play a significant role as well. Weather conditions like extreme temperatures or heavy rainfall can affect both the placement and curing of concrete. A hot day might accelerate curing too quickly, while rain could compromise the integrity of freshly poured concrete. Thus, weather forecasting becomes part of the preparatory phase.

Lastly, there's the aspect of cost versus benefit analysis. Mass concrete underpinning is not cheap; it involves significant material costs along with specialized labor for execution and monitoring. Stakeholders need to weigh these costs against long-term benefits like increased structural longevity and safety before proceeding.

In conclusion, implementing mass concrete underpinning requires a delicate balance between technical precision in managing heat and settlement, logistical planning around curing times and environmental conditions, and financial considerations. Each project will have its unique set of challenges based on location-specific factors like soil type or existing structure condition, making each implementation a tailored engineering endeavor aimed at ensuring structural integrity for years to come.



When it comes to the complex world of construction, mass concrete underpinning stands out as a critical technique for reinforcing and stabilizing existing structures. This process involves pouring large volumes of concrete beneath a building's foundation to provide additional support, especially when the original foundation is inadequate or when soil conditions have changed over time. Here are a few successful case studies that illustrate how mass concrete underpinning has been effectively implemented.

First, consider the renovation of an old warehouse in downtown Chicago. Originally built in the early 1900s, this structure had begun to show signs of settling due to the shifting clay-rich soil beneath it. Engineers opted for mass concrete underpinning to address these issues. They excavated beneath the existing footings in controlled sections, carefully ensuring structural stability throughout the process. High-strength concrete was then poured into these excavated areas, creating new, robust footings that extended deep into more stable soil layers. The project was deemed a success not only because it halted further settling but also because it preserved the historical integrity of the building.

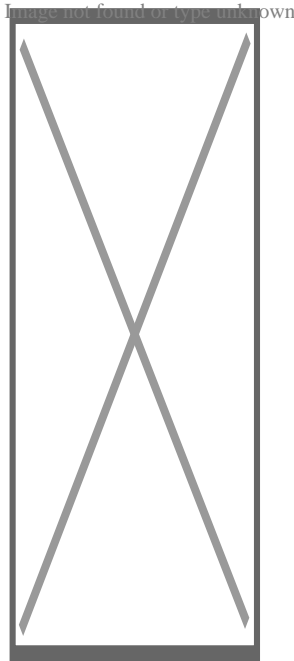
Another notable example took place in London, where a Victorian-era townhouse required underpinning due to subsidence caused by nearby tunneling work for a new subway line. The challenge here was not just about providing support but doing so without disturbing the delicate interior finishes and architectural details of this heritage-listed property. By employing mass concrete underpinning in small, manageable phases and using vibration-free equipment during excavation, engineers were able to reinforce the foundation without compromising the building's aesthetic value. Post-project assessments showed that the house was now securely supported with no further risk from ground movement.

In Sydney, Australia, a multi-story office building faced similar foundational challenges due to expansive soils that expand and contract with moisture changes. Here, mass concrete underpinning was selected for its ability to distribute loads more evenly across these variable soils. The operation involved strategic placement of deep concrete piers which were interconnected by beams at foundation level. This approach not only stabilized the building but also allowed for future expansions as part of urban development plans.

These case studies highlight how mass concrete underpinning can be adapted to various scenarios - from historical preservation to modern urban settings - providing long-term stability and safety while respecting architectural or operational constraints. Each project underscores the importance of thorough planning, precise execution, and an understanding of both structural dynamics and local geological conditions to ensure success in mass concrete underpinning projects. Through these examples, we see that this method offers a robust solution when traditional foundation repair methods fall short, proving its value time and again in real-world applications.

About Carbon-fiber reinforced polymer

"Carbon fiber" redirects here. For fibers of carbon, see **Carbon fibers**.



Tail of a **radio-controlled helicopter**, made of CFRP

Carbon fiber-reinforced polymers (**American English**), **carbon-fibre-reinforced polymers** (**Commonwealth English**), **carbon-fiber-reinforced plastics**, **carbon-fiber reinforced-thermoplastic** (CFRP, CRP, CFRTTP), also known as **carbon fiber**, **carbon composite**, or just **carbon**, are extremely strong and light **fiber-reinforced plastics** that contain **carbon fibers**. CFRPs can be expensive to produce, but are commonly used wherever high **strength-to-weight ratio** and **stiffness** (rigidity) are required, such as aerospace, superstructures of ships, automotive, civil engineering, sports equipment, and an increasing number of consumer and technical applications.^{[1][2][3][4]}

The binding **polymer** is often a **thermoset** resin such as **epoxy**, but other thermoset or **thermoplastic** polymers, such as **polyester**, **vinyl ester**, or **nylon**, are sometimes used.^[4] The properties of the final CFRP product can be affected by the type of additives introduced to the binding matrix (resin). The most common additive is **silica**, but other additives such as rubber and **carbon nanotubes** can be used.

Carbon fiber is sometimes referred to as *graphite-reinforced polymer* or *graphite fiber-reinforced polymer* (*GFRP* is less common, as it clashes with **glass-(fiber)-reinforced polymer**).

Properties

[edit]

CFRP are **composite materials**. In this case the composite consists of two parts: a matrix and a reinforcement. In CFRP the reinforcement is carbon fiber, which provides its strength. The matrix is usually a thermosetting plastic, such as polyester resin, to bind the reinforcements together.[5] Because CFRPs consist of two distinct elements, the material properties depend on these two elements.

Reinforcement gives CFRPs their strength and rigidity, measured by **stress** and **elastic modulus** respectively. Unlike **isotropic** materials like steel and aluminum, CFRPs have directional strength properties. The properties of a CFRP depend on the layouts of the carbon fiber and the proportion of the carbon fibers relative to the polymer.[6] The two different equations governing the net elastic modulus of composite materials using the properties of the carbon fibers and the polymer matrix can also be applied to carbon fiber reinforced plastics.[7] The **rule of mixtures** for the equal **strain** case gives:

$$E_c = V_m E_m + V_f E_f$$

which is valid for composite materials with the fibers oriented **parallel** to the applied load. E_c is the total composite modulus, V_m and V_f are the fractions of the matrix and fiber respectively in the composite, and E_m and E_f are the elastic moduli of the matrix and fibers respectively.[7] The other extreme case of the elastic modulus of the composite with the fibers oriented transverse to the applied load can be found using the inverse rule of mixtures for the equal stress case:[7]

$$E_c = \left(\frac{V_m}{E_m} + \frac{V_f}{E_f} \right)^{-1}$$

The above equations give an upper and lower bound on the Young's modulus for CFRP and there are many other factors that influence the true value.

The fracture toughness of carbon fiber reinforced plastics is governed by multiple mechanisms:

- Debonding between the carbon fiber and polymer matrix.
- Fiber pull-out.
- Delamination between the CFRP sheets.[8]

Typical epoxy-based CFRPs exhibit virtually no plasticity, with less than 0.5% strain to failure. Although CFRPs with epoxy have high strength and elastic modulus, the brittle fracture mechanics presents unique challenges to engineers in failure detection since failure occurs catastrophically.[8] As such, recent efforts to toughen CFRPs include modifying the existing epoxy material and finding alternative polymer matrix. One such

material with high promise is **PEEK**, which exhibits an order of magnitude greater toughness with similar elastic modulus and tensile strength.^[8] However, PEEK is much more difficult to process and more expensive.^[8]

Despite their high initial strength-to-weight ratios, a design limitation of CFRPs are their lack of a definable **fatigue limit**. This means, theoretically, that stress cycle failure cannot be ruled out. While steel and many other structural metals and alloys do have estimable fatigue or endurance limits, the complex failure modes of composites mean that the fatigue failure properties of CFRPs are difficult to predict and design against; however emerging research has shed light on the effects of low velocity impacts on composites.^[9] Low velocity impacts can make carbon fiber polymers susceptible to damage.^{[9][10][11]} As a result, when using CFRPs for critical cyclic-loading applications, engineers may need to design in considerable strength safety margins to provide suitable component reliability over its service life.

Environmental effects such as temperature and **humidity** can have profound effects on the polymer-based composites, including most CFRPs. While CFRPs demonstrate excellent corrosion resistance, the effect of moisture at wide ranges of temperatures can lead to degradation of the mechanical properties of CFRPs, particularly at the matrix-fiber interface.^[12] While the carbon fibers themselves are not affected by the moisture diffusing into the material, the moisture plasticizes the polymer matrix.^[8] This leads to significant changes in properties that are dominantly influenced by the matrix in CFRPs such as compressive, interlaminar shear, and impact properties.^[13] The epoxy matrix used for engine fan blades is designed to be impervious against jet fuel, lubrication, and rain water, and external paint on the composites parts is applied to minimize damage from ultraviolet light.^{[8][14]}

Carbon fibers can cause **galvanic corrosion** when CFRP parts are attached to aluminum or mild steel but not to stainless steel or titanium.^[15]

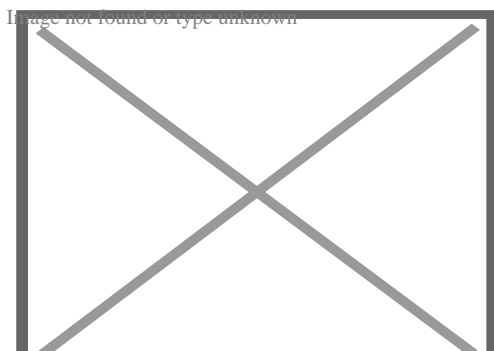
CFRPs are very hard to machine, and cause significant tool wear. The tool wear in CFRP machining is dependent on the fiber orientation and machining condition of the cutting process. To reduce tool wear various types of coated tools are used in machining CFRP and CFRP-metal stack.^[1]

Manufacturing

[\[edit\]](#)



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Carbon fiber reinforced polymer

The primary element of CFRPs is a **carbon filament**; this is produced from a precursor **polymer** such as **polyacrylonitrile** (PAN), **rayon**, or petroleum **pitch**. For synthetic polymers such as PAN or rayon, the precursor is first **spun** into filament yarns, using chemical and mechanical processes to initially align the polymer chains in a way to enhance the final physical properties of the completed carbon fiber. Precursor compositions and mechanical processes used during spinning filament yarns may vary among manufacturers. After drawing or spinning, the polymer filament yarns are then heated to drive off non-carbon atoms (**carbonization**), producing the final carbon fiber. The carbon fibers filament yarns may be further treated to improve handling qualities, then wound onto **bobbins**.^[16] From these fibers, a unidirectional sheet is created. These sheets are layered onto each other in a quasi-isotropic layup, e.g. 0°, +60°, or ±60° relative to each other.

From the elementary fiber, a bidirectional woven sheet can be created, i.e. a **twill** with a 2/2 weave. The process by which most CFRPs are made varies, depending on the piece being created, the finish (outside gloss) required, and how many of the piece will be produced. In addition, the choice of matrix can have a profound effect on the properties of the finished composite.^[17]

Many CFRP parts are created with a single layer of carbon fabric that is backed with fiberglass.^[18] A tool called a chopper gun is used to quickly create these composite parts. Once a thin shell is created out of carbon fiber, the chopper gun cuts rolls of fiberglass into short lengths and sprays resin at the same time, so that the fiberglass and resin are mixed on the spot.^[19] The resin is either external mix, wherein the hardener and resin are sprayed separately, or internal mixed, which requires cleaning after every use. Manufacturing methods may include the following:

Molding

[**edit**]

One method of producing CFRP parts is by layering sheets of carbon fiber cloth into a **mold** in the shape of the final product. The alignment and weave of the cloth fibers is chosen to optimize the strength and stiffness properties of the resulting material. The mold is then filled with **epoxy** and is heated or air-cured. The resulting part is very corrosion-resistant, stiff, and strong for its weight. Parts used in less critical areas are manufactured by draping cloth over a mold, with epoxy either pre-impregnated into the fibers (also known as **pre-preg**) or "painted" over it. High-performance parts using single molds are often vacuum-bagged and/or **autoclave**-cured, because even small air bubbles in the material will reduce strength. An alternative to the autoclave method is to use internal pressure via inflatable air bladders or **EPS foam** inside the non-cured laid-up carbon fiber.

Vacuum bagging

[[edit](#)]

For simple pieces of which relatively few copies are needed (one or two per day), a **vacuum bag** can be used. A fiberglass, carbon fiber, or aluminum mold is polished and waxed, and has a **release agent** applied before the fabric and resin are applied, and the vacuum is pulled and set aside to allow the piece to cure (harden). There are three ways to apply the resin to the fabric in a vacuum mold.

The first method is manual and called a wet layup, where the two-part resin is mixed and applied before being laid in the mold and placed in the bag. The other one is done by infusion, where the dry fabric and mold are placed inside the bag while the vacuum pulls the resin through a small tube into the bag, then through a tube with holes or something similar to evenly spread the resin throughout the fabric. Wire loom works perfectly for a tube that requires holes inside the bag. Both of these methods of applying resin require hand work to spread the resin evenly for a glossy finish with very small pin-holes.

A third method of constructing composite materials is known as a dry layup. Here, the carbon fiber material is already impregnated with resin (pre-preg) and is applied to the mold in a similar fashion to adhesive film. The assembly is then placed in a vacuum to cure. The dry layup method has the least amount of resin waste and can achieve lighter constructions than wet layup. Also, because larger amounts of resin are more difficult to bleed out with wet layup methods, pre-preg parts generally have fewer pinholes. Pinhole elimination with minimal resin amounts generally require the use of **autoclave** pressures to purge the residual gases out.

Compression molding

[[edit](#)]

A quicker method uses a **compression mold**, also commonly known as carbon fiber forging. This is a two (male and female), or multi-piece mold, usually made out of aluminum or steel and more recently 3D printed plastic. The mold components are pressed together with the fabric and resin loaded into the inner cavity that ultimately becomes the desired component. The benefit is the speed of the entire process. Some car manufacturers, such as BMW, claimed to be able to cycle a new part every 80 seconds. However, this technique has a very high initial cost since the molds require CNC machining of very high precision.

Filament winding

[[edit](#)]

For difficult or convoluted shapes, a **filament winder** can be used to make CFRP parts by winding filaments around a mandrel or a core.

Cutting

[[edit](#)]

Carbon fiber-reinforced **pre-pregs** and dry carbon fiber textiles require precise cutting methods to maintain material integrity and reduce defects such as fiber pull-out, **delamination** and fraying of the cutting edge. **CNC digital cutting systems** equipped with drag and oscillating are often used to cut carbon fiber pre-pregs, and rotating knives are commonly used to process carbon fiber fabrics. **Ultrasonic** cutting is another method to cut CFRP pre-pregs and is particularly effective in reducing delamination by minimizing **mechanical stress** during the cutting process. **Waterjet cutting** can be the preferred method for thicker and multilayered polymer **composites**.^[20]

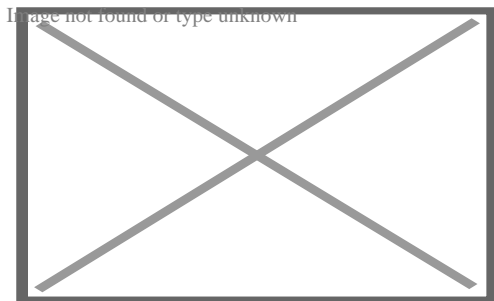
Applications

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Applications for CFRPs include the following:

Aerospace engineering

[[edit](#)]



An **Airbus A350** with carbon fiber themed **livery**. Composite materials are used extensively throughout the A350.

The **Airbus A350 XWB** is 53% CFRP^[21] including wing spars and fuselage components, overtaking the **Boeing 787 Dreamliner**, for the aircraft with the highest weight ratio for CFRP at 50%.^[22] It was one of the first commercial aircraft to have wing spars made from composites. The **Airbus A380** was one of the first commercial airliners to have a central wing-box made of CFRP and the first with a smoothly contoured wing cross-section instead of partitioning it span-wise into sections. This flowing, continuous cross section optimises aerodynamic efficiency.^[citation needed] Moreover, the trailing edge, along with the rear bulkhead, **empennage**, and un-pressurised fuselage are made of CFRP.^[23]

However, delays have pushed order delivery dates back because of manufacturing problems. Many aircraft that use CFRPs have experienced delays with delivery dates due

to the relatively new processes used to make CFRP components, whereas metallic structures are better understood. A recurrent problem is the monitoring of structural ageing, for which new methods are required, due to the unusual multi-material and anisotropic[24][25][26] nature of CFRPs.[27]

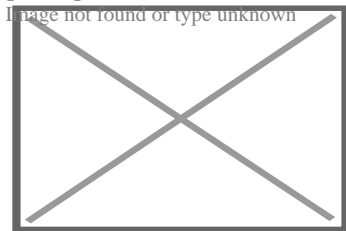
In 1968 a *Hyfil* carbon-fiber fan assembly was in service on the **Rolls-Royce Conways** of the **Vickers VC10s** operated by **BOAC**. [28]

Specialist aircraft designers and manufacturers **Scaled Composites** have made extensive use of CFRPs throughout their design range, including the first private crewed spacecraft **Spaceship One**. CFRPs are widely used in **micro air vehicles** (MAVs) because of their high strength-to-weight ratio.

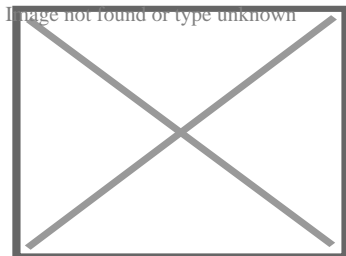
Airbus then moved to adopt CFRTTP, because it can be reshaped and reprocessed after forming, can be manufactured faster, has higher impact resistance, is recyclable and remoldable, and has lower processing costs.[29]

Automotive engineering

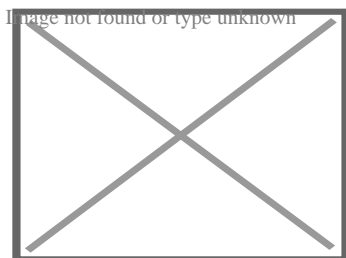
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Citroën SM that won
1971 **Rally of Morocco**
with carbon fiber wheels



1996 **McLaren F1** –
first carbon fiber body
shell



McLaren MP4 (MP4/1),
first carbon fiber F1 car

CFRPs are extensively used in high-end automobile racing.[30] The high cost of carbon fiber is mitigated by the material's unsurpassed strength-to-weight ratio, and low weight is essential for high-performance automobile racing. Race-car manufacturers have also developed methods to give carbon fiber pieces strength in a certain direction, making it strong in a load-bearing direction, but weak in directions where little or no load would be placed on the member. Conversely, manufacturers developed omnidirectional carbon fiber weaves that apply strength in all directions. This type of carbon fiber assembly is most widely used in the "safety cell" **monocoque** chassis assembly of high-performance race-cars. The first carbon fiber monocoque chassis was introduced in **Formula One** by **McLaren** in the 1981 season. It was designed by **John Barnard** and was widely copied in the following seasons by other F1 teams due to the extra rigidity provided to the chassis of the cars.[31]

Many **supercars** over the past few decades have incorporated CFRPs extensively in their manufacture, using it for their monocoque chassis as well as other components.[32] As far back as 1971, the **Citroën SM** offered optional lightweight carbon fiber wheels.[33][34]

Use of the material has been more readily adopted by low-volume manufacturers who used it primarily for creating body-panels for some of their high-end cars due to its increased strength and decreased weight compared with the **glass-reinforced polymer** they used for the majority of their products.

Civil engineering

[edit]

Further information: **Structural applications of FRP**

CFRPs have become a notable material in **structural engineering** applications. Studied in an academic context as to their potential benefits in construction, CFRPs have also proved themselves cost-effective in a number of field applications strengthening concrete, masonry, steel, cast iron, and timber structures. Their use in industry can be either for **retrofitting** to strengthen an existing structure or as an alternative reinforcing (or prestressing) material instead of steel from the outset of a project.

Retrofitting has become the increasingly dominant use of the material in civil engineering, and applications include increasing the load capacity of old structures (such as bridges, beams, ceilings, columns and walls) that were designed to tolerate far lower service loads than they are experiencing today, seismic retrofitting, and repair of damaged structures. Retrofitting is popular in many instances as the cost of replacing the deficient structure can greatly exceed the cost of strengthening using CFRP.[35]

Applied to reinforced concrete structures for flexure, the use of CFRPs typically has a large impact on strength (doubling or more the strength of the section is not uncommon), but only moderately increases **stiffness** (as little as 10%). This is because the material used in such applications is typically very strong (e.g., 3 GPa ultimate **tensile strength**, more than 10 times mild steel) but not particularly stiff (150 to 250 GPa elastic modulus, a little less than steel, is typical). As a consequence, only small cross-sectional areas of the material are used. Small areas of very high strength but moderate stiffness material will significantly increase strength, but not stiffness.

CFRPs can also be used to enhance **shear strength** of reinforced concrete by wrapping fabrics or fibers around the section to be strengthened. Wrapping around sections (such as bridge or building columns) can also enhance the **ductility** of the section, greatly increasing the resistance to collapse under dynamic loading. Such 'seismic retrofit' is the major application in earthquake-prone areas, since it is much more economic than alternative methods.

If a column is circular (or nearly so) an increase in axial capacity is also achieved by wrapping. In this application, the confinement of the CFRP wrap enhances the **compressive strength** of the concrete. However, although large increases are achieved in the ultimate collapse load, the concrete will crack at only slightly enhanced load, meaning that this application is only occasionally used. Specialist ultra-high modulus CFRP (with tensile modulus of 420 GPa or more) is one of the few practical methods of strengthening **cast iron** beams. In typical use, it is bonded to the tensile flange of the section, both increasing the stiffness of the section and lowering the **neutral axis**, thus greatly reducing the maximum tensile stress in the cast iron.

In the United States, **prestressed concrete** cylinder pipes (PCCP) account for a vast majority of water transmission mains. Due to their large diameters, failures of PCCP are usually catastrophic and affect large populations. Approximately 19,000 miles (31,000 km) of PCCP were installed between 1940 and 2006. **Corrosion** in the form of hydrogen embrittlement has been blamed for the gradual deterioration of the prestressing wires in many PCCP lines. Over the past decade, CFRPs have been used to internally line PCCP, resulting in a fully structural strengthening system. Inside a PCCP line, the CFRP liner acts as a barrier that controls the level of strain experienced by the steel cylinder in the host pipe. The composite liner enables the steel cylinder to perform within its elastic range, to ensure the pipeline's long-term performance is maintained. CFRP liner designs are based on strain compatibility between the liner and host pipe.[\[36\]](#)

CFRPs are more costly materials than commonly used their counterparts in the construction industry, **glass fiber-reinforced polymers** (GFRPs) and **aramid** fiber-reinforced polymers (AFRPs), though CFRPs are, in general, regarded as having superior properties. Much research continues to be done on using CFRPs both for retrofitting and as an alternative to steel as reinforcing or prestressing materials. Cost remains an issue and long-term **durability** questions still remain. Some are concerned about the **brittle** nature of CFRPs, in contrast to the ductility of steel. Though design codes have been drawn up by

institutions such as the **American Concrete Institute**, there remains some hesitation among the engineering community about implementing these alternative materials. In part, this is due to a lack of standardization and the proprietary nature of the fiber and resin combinations on the market.

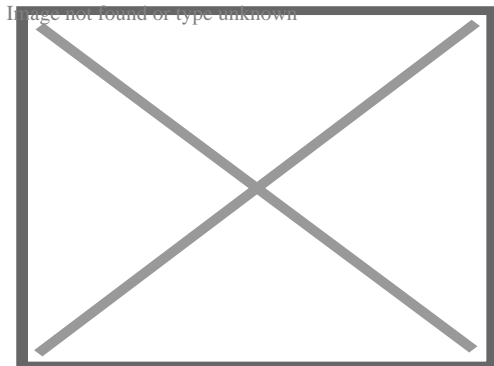
Carbon-fiber microelectrodes

[[edit](#)]

Carbon fibers are used for fabrication of carbon-fiber **microelectrodes**. In this application typically a single carbon fiber with diameter of 5–7 μm is sealed in a glass capillary.^[37] At the tip the capillary is either sealed with epoxy and polished to make carbon-fiber disk microelectrode or the fiber is cut to a length of 75–150 μm to make carbon-fiber cylinder electrode. Carbon-fiber microelectrodes are used either in **amperometry** or **fast-scan cyclic voltammetry** for detection of biochemical signalling.

Sports goods

[[edit](#)]



A carbon-fiber and **Kevlar** canoe (Placid Boatworks Rapidfire at the **Adirondack Canoe Classic**)

CFRPs are now widely used in sports equipment such as in squash, tennis, and badminton racquets, **sport kite** spars, high-quality arrow shafts, hockey sticks, fishing rods, **surfboards**, high end swim fins, and rowing **shells**. Amputee athletes such as **Jonnie Peacock** use carbon fiber blades for running. It is used as a shank plate in some **basketball** sneakers to keep the foot stable, usually running the length of the shoe just above the sole and left exposed in some areas, usually in the arch.

Controversially, in 2006, cricket bats with a thin carbon-fiber layer on the back were introduced and used in competitive matches by high-profile players including **Ricky Ponting** and **Michael Hussey**. The carbon fiber was claimed to merely increase the durability of the bats, but it was banned from all first-class matches by the **ICC** in 2007.^[38]

A CFRP **bicycle frame** weighs less than one of steel, aluminum, or **titanium** having the same strength. The type and orientation of the carbon-fiber weave can be designed to maximize stiffness in required directions. Frames can be tuned to address different riding styles: sprint events require stiffer frames while endurance events may require more flexible frames for rider comfort over longer periods.[39] The variety of shapes it can be built into has further increased stiffness and also allowed **aerodynamic** tube sections. CFRP **forks** including suspension fork crowns and steerers, **handlebars**, **seatposts**, and **crank arms** are becoming more common on medium as well as higher-priced bicycles. CFRP **rim**s remain expensive but their stability compared to aluminium reduces the need to re-true a wheel and the reduced mass reduces the **moment of inertia** of the wheel. CFRP spokes are rare and most carbon wheelsets retain traditional stainless steel spokes. CFRPs also appear increasingly in other components such as derailleur parts, brake and shifter levers and bodies, cassette sprocket carriers, suspension linkages, disc brake rotors, pedals, shoe soles, and saddle rails. Although strong and light, impact, over-torquing, or improper installation of CFRP components has resulted in cracking and failures, which may be difficult or impossible to repair.[40][41]

Other applications

[**edit**]

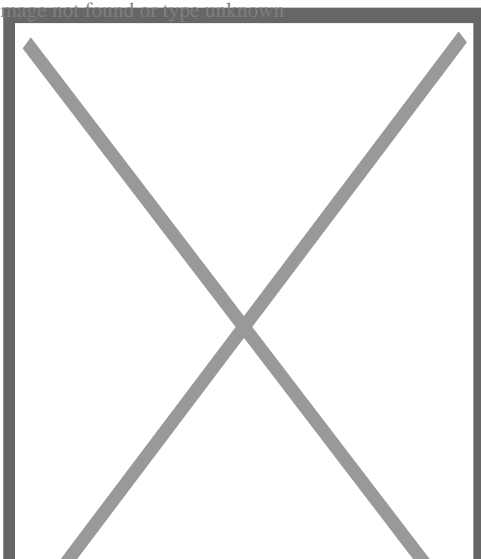
Dunlop "Max-Grip" carbon fiber guitar picks. Sizes 1mm and Jazz III.

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Dunlop "Max-Grip" carbon fiber guitar picks. Sizes 1mm and Jazz III.

The fire resistance of polymers and thermo-set composites is significantly improved if a thin layer of carbon fibers is moulded near the surface because a dense, compact layer of carbon fibers efficiently reflects heat.[42]

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Strandberg Boden Plini **neck-thru** & **bolt on** versions that both utilize carbon fiber reinforcement strips to maintain rigidity.

CFRPs are being used in an increasing number of high-end products that require stiffness and low weight, these include:

- Musical instruments, including violin bows; guitar picks, guitar necks (fitted with carbon fiber rods), **pickguards**/scratchplates; drum shells; bagpipe chanters; piano actions; and entire musical instruments such as carbon fiber cellos, violas, and violins, acoustic guitars and ukuleles; also, audio components such as turntables and loudspeakers.
- Firearms use it to replace certain metal, wood, and fiberglass components but many of the internal parts are still limited to metal alloys as current reinforced plastics are unsuitable.
- High-performance drone bodies and other radio-controlled vehicle and aircraft components such as helicopter rotor blades.
- Lightweight poles such as: tripod legs, tent poles, fishing rods, billiards cues, walking sticks, and high-reach poles such as for window cleaning.
- Dentistry, **carbon fiber posts** are used in restoring root canal treated teeth.
- Railed train **bogies** for passenger service. This reduces the weight by up to 50% compared to metal bogies, which contributes to energy savings.^[43]
- Laptop shells and other high performance cases.
- Carbon woven fabrics.^{[44][45]}
- Archery: carbon fiber arrows and bolts, **stock** (for crossbows) and **riser** (for vertical bows), and rail.
- As a filament for the 3D fused deposition modeling printing process,^[46] carbon fiber-reinforced plastic (polyamide-carbon filament) is used for the production of sturdy but lightweight tools and parts due to its high strength and tear length.^[47]
- District heating pipe rehabilitation, using a **CIPP** method.

Disposal and recycling

[**edit**]



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The key aspect of recycling fiber-reinforced polymers is preserving their mechanical properties while successfully recovering both the **thermoplastic** matrix and the reinforcing fibers. CFRPs have a long service lifetime when protected from the sun. When it is time to decommission CFRPs, they cannot be melted down in air like many metals. When free of vinyl (PVC or **polyvinyl chloride**) and other halogenated polymers, CFRPs recycling processes can be categorized into four main approaches: mechanical, **thermal**, chemical, and biological. Each method offers distinct advantages in terms of material or **energy recovery**, contributing to **sustainability** efforts in composite waste management.

Process	Matrix recovery	Fiber recovery	Degradation of Mechanical Properties	Advantages/Drawbacks
Mechanical	X	X	X	+No use of hazardous chemical substances +No gas emissions +Low-cost energy needed +Big volumes can be recycled -Poor bonding between fiber/matrix - Fibers can damage the equipment
Chemical		X		+Long clean fibers +Retention of mechanical properties +Sometimes there is high recovery of the matrix -Expensive equipment -Possible use of hazardous solvent
Thermal		X	X	+Fiber length retention +No use of hazardous chemical substances +better mechanical properties than mechanical approach +Matrix used to produce energy -Recovered fiber properties highly influenced by process parameters -some processes have no recovery of matrix material

Mechanical Recycling

[[edit](#)]

The mechanical process primarily involves **grinding**, which breaks down composite materials into pulverulent charges and fibrous reinforcements. This method is focused on both the thermoplastic and filler material recovery; however, this process shortens the fibers dramatically. Just as with **downcycled** paper, the shortened fibers cause the recycled material to be weaker than the original material. There are still many industrial applications that do not need the strength of full-length carbon fiber reinforcement. For example, chopped reclaimed carbon fiber can be used in consumer electronics, such as laptops. It provides excellent reinforcement of the polymers used even if it lacks the strength-to-weight ratio of an aerospace component.^[48]

Electro fragmentation

[[edit](#)]

This method consists in shredding CFRP by pulsed **electrical discharges**. Initially developed to extract crystals and precious stones from mining rocks, it is now expected to be developed for composites. The material is placed in a vessel containing water and two **electrodes**. The high voltage electrical pulse generated between the electrodes (50-200 kV) fragments the material into smaller pieces.[\[49\]](#) The inconvenient of this technique is that the energy consumed is 2.6 times the one of a mechanical route making it not economically competitive in terms of energy saving and needs further investigation.

Thermal Recycling

[[edit](#)]

Thermal processes include several techniques such as **incineration**, **thermolysis**, **pyrolysis**, **gasification**, fluidized bed processing, and **cement plant** utilization. This processes imply the recovery of the fibers by the removal of the **resin** by volatilizing it, leading to by-products such as gases, liquids or inorganic matter.[\[50\]](#)

Oxidation in fluidized bed

[[edit](#)]

This technique consists in exposing the composite to a hot and **oxygen-rich** flow, in which it is combusted (450–550 °C, 840–1,020 °F) . The working temperature is selected in function of the matrix to be **decomposed**, to limit damages of the fibers. After a shredding step to 6-20 mm size, the composite is introduced into a bed of **silica sand**, on a metallic mesh, in which the resin will be decomposed into oxidized molecules and fiber filaments. These components will be carried up with the air stream while heavier particles will sink in the bed. This last point is a great advantage for contaminated end-of-life products, with painted surfaces, **foam cores** or metal insert. A **cyclone** enables the recovery of fibers of length ranging between 5 and 10 mm and with very little contamination . The matrix is fully oxidized in a second burner operating at approximatively 1,000 °C (1,850 °F) leading to **energy recovery** and a clean flue gas.[\[51\]](#)

Chemical Recycling

[[edit](#)]

The chemical recycling of CFRPs involves using a reactive **solvent** at relatively low temperatures (below 350°C) to break down the resin while leaving the fibers intact for reuse. The solvent degrades the composite matrix into smaller molecular fragments (**oligomer**), and depending on the chosen solvent system, various processing parameters such as temperature, pressure, and **catalysts** can be adjusted to optimize the process. The solvent, often combined with **co-solvents** or catalysts, penetrates the composite and **breaks specific chemical bonds**, resulting in recovered **monomers** from the resin and clean, long fibers with preserved mechanical properties. The required temperature and pressure depend on the type of resin, with **epoxy resins** generally needing higher temperatures than polyester resins. Among the different reactive mediums studied, water is the most commonly used due to its environmental benefits. When combined with **alkaline** catalysts, it effectively degrades many resins, while **acidic** catalysts are used for more resistant polymers. Other solvents, such as **ethanol**, **acetone**, and their mixtures, have also been explored for this process.

Despite its advantages, this method has some limitations. It requires specialized equipment capable of handling **corrosive** solvents, hazardous chemicals, and high temperatures or pressures, especially when operating under **supercritical** conditions. While extensively researched at the laboratory scale, industrial adoption remains limited, with the technology currently reaching a **Technology Readiness Level** (TRL) of 4 for carbon fiber recycling.[52]

Dissolution Process

[edit]

The dissolution process is a method used to recover both the polymer matrix and fibers from thermoplastic composites without breaking **chemical bonds**. Unlike **solvolysis**, which involves the **chemical degradation** of the polymer, dissolution simply dissolves the polymer chains into a solvent, allowing for material recovery in its original form. An energy analysis of the process indicated that dissolution followed by **evaporation** was more energy-efficient than **precipitation**. Additionally, avoiding precipitation helped minimize polymer loss, improving overall material recovery efficiency. This method offers a promising approach for sustainable recycling of thermoplastic composites.[53]

Biological Recycling

[edit]

The biological process, though still under development, focuses on **biodegradation** and **composting**. This method holds promise for bio-based and agro-composites, aiming to create an environmentally friendly end-of-life solution for these materials. As research advances, biological recycling may offer an effective means of reducing plastic composite waste in a sustainable manner.[54]

Carbon nanotube reinforced polymer (CNRP)

[[edit](#)]

In 2009, **Zyvex Technologies** introduced carbon nanotube-reinforced epoxy and carbon **pre-pregs**.^[55] **Carbon nanotube** reinforced polymer (CNRP) is several times stronger and tougher than typical CFRPs and is used in the **Lockheed Martin F-35 Lightning II** as a structural material for aircraft.^[56] CNRP still uses carbon fiber as the primary reinforcement,^[57] but the binding matrix is a carbon nanotube-filled epoxy.^[58]

See also

[[edit](#)]

- o **Carbon fibers** – Material fibers about 5–10 μm in diameter composed of carbon
- o **Composite repair** – Composite repair patch preparation and application
- o **Mechanics of Oscar Pistorius's running blades** – Blades used by South African Paralympic runner Oscar Pistorius
- o **Reinforced carbon–carbon** – Graphite-based composite material
- o **Forged carbon fiber**
- o **Carbon-ceramic**
- o **Carbotanium**

References

[[edit](#)]

1. [^] **a b** Nguyen, Dinh; Abdullah, Mohammad Sayem Bin; Khawarizmi, Ryan; Kim, Dave; Kwon, Patrick (2020). "The effect of fiber orientation on tool wear in edge-trimming of carbon fiber reinforced plastics (CFRP) laminates". *Wear*. 450–451. Elsevier B.V: 203213. doi:10.1016/j.wear.2020.203213. ISSN 0043-1648. S2CID 214420968.
2. [^] Geier, Norbert; Davim, J. Paulo; Szalay, Tibor (1 October 2019). "**Advanced cutting tools and technologies for drilling carbon fibre reinforced polymer (CFRP) composites: A review**". *Composites Part A: Applied Science and Manufacturing*. 125: 105552. doi:10.1016/j.compositesa.2019.105552. hdl:10773/36722.
3. [^] Dransfield, Kimberley; Baillie, Caroline; Mai, Yiu-Wing (1 January 1994). "**Improving the delamination resistance of CFRP by stitching—a review**". *Composites Science and Technology*. 50 (3): 305–317. doi:10.1016/0266-3538(94)90019-1.
4. [^] **a b** Kudo, Natsuko; Fujita, Ryohei; Oya, Yutaka; Sakai, Takenobu; Nagano, Hosei; Koyanagi, Jun (30 June 2023). "**Identification of invisible fatigue damage of thermosetting epoxy resin by non-destructive thermal measurement using entropy generation**". *Advanced Composite Materials*. 33 (2): 233–249. doi:10.1080/09243046.2023.2230687. ISSN 0924-3046.
5. [^] Kopeliovich, Dmitri. "**Carbon Fiber Reinforced Polymer Composites**". Archived from the original on 14 May 2012.. substech.com

6. ^ Corum, J. M.; Battiste, R. L.; Liu, K. C; Ruggles, M. B. (February 2000). **"Basic Properties of Reference Crossply Carbon-Fiber Composite, ORNL/TM-2000/29, Pub57518"** (PDF). Oak Ridge National Laboratory. **Archived** (PDF) from the original on 27 December 2016.
7. ^ **a b c** Courtney, Thomas (2000). Mechanical Behavior of Materials. United States of America: Waveland Press, Inc. pp. 247–249. **ISBN 1-57766-425-6**.
8. ^ **a b c d e f** Chawla, Krishan (2013). Composite Materials. United States of America: Springer. **ISBN 978-0-387-74364-6**.
9. ^ **a b** Liao, Binbin; Wang, Panding; Zheng, Jinyang; Cao, Xiaofei; Li, Ying; Ma, Quanjin; Tao, Ran; Fang, Daining (1 September 2020). **"Effect of double impact positions on the low velocity impact behaviors and damage interference mechanism for composite laminates"**. Composites Part A: Applied Science and Manufacturing. **136**: 105964. doi:10.1016/j.compositesa.2020.105964. **ISSN 1359-835X**.
10. ^ Ma, Binlin; Cao, Xiaofei; Feng, Yu; Song, Yujian; Yang, Fei; Li, Ying; Zhang, Deyue; Wang, Yipeng; He, Yuting (15 February 2024). **"A comparative study on the low velocity impact behavior of UD, woven, and hybrid UD/woven FRP composite laminates"**. Composites Part B: Engineering. **271**: 111133. doi:10.1016/j.compositesb.2023.111133. **ISSN 1359-8368**.
11. ^ Aminakbari, Nariman; Kabir, Mohammad Zaman; Rahai, Alireza; Hosseinnia, Amirali (1 January 2024). **"Experimental and Numerical Evaluation of GFRP-Reinforced Concrete Beams Under Consecutive Low-Velocity Impact Loading"**. International Journal of Civil Engineering. **22** (1): 145–156. **Bibcode: 2024IJCE...22..145A**. doi:10.1007/s40999-023-00883-9. **ISSN 2383-3874**.
12. ^ Ray, B. C. (1 June 2006). "Temperature effect during humid ageing on interfaces of glass and carbon fibers reinforced epoxy composites". Journal of Colloid and Interface Science. **298** (1): 111–117. **Bibcode:2006JCIS..298..111R**. doi:10.1016/j.jcis.2005.12.023. **PMID 16386268**.
13. ^ Almudaihesh, Faisel; Holford, Karen; Pullin, Rhys; Eaton, Mark (1 February 2020). **"The influence of water absorption on unidirectional and 2D woven CFRP composites and their mechanical performance"**. Composites Part B: Engineering. **182**: 107626. doi:10.1016/j.compositesb.2019.107626. **ISSN 1359-8368**. **S2CID 212969984**. **Archived** from the original on 1 October 2021. Retrieved 1 October 2021.
14. ^ Guzman, Enrique; Cugnoni, Joël; Gmür, Thomas (May 2014). "Multi-factorial models of a carbon fibre/epoxy composite subjected to accelerated environmental ageing". Composite Structures. **111**: 179–192. doi:10.1016/j.compstruct.2013.12.028.
15. ^ Yari, Mehdi (24 March 2021). **"Galvanic Corrosion of Metals Connected to Carbon Fiber Reinforced Polymers"**. corrosionpedia.com. **Archived** from the original on 24 June 2021. Retrieved 21 June 2021.
16. ^ **"How is it Made"**. Zoltek. **Archived** from the original on 19 March 2015. Retrieved 26 March 2015.
17. ^ Syed Mobin, Syed Mobin; Azgerpasha, Shaik (2019). **"Tensile Testing on Composite Materials (CFRP) with Adhesive"** (PDF). International Journal of Emerging Science and Engineering. **5** (12): 6. **Archived** (PDF) from the original on 21 August 2022. Retrieved 21 August 2022 – via IJESE.

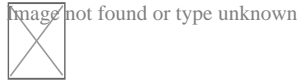
18. ^ Glass Companies, Molded Fiber (2018), **Technical Design Guide for FRP Composite Products and Parts** (PDF), vol. 1, p. 25, archived from **the original** (PDF) on 21 August 2022, retrieved 21 August 2022
19. ^ Unknown, Chris (22 January 2020). **"Composite Manufacturing Methods"**. Explore Composites!. **Archived** from the original on 21 August 2022. Retrieved 21 August 2022.
20. ^ **"Cutting of Fiber-Reinforced Composites: Overview"**. Sollex. 6 March 2025. Retrieved 31 March 2025.
21. ^ **"Taking the lead: A350XWB presentation"** (PDF). EADS. December 2006. Archived from the original on 27 March 2009.
22. ^ **"AERO – Boeing 787 from the Ground Up"**. Boeing. 2006. **Archived** from the original on 21 February 2015. Retrieved 7 February 2015.
23. ^ Pora, Jérôme (2001). **"Composite Materials in the Airbus A380 – From History to Future"** (PDF). Airbus. **Archived** (PDF) from the original on 6 February 2015. Retrieved 7 February 2015.
24. ^ Machado, Miguel A.; Antin, Kim-Niklas; Rosado, Luís S.; Vilaça, Pedro; Santos, Telmo G. (November 2021). **"High-speed inspection of delamination defects in unidirectional CFRP by non-contact eddy current testing"**. *Composites Part B: Engineering*. **224**: 109167. doi:10.1016/j.compositesb.2021.109167.
25. ^ Machado, Miguel A.; Antin, Kim-Niklas; Rosado, Luís S.; Vilaça, Pedro; Santos, Telmo G. (July 2019). **"Contactless high-speed eddy current inspection of unidirectional carbon fiber reinforced polymer"**. *Composites Part B: Engineering*. **168**: 226–235. doi:10.1016/j.compositesb.2018.12.021.
26. ^ Antin, Kim-Niklas; Machado, Miguel A.; Santos, Telmo G.; Vilaça, Pedro (March 2019). **"Evaluation of Different Non-destructive Testing Methods to Detect Imperfections in Unidirectional Carbon Fiber Composite Ropes"**. *Journal of Nondestructive Evaluation*. **38** (1). doi:10.1007/s10921-019-0564-y. ISSN 0195-9298.
27. ^ Guzman, Enrique; Gmür, Thomas (dir.) (2014). **A Novel Structural Health Monitoring Method for Full-Scale CFRP Structures** (PDF) (Thesis). EPFL PhD thesis. doi:10.5075/epfl-thesis-6422. **Archived** (PDF) from the original on 25 June 2016.
28. ^ **"Engines"**. Flight International. 26 September 1968. **Archived** from the original on 14 August 2014.
29. ^ Szondy, David (28 March 2025). **"Airbus previews next-gen airliner with bird-inspired wings"**. New Atlas. Retrieved 7 April 2025.
30. ^ **"Red Bull's How To Make An F1 Car Series Explains Carbon Fiber Use: Video"**. motorauthority. 25 September 2013. **Archived** from the original on 29 September 2013. Retrieved 11 October 2013.
31. ^ Henry, Alan (1999). **McLaren: Formula 1 Racing Team**. Haynes. ISBN 1-85960-425-0.
32. ^ Howard, Bill (30 July 2013). **"BMW i3: Cheap, mass-produced carbon fiber cars finally come of age"**. Extreme Tech. **Archived** from the original on 31 July 2015. Retrieved 31 July 2015.
33. ^ Petrány, Máté (17 March 2014). **"Michelin Made Carbon Fiber Wheels For Citroën Back In 1971"**. Jalopnik. **Archived** from the original on 18 May 2015. Retrieved 31 July 2015.

34. ^ L: aChance, David (April 2007). **"Reinventing the Wheel Leave it to Citroën to bring the world's first resin wheels to market"**. Hemmings. **Archived** from the original on 6 September 2015. Retrieved 14 October 2015.
35. ^ Ismail, N. **"Strengthening of bridges using CFRP composites."** najif.net.
36. ^ Rahman, S. (November 2008). **"Don't Stress Over Prestressed Concrete Cylinder Pipe Failures"**. Opflow Magazine. **34** (11): 10–15. **Bibcode: 2008Opflo..34k..10R. doi:10.1002/j.1551-8701.2008.tb02004.x. S2CID 134189821. Archived** from the original on 2 April 2015.
37. ^ Pike, Carolyn M.; Grabner, Chad P.; Harkins, Amy B. (4 May 2009). **"Fabrication of Amperometric Electrodes"**. Journal of Visualized Experiments (27). **doi: 10.3791/1040. PMC 2762914. PMID 19415069.**
38. ^ **"ICC and Kookaburra Agree to Withdrawal of Carbon Bat"**. NetComposites. 19 February 2006. Archived from the original on 28 September 2018. Retrieved 1 October 2018.
39. ^ **"Carbon Technology"**. Look Cycle. **Archived** from the original on 30 November 2016. Retrieved 30 November 2016.
40. ^ **"The Perils of Progress"**. Bicycling Magazine. 16 January 2012. Archived from **the original** on 23 January 2013. Retrieved 16 February 2013.
41. ^ **"Busted Carbon"**. **Archived** from the original on 30 November 2016. Retrieved 30 November 2016.
42. ^ Zhao, Z.; Gou, J. (2009). **"Improved fire retardancy of thermoset composites modified with carbon nanofibers"**. Sci. Technol. Adv. Mater. **10** (1): 015005. **Bibcode:2009STAdM..10a5005Z. doi:10.1088/1468-6996/10/1/015005. PMC 5109595. PMID 27877268.**
43. ^ **"Carbon fibre reinforced plastic bogies on test"**. Railway Gazette. 7 August 2016. **Archived** from the original on 8 August 2016. Retrieved 9 August 2016.
44. ^ Lomov, Stepan V.; Gorbatiikh, Larissa; Kotanjac, Željko; Koissin, Vitaly; Houille, Matthieu; Rochez, Olivier; Karahan, Mehmet; Mezzo, Luca; Verpoest, Ignaas (February 2011). **"Compressibility of carbon woven fabrics with carbon nanotubes/nanofibres grown on the fibres"** (PDF). Composites Science and Technology. **71** (3): 315–325. **doi:10.1016/j.compscitech.2010.11.024.**
45. ^ Hans, Kreis (2 July 2014). **"Carbon woven fabrics"**. compositesplaza.com. Archived from **the original** on 2 July 2018. Retrieved 2 January 2018.
46. ^ Ali Nahran, Shakila; Saharudin, Mohd Shahneel; Mohd Jani, Jaronie; Wan Muhammad, Wan Mansor (2022). **"The Degradation of Mechanical Properties Caused by Acetone Chemical Treatment on 3D-Printed PLA-Carbon Fibre Composites"**. In Ismail, Azman; Dahalan, Wardiah Mohd; Öchsner, Andreas (eds.). Design in Maritime Engineering. Advanced Structured Materials. Vol. 167. Cham: Springer International Publishing. pp. 209–216. **doi:10.1007/978-3-030-89988-2_16. ISBN 978-3-030-89988-2. S2CID 246894534.**
47. ^ **"Polyamid CF Filament – 3D Druck mit EVO-tech 3D Druckern"** [Polyamide CF Filament – 3D printing with EVO-tech 3D printers] (in German). Austria: EVO-tech. **Archived** from the original on 30 April 2019. Retrieved 4 June 2019.
48. ^ Schinner, G.; Brandt, J.; Richter, H. (1 July 1996). **"Recycling Carbon-Fiber-Reinforced Thermoplastic Composites"**. Journal of Thermoplastic Composite Materials. **9** (3): 239–245. **doi:10.1177/089270579600900302. ISSN 0892-7057.**

49. ^ Roux, Maxime; Eguémann, Nicolas; Dransfeld, Clemens; Thiébaud, Frédéric; Perreux, Dominique (1 March 2017). **"Thermoplastic carbon fibre-reinforced polymer recycling with electrodynamical fragmentation: From cradle to cradle"**. *Journal of Thermoplastic Composite Materials*. **30** (3): 381–403. doi: [10.1177/0892705715599431](https://doi.org/10.1177/0892705715599431). ISSN 0892-7057.
50. ^ Bernatas, Rebecca; Dagréou, Sylvie; Despax-Ferreres, Auriane; Barasinski, Anaïs (2021). **"Recycling of fiber reinforced composites with a focus on thermoplastic composites"**. *Cleaner Engineering and Technology*. **5**: 100272. Bibcode: [2021CEngT...500272B](https://doi.org/10.1016/j.clet.2021.100272). doi:[10.1016/j.clet.2021.100272](https://doi.org/10.1016/j.clet.2021.100272).
51. ^ Naqvi, S. R.; Prabhakara, H. Mysore; Bramer, E. A.; Dierkes, W.; Akkerman, R.; Brem, G. (1 September 2018). **"A critical review on recycling of end-of-life carbon fibre/glass fibre reinforced composites waste using pyrolysis towards a circular economy"**. *Resources, Conservation and Recycling*. **136**: 118–129. Bibcode: [2018RCR...136..118N](https://doi.org/10.1016/j.resconrec.2018.04.013). doi:[10.1016/j.resconrec.2018.04.013](https://doi.org/10.1016/j.resconrec.2018.04.013). ISSN 0921-3449.
52. ^ Zhang, Jin; Chevali, Venkata S.; Wang, Hao; Wang, Chun-Hui (15 July 2020). **"Current status of carbon fibre and carbon fibre composites recycling"**. *Composites Part B: Engineering*. **193**: 108053. doi: [10.1016/j.compositesb.2020.108053](https://doi.org/10.1016/j.compositesb.2020.108053). ISSN 1359-8368.
53. ^ Cousins, Dylan S.; Suzuki, Yasuhito; Murray, Robynne E.; Samaniuk, Joseph R.; Stebner, Aaron P. (1 February 2019). **"Recycling glass fiber thermoplastic composites from wind turbine blades"**. *Journal of Cleaner Production*. **209**: 1252–1263. Bibcode:[2019JCPro.209.1252C](https://doi.org/10.1016/j.jclepro.2018.10.286). doi:[10.1016/j.jclepro.2018.10.286](https://doi.org/10.1016/j.jclepro.2018.10.286). ISSN 0959-6526.
54. ^ Bernatas, Rebecca; Dagreou, Sylvie; Despax-Ferreres, Auriane; Barasinski, Anaïs (1 December 2021). **"Recycling of fiber reinforced composites with a focus on thermoplastic composites"**. *Cleaner Engineering and Technology*. **5**: 100272. Bibcode:[2021CEngT...500272B](https://doi.org/10.1016/j.clet.2021.100272). doi:[10.1016/j.clet.2021.100272](https://doi.org/10.1016/j.clet.2021.100272). ISSN 2666-7908.
55. ^ **"Zyvex Performance Materials Launch Line of Nano-Enhanced Adhesives that Add Strength, Cut Costs"** (PDF) (Press release). Zyvex Performance Materials. 9 October 2009. Archived from [the original](#) (PDF) on 16 October 2012. Retrieved 26 March 2015.
56. ^ Trimble, Stephen (26 May 2011). **"Lockheed Martin reveals F-35 to feature nanocomposite structures"**. *Flight International*. Archived from the original on 30 May 2011. Retrieved 26 March 2015.
57. ^ Pozegic, T. R.; Jayawardena, K. D. G. I.; Chen, J-S.; Anguita, J. V.; Balocchi, P.; Stolojan, V.; Silva, S. R. P.; Hamerton, I. (1 November 2016). **"Development of sizing-free multi-functional carbon fibre nanocomposites"**. *Composites Part A: Applied Science and Manufacturing*. **90**: 306–319. doi: [10.1016/j.compositesa.2016.07.012](https://doi.org/10.1016/j.compositesa.2016.07.012). hdl:[1983/9e3d463c-20a8-4826-89f6-759e950f43e6](https://hdl.handle.net/1983/9e3d463c-20a8-4826-89f6-759e950f43e6). ISSN 1359-835X. S2CID [137846813](https://doi.org/10.1016/j.compositesa.2016.07.012). Archived from the original on 1 October 2021. Retrieved 1 October 2021.
58. ^ **"AROVEX™ Nanotube Enhanced Epoxy Resin Carbon Fiber Prepreg – Material Safety Data Sheet"** (PDF). Zyvex Performance Materials. 8 April 2009. Archived from [the original](#) (PDF) on 16 October 2012. Retrieved 26 March 2015.

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About Soil mechanics

Soil auto mechanics is a branch of dirt physics and used auto mechanics that explains the habits of soils. It varies from liquid auto mechanics and solid mechanics in the sense that dirt contains a heterogeneous mix of liquids (generally air and water) and bits (typically clay, silt, sand, and gravel) but soil might also have natural solids and other matter. Along with rock auto mechanics, soil mechanics gives the academic basis for analysis in geotechnical design, a subdiscipline of civil engineering, and engineering geology, a subdiscipline of geology. Soil mechanics is utilized to assess the contortions of and flow of liquids within natural and manufactured structures that are supported on or made from dirt, or frameworks that are buried in soils. Example applications are building and bridge structures, retaining walls, dams, and hidden pipeline systems. Principles of dirt technicians are additionally used in relevant self-controls such as geophysical design, coastal design, agricultural engineering, and hydrology. This article defines the genesis and make-up of dirt, the distinction between pore water pressure and inter-granular effective stress and anxiety, capillary action of liquids in the soil pore spaces, soil category, infiltration and leaks in the structure, time dependent adjustment of quantity due to pressing water out of little pore rooms, additionally known as combination, shear stamina and tightness of soils. The shear strength of soils is largely stemmed from friction between the bits and interlocking, which are extremely conscious the efficient tension. The write-up concludes with some instances of applications of the principles of soil technicians such as slope stability, lateral earth stress on keeping wall surfaces, and birthing ability of foundations.

About Cook County

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