Composition and structure of composite building materials

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Abstract: In today's industry, fiber reinforced thermosets and thermoplastics play an important role in production, engineering, usage and education. This chapter provides an overview of the materials from which a composite can be composed, and their most important properties. First we shall determine what a composite actually is.

Various definitions of composites may be used:
• 'a combination of a stronger and a weaker material'
• 'a material composed of different parts'
• 'a combination of two materials'

The third definition implies that alloys, two component adhesives and solutions are composites. The first and last definitions are restrictive, since no further materials are included. In this book, the following definition will be used:

A composite is a material structure that consists of at least two macroscopically identifiable materials that work together to achieve a better result.

This is quite a mouthful, but at least the objections raised above no longer apply. This description still requires further explanation.

When a composite product is manufactured, the material itself and the structure are often made at the same time. Usually there is no raw, unmachined material that is kneaded, deformed and assembled into a structure, but the structure as well as the material are made in one go; hence the term 'material structure'. Composites as defined in this book are manufactured of fibres mixed with a (polymer) resin or matrix. These two components do not dissolve into each other and remain visible ("macroscopically identifiable"). The favourable properties of fibres and matrix are utilised to the maximum, while the unfavourable properties of one component are compensated for by the other component as much as possible, achieving a structure that could not have been made with either of the separate components.

Composite materials are relatively unknown and are often regarded as hightech materials for modern applications. Almost every material has previously gone through this phase; even wood used for building ships was once regarded as revolutionary and later the same applied to steel.

This process was not straightforward. A certain motivation was required for adopting new materials (e.g. strength, stiffness, shortage of existing materials) and new construction methods became necessary. Shipyards, for example, disappeared or had to be completely reorganised in order to process the new material. Design methods and computational procedures changed, often through a process of bitter experience; for example, unexpected brittle fractures in American Liberty ships eventually helped improve steel ship design.

The mechanical and other properties of the composite are determined by three main parameters: the high strength of the reinforcing fibers, the rigidity of the matrix, and the strength of the bond at the matrix-fiber interface. The ratio of these parameters characterizes the entire complex of mechanical properties of the material and the mechanism of its destruction. The operability of the composite is ensured both by the correct choice of the initial components and by a rational production technology that ensures the preservation of their original properties.

The variety of fibers and matrix materials, as well as reinforcement schemes, makes it possible to precisely control the strength, stiffness indicators, as well as the level of operating temperatures

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and other mechanical and physical properties of materials by selecting the composition, changing the ratio of components, etc.

There are several classifications for fibrous composite materials, for example, materials science (by the nature of the components); constructive (according to the type of reinforcement and its orientation in the matrix). Several large groups of composites can be distinguished: those with a polymer matrix (plastics), those with a metal matrix (metal composites), those with a ceramic matrix, and those with a carbon matrix.

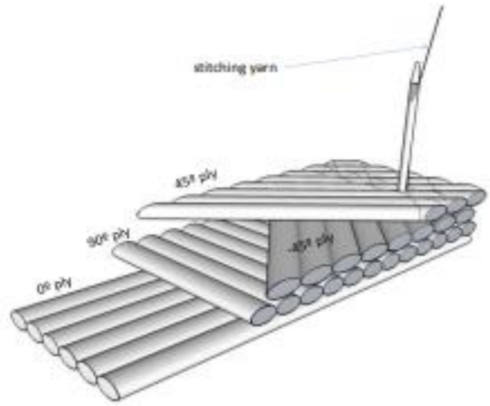
- you can find out in detail about all the work performed as part of the expertise in the section: “Construction and technical expertise. Forensic examination."

Depending on the origin of the fibers used for reinforcement, the following types of composites are distinguished, for example, on a polymer matrix: fiberglass, carbon fiber, boron plastics, organoplastics, etc. The same is true for other matrices.

Composites are also distinguished from reinforcement methods: compactly formed from layers reinforced with parallel-continuous fibers, reinforced with fabrics with random and spatial reinforcement.

Depending on the type of reinforcement, composites can be divided into two groups: dispersion-strengthened and fibrous, which differ in structure and mechanism of high strength formation.

Dispersion-strengthening composites



Dispersion-strengthening composites **-** are a material in the matrix of which fine particles are evenly distributed, their optimal content is 2-4%. But the effect of hardening is associated with particle sizes and their convergence, i.e. concentration. For example, when hardening with small particles (0.001-0.1 μm), the volume concentration can reach up to 15%; with particles larger than 1.0 μA, the volume concentration may be 25% or more. At the same time, strength, hardness, heat resistance increase, elasticity is preserved (for example, matrix - bitumen, rubber, artificial polymer; reinforcing particles - chalk, mica, carbon, silica, limestone). In such materials, when loaded, the entire load is taken up by the matrix.

In fibrous, structurally, composite materials, high-strength fibers perceive the main stresses under external and internal loads and provide the necessary rigidity and strength. A feature of the fibrous composite structure is the uniform distribution of fibers in the plastic matrix, their volume fraction can reach 75% or more.

Reinforcing fibers must meet a set of operational and technological requirements. The former include requirements for strength, rigidity, density, stability of properties in a certain temperature range, chemical resistance, etc.

The theoretical strength of materials increases with an increase in the elastic modulus and surface energy of a substance and decreases with an increase in the distance between adjacent atomic planes.

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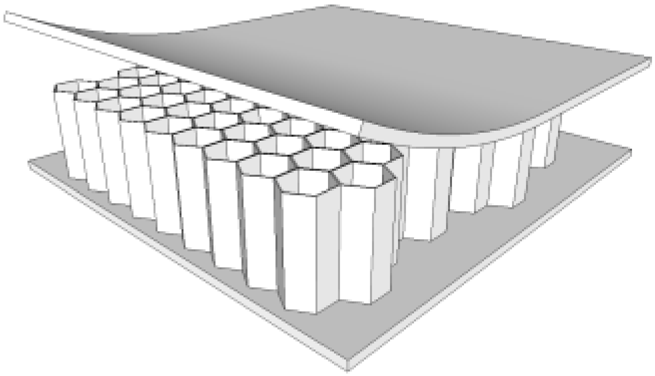
Consequently, high-strength solids must have a sufficiently high elastic modulus and surface energy and the largest possible number of atoms per unit volume. These requirements are met by beryllium, boron, carbon, nitrogen, oxygen, aluminum and silicon. The strongest materials always contain one of these elements, and often consist of only these elements.

When creating fibrous composites, high-strength glass, carbon, boron and organic fibers, metal wire plates, as well as fibers and filamentous crystalline components of a number of carbides, oxides, nitrides and other compounds are used. Reinforcing components in composites are used in the form of monofilaments, threads, wires, bundles, nets, fabrics, tapes, canvases.

Technological requirements include those that make it possible to create a high-performance process for manufacturing products based on them. An important requirement is also the compatibility of the fibers with the matrix material, i.e. the possibility of achieving a strong fiber-matrix bond while maintaining the initial values of the mechanical properties of the components.

Matrix materials



Matrix materials. The matrix provides a monolithic structure of the composite, fixes the given shape of the product or structure and the relative position of the reinforcing fibers, distributes the acting stresses over the volume of the material, ensuring a uniform load on the fibers and its redistribution when the fiber particles are destroyed. The material of the matrix determines the method of manufacturing products, the possibility of making structures of given dimensions and shapes, as well as the parameters of technical processes, etc. The requirements for matrices can be divided into operational and technological ones. Operational requirements include the requirements associated with the mechanical and physico-chemical properties of the matrix material, which ensure the performance of the composition under the influence of various operational factors. Technological requirements are determined by the processes of obtaining a composite, i.e. combining the reinforcing fibers with the matrix and the final formation of the product.

The purpose of technological operations is to ensure a uniform distribution of fibers in the matrix (without touching each other) at a given volume content; the maximum possible preservation of the properties of the fibers, most importantly - strength; creation of a sufficiently reliable interaction at the fiber-matrix interface.

- you can learn in detail about all the work performed as part of research and expertise in the section: “Study of structures and materials. Examination of parts, products, assemblies, elements, etc.”

Section boundaries. First of all, the adhesive (gluing) interaction of the fiber and the matrix determines the level of properties of the composites and their operation during operation. Local stresses in the component reach their maximum values near or directly at the interface, where the destruction of the material usually begins. The interface must ensure efficient transfer of the load

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from the matrix to the fibers. The adhesive bond along the interface should not be destroyed under the action of thermal and shrinkage stresses, due to differences in the temperature coefficient of linear expansion of the matrix and fiber, or as a result of chemical shrinkage of the binder during its curing. The protection of fibers from the impact of the external environment is also largely determined by the adhesive interaction along the interface.

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