Plastics + Asbestos

# Asbestos fibers

By Robert E. Byrne Jr.*

Asbestos has been used in plastics in large quantities since the development of phenol-formaldehyde resins in 1909. The longer grades have traditionally been used for reinforcement in the form of fibers, yarns, or textiles. The shorter grades are used as fillers or extenders and, to some extent, for viscosity control. The utility of asbestos has been demonstrated in most types of resins and in myriad applications.

Asbestos, a comparative newcomer in industry, is one of the few important non-metallic minerals that the United States imports from foreign sources. Less than 10% of our annual requirement is currently produced from domestic deposits. The remainder comes mainly from Canada. Since 1960, however, domestic production has increased rapidly to an estimated 1968 production valued at more than $6 million.

The name asbestos is a broad, commercial term that has been applied to a number of natural fibrous silicate minerals that are incombustible and can be separated by mechanical or chemical means into fibers of various lengths and thicknesses. They differ in chemical composition and other properties.

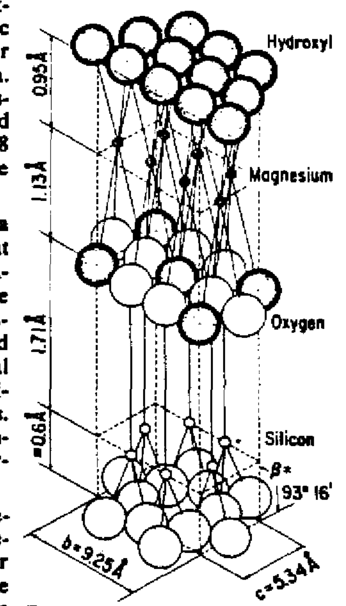


**Fig. 1: Hydroxyl outer surface of a chrysotile asbestos fibril.**

Low cost, exceptional mechanical properties, and resistance to heat account for much of the growth in the use of asbestos in plastics products. It has recently been recognized that the asbestos unit fibril is a naturally occurring "whisker", i.e., an inorganic crystal grown under controlled pressures and temperature. Because of its high strength, stiffness, and aspect ratio, the asbestos fibril is an excellent whisker reinforcement. Maximum utilization of its desirable reinforcing characteristics requires a high degree of fibril liberation and the absence of extraneous gangue material.

Asbestos research is expanding the variety of products available, with a strong trend toward more highly refined fiber with higher standards of quality control. High performance, chemically modified asbestos products with altered surface properties are now on the market. The industry is working to keep pace with the increasing sophistication of the plastics industry. Chemically "designed" asbestos products will be part of custom engineered plastics systems of the future.

## The asbestos minerals

The six generally recognized varieties of asbestos include the fibrous form of serpentine, known as chrysotile, and five minerals of the amphibole group: anthophyllite, crocidolite, actinolite, tremolite, and amosite. Their comparative properties are shown in Table I.

*Chrysotile* is the most plentiful and useful form of asbestos. Of the more than two billion lbs. of asbestos used each year by the plastics industry, 90-plus % is chrysotile. Its positive surface charge, softness and flexibility, and its low refractive index set it apart from other asbestos. Chrysotile's fiber diameters, less than 0.03 micron, are the smallest among commonly known fibers, and the material has exceptional mechanical strength, as indicated by the evidence listed in Table I, p. 388.

Chrysotile's crystal structure is similar to that of the kaolinite minerals, consisting of alternate layers of tetrahedrally co-ordinated silica and octahedrally co-ordinated magnesium hydroxide joined into a composite sheet. The outer surface of the chrysotile fibril, essentially magnesium hydroxide, is similar to the mineral brucite. Fig. 1 is a representation of this structure showing the hydroxyl outer surface of the fibril. The magnesium hydroxide surface of chrysotile, with its resultant cationic charge, determines its chemical affinity for many resin systems.

Because of a mismatch of the brucite and silica layers within the chrysotile structure, curved composite sheets are formed that result in closed cylinders of extreme length-to-diameter ratio (often as high as 1000:1). Evidence for the cylindrical structure of chrysotile has been obtained from X-ray and electron diffraction studies, and from electron micrographs. Recent high resolution electron microscopic studies in Japan have shown the average outside diameter of the chrysotile fiber to be about 250 Å, and its inside diameter to be about 140 Å.

Chrysotile occurs only in serpentinite rock bodies, most commonly as cross-fiber veins. These cross fibers, an electron micrograph of which is shown in Fig. 2, vary in length up to 2 in. and are usually shortened during processing. In most mining operations with ore containing less than 15% asbestos, the fiber must be separated from its host rock by crushing and milling, with subsequent grading. Chrysotile is graded by a Quebec standard according to fiber length, from the longest, Grade 3, to the shortest, Grade 7.

Fiber purification is accomplished by conventional dry milling techniques as well as by newly developed hydraulic processes. Figure 2 shows the fibril liberation possible through pneumatic and hydraulic processing, respectively. The high purity colloidal fiber products, represented by Fig. 3, resulting from hydraulic milling are one example of the trend within the asbestos industry toward controlled, higher purity products.

Recently, commercial products based on chrysotile have been introduced which, by chemical modifications of the normal chrysotile fiber, have novel surface properties. These materials are used mainly for viscosity control in anti-sag and thixotropic applications.

Compared with chrysotile, *amphibole* fibers are larger in cross section, harsh and hard. The amphibole asbestos minerals are anionic in surface charge and are more resistant to acids than is chrysotile.

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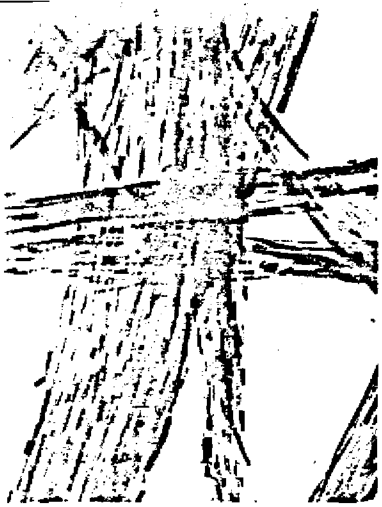

**Fig. 2** (left): Electron micrograph of chrysotile asbestos fibers. **Fig. 3:** Purified colloidal asbestos fiber products after hydraulic milling.

*Anthophyllite* fibers usually occur as fibrous masses containing randomly oriented cubic blocks of fiber up to an inch in length. They are generally used in insulating materials, as filtering media, and as fillers in plastics, paints, and asbestos-cement products. Asbestos-reinforced polypropylene contains anthophyllite almost exclusively.

*Crocidolite*, or blue asbestos, is found principally in South Africa. Needle-like in structure and possessed of exceptionally high mechanical strength, it is used in plastics where its pronounced color is not detrimental.

*Tremolite* and *actinolite* are very similar, except for the higher iron content of the latter. Both are in relatively short supply and are used mainly as filter media or fillers. *Amosite* is a long yellowish-brown fiber which is harsh and brittle, and is used mainly in thermal insulation.

## Thermoplastics applications

The largest single use for asbestos in thermoplastics is in vinyl-asbestos floor tile. It is also used in numerous sealants and mastics for the automotive and construction industries, in compounds based on butyl rubber, vinyl plastisols, and asphalt. Commercial thermoplastic molding compounds using asbestos include polypropylene, nylon, rigid PVC, and linear polyethylene.

Short fiber chrysotile is incorporated into vinyl asbestos floor tile to improve heat resistance and dimensional stability.

Since 1965, the consumption of asbestos-reinforced polypropylene by the automotive industry has increased rapidly. This trend toward the use of short fiber products for reinforcement is dependent on the inherent strength and fibril geometry of asbestos. Table II shows the increased stiffness, heat resistance, and other properties of polypropylene containing 40% anthophyllite. Lowering the asbestos content to 20% is said to double or triple impact strength, and improve stability and gloss while sacrificing only 25% in flexural modulus and 25° F. in heat distortion temperature.

The volume of short fiber chrysotile used in mastics, sealants, and adhesives of various types is increasing. From 5 to 60% asbestos is used in adhesives to reduce crazing, shrinkage, and embrittlement. Asbestos also reduces cost, increases bulk, and provides controlled penetration and resistance to heat in such adhesives as phenolics, urea, resorcinol, epoxy, nitrile and reclaimed rubber, and silicates. In mastics and sealants, asbestos provides toughness, flow and penetration control, and reduced cost. The colloidal grades of chrysotile are reported to contribute additional performance and handling improvements to this type of product.

### Table I: Comparative properties of asbestos minerals

| Property | Chrysotile | Anthophyllite | Crocidolite | Actinolite | Tremolite | Amosite |
|---|---|---|---|---|---|---|
| Composition | $Mg_3Si_2O_5(OH)_4$ | $Mg_7Si_8O_{22}(OH)_2$ | $Na_2Fe_5Si_8O_{22}(OH)_2$ | $Ca_2Fe_5Si_8O_{22}(OH)_2$ | $Mg_5Ca_2Si_8O_{22}(OH)_2$ | $(Fe, Mg)_7Si_8O_{22}(OH)_2$ |
| Crystal habit | Fine, easily separable fibers | Prismatic crystals and fibers | Long brittle fibers | Prismatic crystals and fibers | Prismatic crystals and fibers | Prismatic crystals and fibers |
| Veining | Cross-, slip-, & massive-fiber | Slip- & massive-fiber | Cross-fiber | Slip- & massive-fiber | Slip- & massive-fiber | Cross-fiber |
| Color | White, gray, green | Gray-white | Blue | Green | White, gray-white, green | Ash gray or brown |
| Luster | Silky | Vitreous to pearly | Silky to dull | Silky | Silky | Vitreous to pearly |
| Texture | Soft to harsh, also silky | Harsh | Soft to harsh | Harsh | Harsh | Harsh |
| Flexibility | Very good | Poor | Good | Poor | Poor | Good |
| Hardness | 2.5-4 | 5.5-6 | 4 | 6 | 5.5 | 5.5-6 |
| Fiber diameter, A | 200-400 | 600-900 | 600-900 | 600-900 | 600-900 | 600-900 |
| Tensile strength, p.s.i. | 300,000-800,000 | <4000 | 400,000-600,000 | <1000 | 1000-8000 | 100,000-200,000 |
| Modulus of elasticity, p.s.i. | $23x10^6$ | — | $27x10^6$ | — | — | $24x10^6$ |
| Specific heat, Btu/lb./° F. | 0.266 | 0.210 | 0.201 | 0.217 | 0.212 | 0.193 |
| Specific gravity | 2.4-2.6 | 2.8-3.1 | 3.2-3.3 | 3.0-3.2 | 2.9-3.2 | 3.1-3.3 |
| Refractive index (mean) | 1.51-1.55 | 1.61 | 1.7 | 1.63 | 1.61 | 1.64 |
| pH | 9.5-10.3 | 9.4 | 9.1 | 9.5 | 9.5 | 9.1 |
| Electric charge in aqueous slurry | Positive | Negative | Negative | Negative | Negative | Negative |
| Resistance to acids | Poor | Very good | Good | Fair | Good | Good |

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## Table II: Physical properties of asbestos reinforced thermoplastics[a]

| Property | Polypropylene Base resin | Polypropylene 40% asbestos | Nylon (with 30% asbestos) 6 | Nylon (with 30% asbestos) 6/10 | Nylon (with 30% asbestos) 6/6 |
|---|---|---|---|---|---|
| Tensile strength, p.s.i.x$10^{-3}$ | 5.0 | 4.8 | 20.0 | 14.0 | 20.0 |
| Ultimate elongation, % | 200 | 5 | — | — | — |
| Flexural strength, p.s.i.x$10^{-3}$ | — | — | 30.0 | 21.0 | 30.0 |
| Flexural modulus, p.s.i.x$10^{-6}$ | 0.18 | 0.65 | 1.5 | 1.2 | 1.5 |
| Izod impact, ft.lb./in. | | | | | |
| notched | 0.4 | 0.5 | 0.9 | 0.8 | 0.8 |
| unnotched | — | — | 13 | 14 | 12 |
| Heat deflection temp., °F. | | | | | |
| 66 p.s.i. | 230 | 290 | — | — | — |
| 264 p.s.i. | — | — | 385 | 340 | 465 |
| Deformation under load, 24 hr., @ 2000 p.s.i., 122° F., % | 3.5 | 1.6 | — | — | — |
| Specific gravity | 0.91 | 1.24 | — | — | — |
| Water absorption, 24 hr., % | <0.01 | 0.02 | — | — | — |
| Coefficient of linear thermal expansion, $10^{-5}$ in./in./° F. | 3.8 | 2.1 | — | — | — |
| Mold shrinkage, in./in. | 0.015 | 0.01 | — | — | — |
| Dielectric strength, S/T, VPM | 650 | 450 | 450 | 450 | 450 |
| Volume resistivity, ohms/cm. | 1.0x$10^{17}$ | 1.5x$10^{15}$ | 6.9x$10^{11}$ | 9.6x$10^{12}$ | 7.6x$10^{12}$ |
| Arc resistance, sec. | 136 | 121 | 127 | 123 | 126 |
| Dielectric constant, | | | | | |
| @ 60 Cyc. | 2.2 | 2.75 | 4.3 | 4.0 | 4.1 |
| @ $10^6$ Cyc. | 2.2 | 2.6 | 3.5 | 3.3 | 3.5 |
| Dissipation factor, | | | | | |
| @ 60 Cyc. | 0.0002 | 0.007 | 0.053 | 0.031 | 0.032 |
| @ $10^6$ Cyc. | 0.0002 | 0.002 | 0.019 | 0.018 | 0.017 |

*a—Comparisons with properties of unreinforced nylons may be made by consulting the Plastics Properties Charts in Section 5 of this Encyclopedia.*

Recently, several manufacturers have introduced asbestos-reinforced nylon and polyolefin molding compounds. The mechanical and electrical properties of several nylon compounds containing 30% chrysotile are also shown in Table II. The performance of colloidal chrysotile in this application is illustrative of the type of whisker reinforcement which occurs through optimum natural affinity of the fiber and the polymer matrix. High levels of reinforcement can be attained in resins lacking this affinity by using high purity colloidal chrysotile and technology to improve fiber wetting and fiber dispersion. Recently disclosed "ceraplast" products, for example, exhibit threefold increases in tensile strength and modulus with 40% asbestos in linear polyethylene. The fineness of chrysotile fibers permits dense structures with maximum resin fiber adhesion enhanced by the high surface area, ca. 60 $m^2/g$, of the asbestos. An extension of this technology is reported to produce a number of products useful when transparency or translucency is desired in the composite. Transparent resins such as vinyls and inonomers can, in many cases, be reinforced with little loss in clarity since the diameter of colloidal asbestos is well under the wave-length of visible light.

### Thermoset applications

Asbestos-filled or reinforced plastic products originated with phenolic molding compounds. However, virtually every type of thermosetting resin, including urea-formaldehyde, melamines, furanes, epoxies, polyesters, and silicones, may be asbestos-filled. Asbestos shorts and floats are used in molding compounds to produce desirable molding characteristics, good surface finish, and improved physical properties in the molded pieces to be employed as electrical insulation, heat insulation, or high friction brake and clutch facings.

Polyester premixes used to fabricate automotive parts, tractor and marine engine housings, and materials handling bins and containers often contain short fiber chrysotile to provide flow control, improved surface appearances, reduced shrinkage, and low cost. The new low profile systems utilize asbestos for controlled shrinkage, improved mechanical strength, and heat resistance.

The amount of asbestos needed varies with the particular resin system and the fiber length and degree of openness of the asbestos. Each system has an optimum level for maximum mechanical strength. For example, in phenolics about 25% is typical for asbestos floats, or as low as 5% colloidal chrysotile. This level may vary up to 60%, however, depending on the levels of chemical, thermal, and impact resistance, and the electrical properties desired. Asbestos-filled phenolic and urea-formaldehyde resins find use in many electrical applications where heat resistance is also required. Asbestos-filled polyester and diallyl phthalate compounds are also used in electrical applications. The asbestos-containing compounds offer the capability of molding with exceptional accuracy, molding-in metal inserts easily, and mass producing intricate shapes difficult to fabricate from other dielectric materials.

Phenolic-asbestos laminates used for rocket flame tubes are one example of the increased demand for asbestos-reinforced systems brought about by space age requirements for heat, chemical, and shock resistance.—**End**

## Table III: Asbestos in plastics

As a reinforcing fiber

| Advantages | Disadvantages |
|---|---|
| Higher modulus | increase in viscosity of resin |
| Some improvement in tensile | fair electrical resistance |
| Flow control in mold | somewhat abrasive |
| Good surface finish | possible polymer degration |
| Heat stability | high density |
| Dimensional stability | |
| Reduced creep | |
| Chemical resistance | |
| Higher hardness | |
| Arc resistance | |
| Low water absorption | |

As a reinforcing filler

| Advantages | Disadvantages |
|---|---|
| Low cost | fair impact strength |
| Easy flash removal | dark color |
| Flow control in mold | possible mixing difficulties |
| Minimum fiber degration | |
| Good flexural strength | |
| Low water absorption | |
| Heat resistance | |
| Good electrical properties | |
| Chemical resistance | |

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