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"ASBESTOS FIBERS PROPERTIES AND USAGE"

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Definition

Asbestos is a general commercial name that has been accepted and applied to a number of natural occurring fibrous mineral silicates that differ in chemical composition, physical properties, are incombustible and can be separated by mechanical means into filaments of various lengths and widths.

Occurrence

Asbestos of one variety or another occurs in all parts of the world. The large deposits are located in Canada, Rhodesia, Transvaal South Africa, Cape South Africa, Russia, Australia, Venezuela and India. In the United States it is found in Vermont, Arizona, California and many other states.

Asbestos fibers are found sandwiched in certain types of rocks in the form of cross vein fibers, slip fibers, ribbon fibers or mass fibers of random orientation.

Many deposits exist that are not commercially operative and are not placed in production.

Origin

In Canada the chrysotile fibers originate from such rocks as dunite, peridotite and pyroxenite which have been altered to the form of serpentine by hydrothermal reactions upon magnesia rich minerals such as olivine, forsterite, enstatite and diopside.

In Arizona and in the Carolina district of the Transvaal South Africa the chrysotile fibers occur in sedimentary rocks and are the products of the alteration of magnesian limestone.

In South Africa the crocidolites and amosites originate from rocks derived from sediments rich in iron and silica called ironstone. Sometimes these fibers are found in deposits close by, however, the blue fiber always contains the element of sodium in the molecule, whereas the amosite is void of this element.

Theories of Formation

Many theories have been advanced by the geologists on the formation of asbestos fiber, but, in general, it is more or less accepted that the rocks were conditioned by upheavals, faulting, cracking, volcanic activity, etc., and that the cracks and small fissures in the rocks served as a chemical laboratory for the physical and chemical reactions that took place over geological periods. These periods are estimated as Devonian and Pre-Cambrian. (1)

In Canada during the alteration of the peridotite, about half of the original olivine or pyroxene was converted into serpentine and the general serpentinization was caused by water present in a peridotite magma. A second and more local alteration produced the asbestos veins by the injection of heated vapors or waters. These entered along faults converting the walls into serpentine. In many cases, the continued action converted the fibrous material in the fault planes into brucite.

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...m the fault fissures the waters penetrated all the pores of the rocks and reactions ...t up with the peridotite to convert the walls into serpentine, and then the excess ...terial was carried into the fissures where it was deposited and crystallized as ...bestos.

...e fiber lengths then were governed by the small openings in the rocks. Thus, a ... inch opening produced a one inch fiber, and, likewise, a 1/16 inch opening pro... ...uced a 1/16 inch fiber.

...arieties of Asbestos Fibers and Their Properties (2)

...hrysotile - the most common and universal used fiber is a hydrous magnesium silicate having the formula of $3MgO \cdot 2SiO_2 \cdot 2H_2O$ or it is sometimes expressed as $Mg_6Si_4O_{11}(OH)_6 \cdot H_2O$.

...nthophyllite - is a magnesium iron silicate of the amphibole group having a formula of $(Mg \cdot Fe)_7\ Si_8O_{22}(OH)_2$ or 7 $(MgO.FeO)_8SiO_2.H_2O$.

...mosite - is considered by some mineralogists as a form of anthophyllite in which a part of the magnesium is replaced by iron. Its formula is $(Fe \cdot Mg) \cdot SiO_3$ or $(FeO \cdot MgO) \cdot SiO_2$. It does not contain any sodium as a part of its molecule as found in crocidolite.

...rocidolite - is a hydrated ferrous-ferric silicate in which there is a partial replacement of the iron by sodium. Its formula is $NaFe_3^{II}Fe_2^{III}.Si_8O_{22}(OH)_2$ or $Na_2O \cdot 3FeO \cdot Fe_2O_3 \cdot 8SiO_2 \cdot H_2O$.

...ctinolite - is a complex magnesium iron silicate and differs from tremolite by having iron as a part of the molecule. Its formula is $Ca(MgFe)_3(SiO_3)_4$.

...remolite - is a calcium magnesium silicate void of iron. Its formula is $Ca_2Mg_5Si_8O_{22}(OH)_2$ or $2CaO \cdot 5MgO \cdot 8SiO_2 \cdot H_2O$.

...hemical Properties

...he chemical properties of each variety of asbestos differ as shown by the chemical ...nalysis.

	Canadian Chrysotile	Rhodesian Chrysotile	African Blue	Amosite
...nition loss 1800°F	13.95	14.35	3.06*	0.00*
...O2	38.90	38.40	46.70	48.46
...O	41.45	41.80	2.74	6.24
...e2O3	2.57	3.18	24.99	4.33
...O	1.73	0.83	14.00	34.90
...2O3	0.77	1.13	0.59	0.61
...O	0.21	0.15	Tr	Tr
...O	0.18	0.08	0.20	0.44
...2O	0.09	0.06	3.72	0.01
...O5	< 0.05	< 0.10	0.13	0.08
...2	< 0.01	< 0.01	0.04	0.08
...O	< 0.10	< 0.10	2.38	0.20
...e2O3	0.03	0.02	0.18	0.77
...lfates as SO3	0.09	0.27	0.03	0.02
...lorides as Cl	0.27	0.02	< 0.01	0.02
...ter soluble	0.39	0.24	0.14	0.22

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Ignition loss low due to oxidation of Fe^{+2} to Fe^{+3} and a subsequent gain in sample weight.

Approximate Chemical Analysis of Asbestos Fibers (3)

	Chrysotile	Anthophyllite	Amosite	Tremolite	Crocidolite
SiO_2 %	37 - 44	56 - 58	49 - 53	51 - 62	49 - 53
MgO %	39 - 44	28 - 34	1 - 7	0 - 30	0 - 3
CaO %	0.0 - 6.0	3 - 12	34 - 44	1.5 - 5.0	13 - 20
Fe_2O_3 %	0.1 - 5.0	—	—	—	17 - 20
Al_2O_3 %	0.2 - 1.5	0.5 - 1.5	2 - 9	1.0 - 4.0	—
MnO %	12.0 - 15.0	1.0 - 6.0	2 - 5	0 - 5.0	2.5 - 4.5
NiO %	Tr - 5.0	—	—	0 - 18	—
H_2O %	—	—	—	0 - 9	4.0 - 8.5
Na_2O %	—	—	0.5 - 2.5	—	—

Resistance to Acids

Chrysotile fiber is attacked by mineral and some organic acids to the extent that all the magnesium can be dissolved, leaving the silica structure. The solubility depends upon the kind of acid, strength, temperature and time of contact.

$$6MgO \cdot 4SiO_2 \cdot 4H_2O + 12\ HCl \rightarrow 6MgCl_2 + (SiO_2)_4 \cdot H_2O + 9H_2O$$
chrysotile → amorphous silica

This would give a theoretical weight loss of 53.4 per cent and this agrees with analysis reported.

X-ray patterns show that when the acid reaction is completed, the broad halos of amorphous silica appear strongly and that the chrysotile pattern has disappeared.

The amphibole fibers such as anthophyllite, amosite, tremolite and crocidolite are more acid resistant than chrysotile.

The solubility of the different varieties of asbestos may be shown by refluxing the fibers in 25 per cent solutions of acid or caustic for periods of two hours. (4)

Per Cent Loss in Weight

	HCl	CH_3COOH	H_3PO_4	H_2SO_4	NaOH
Actinolite	20.31	12.28	20.19	20.38	9.25
Amosite	12.84	2.63	11.67	11.35	6.97
Anthophyllite	2.66	0.60	3.16	2.73	1.22
Chrysotile	55.69	23.42	55.18	55.75	0.99
Crocidolite	4.38	0.91	4.37	3.69	1.35
Tremolite	4.77	1.99	4.99	4.56	1.80

At room temperature the rates of solubility are slower but apparently equal those by two hours of refluxing after standing 528 hours at 26°C.

pH of Asbestos Fibers

Chrysotile asbestos fibers show a pH of approximately 9.7 which is alkaline. This is probably due to the dissociation of the hydroxyl groups from the surface of the fiber, and thus producing the alkaline reaction.

Crocidolite has a pH of 9.4, amosite 8.8, anthophyllite 10.0 and tremolite 9.93.

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Physical Properties

The electrokinetic charge of chrysotile fiber is positive; this is probably due to the dissociation of the (OH) group on the outside chain of the molecule. Other physical properties such as specific heat, tensile strength, fusion point, spinnability, ionizable salts, etc. have been recently published. (5)

The isoelectric point of chrysotile suspensions in water can then be determined by careful additions of dilute NaOH, and it was noted that at 11.64 pH the positive charge became negative.

Structure

From a structural point of view, all of the varieties of asbestos, except chrysotile, are considered to be amphiboles. The structural unit consists of silicon --- oxygen chains composed of $Si_4O_{11}^{-6}$ units. From X-ray studies of chrysotile by Warren and Bragg and others, it was felt that the fibers were in layers and that the layers were built up in the sequence of 3 O, 2Si, 2O OH, 3Mg and 3(OH).

Recent work on the electron microscope showed that chrysotile fibers were tubular or cylindrical layers with cross sections of the order of 200 A units.

Effect of Heat

Chrysotile fibers loose water of crystallization when heated above certain temperatures such as 500°C to 1000°C.

$$Mg_6Si_4O_{10}.(OH)_8 \rightarrow 3Mg_2SiO_4 + SiO_2 + 4H_2O$$

The effect of temperature on the different variations of asbestos is best shown by the following table.

Loss in Weight (7)

Temp °F	Time	Amosite-%	Anthophyllite-%	Chrysotile-%	Crocidolite-%	Tremolite-%
400	2 hrs	0.23	0.05	0.30	0.08	0.04
600	2 hrs	0.57	0.24	0.85	0.25	0.08
700	2 hrs	0.80	0.30	1.78	0.49	0.13
800	2 hrs	0.98	0.38	2.17	0.73	0.22
900	2 hrs	1.07	0.41	2.83	0.83	0.26
1000	2 hrs	1.16	0.44	3.99	0.86	0.29
1100	2 hrs	1.36	0.52	10.38	1.00	0.37
1200	2 hrs	1.39	0.54	12.75	1.04	0.37
1400	2 hrs	1.43	0.54	13.43	1.03	0.47
1500	2 hrs	----	0.64	---	----	0.56
1600	2 hrs	1.52	1.12	13.62	0.93*	0.67
1700	2 hrs	----	1.73	---	----	1.40
1800	2 hrs	1.53	2.39	13.77	0.77*	2.18

* Iron change due to oxidation.

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Fiber Area

The surface area of asbestos fibers has been tested by various means, such as air permeability, iodine absorption, nitrogen, krypton and butyl alcohol.

The surface area of chrysotile calculated from iodine absorption data was 19.2 square meters per gram, which agrees with values obtained by the use of gases; water absorption isotherm data when calculated into surface area gave 18.4 square meters per gram.

The air permeability method is measuring the effective surface area and depends upon degree of openness of fiber while regular absorption techniques give higher values.

In general, it may be said that chrysotile has a surface area of approximately 20 square meters per gram. An extraction of the fines present in asbestos or the so-called dust has a surface area of 38 square meters per gram.

Since the dust fraction mostly consists of serpentine rock or a form of antigorite and the chrysotile is in the form of hollow tubes, then it is not surprising that the dust has a higher surface area than the fiber.

The surface areas of the so-called amphibole fibers are 9.2 square meters per gram for crocidolite, 8.4 square meters per gram for amosite, and 6.1 square meters per gram for anthophyllite.

In all cases, the surface areas of asbestos fibers are far greater than the surface areas of other types of fiber, such as Nylon, rayon, cotton, silk and wool.

Tensile Strength (3)

The breaking of fibers by a tensile pull shows that asbestos fibers are very strong. For example, chrysotile varies from 80,000 to 100,000 lb/sq in., crocidolite 100,000 to 300,000 lb/sq in., amosite 16,000 to 90,000 lb/sq in. and tremolite 1,000 to 8,000 lb/sq in.

Flexing

The flexibility of asbestos fibers varies considerably. For example, the soft chrysotile fiber has a very good flexing property before breaking while the harsh chrysotile fiber breaks quickly.

The amphiboles, particularly the amosite and anthophyllites, have poor flexing properties.

The crocidolites are usually better than the amosites, but, again, it depends upon the degree of harshness.

The flexing ability of a fiber is of particular interest to the textile industry as spinning and weaving require good flexing strength.

Production (3)

The chrysotile asbestos fiber produced in 1952 for the entire world is approximately [illegible] tons or 94 per cent of all varieties of asbestos mined. The U. S. industries used approximately 734,500 tons of chrysotile in their products.

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