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THE SEARCH FOR ASBESTOS SUBSTITUTES

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[The authors of this article are associated with the Fulmer Research Institute Ltd., Stoke Poges, Slough, England, and have recently produced a booklet entitled "Asbestos, Characteristics, Applications and Alternatives" which includes an examination of the substitute materials commercially available for the major applications of asbestos and asbestos products. The Fulmer Research Institute is a non-profit research organization specializing in materials technology.]

SUMMARY

This article examines in some depth the materials available as alternatives to asbestos for two of its major applications—asbestos-cement and friction materials. Asbestos is used in a wide range of applications and the most successful approach to its replacement is to examine each application individually. It is noted that it is not always possible to replace asbestos on technical grounds and where replacement is possible, cost-penalties are frequently involved.

INTRODUCTION

Asbestos is a material which makes a great contribution to human safety through a number of its applications but it can also constitute a health hazard to those who are exposed to its fine, airborne fibers. In several countries around the world great concern at present exists over the use of asbestos products and attempts are underway to minimize the risks of asbestos exposure by examining the safety precautions taken when carrying out potentially dangerous dust-producing operations with asbestos products (machining, delagging, demolition, etc.) and also by exploring the possible use of suitable alternative materials.

A considerable volume of research has been directed in recent years to finding substitutes for asbestos, the major effort being concentrated in areas that use large quantities of the material and in those applications for which asbestos has technical advantages in addition to its low cost. Two prominent examples which will be discussed here are asbestos-cement products and asbestos-based friction materials, which respectively accounted for 38% and 9% of total United States asbestos consumption in 1974. The properties of asbestos which make it useful in these applications will be considered in the following sections and will be compared with the properties of materials which have been suggested as substitutes.

ASBESTOS-CEMENT PRODUCTS

The primary function of the asbestos in asbestos-cement products is to act as a reinforcing fiber. The properties that make it useful in this role are high fiber strength and modulus and a large aspect ratio (ratio of-length to diameter). This latter parameter is one of the factors that determines the reinforcement efficiency of fibers in composite systems. The asbestos fibers produce useful tensile and flexural properties in the asbestos cement, enabling it to be used for such purposes as roofing sheets and pressure pipes. In this latter application the high tensile strength of the asbestos fibers is particularly important. For this reason most of the Crocidolite (Blue) asbestos consumed is used in asbestos-cement pipes due to its superior strength, compared to the more widely used Chrysotile asbestos with which it is combined in this application. In 1974, for example, more than 90% of the Crocidolite used in the United States went into piping applications.

The initial stages of asbestos-cement manufacture involve the mixing of water, cement and fibers into a slurry. The fibers mix readily into this slurry. This affinity for water is thought to be a consequence of the porous nature of the fibers and it has been suggested that the individual asbestos fibrils are hollow. Additionally the fibers contribute favorable and controllable drainage properties to the mix, enabling the asbestos-cement pipes and sheets to be produced by a relatively simple and flexible process similar to that used in paper making.

The combination of usefully long fiber lengths and flexibility inherent in asbestos fibers confers wet strength and moldability properties on the "green" boards. Thus complex shapes such as corrugated boards may be produced by molding the wet material. The main attractions of asbestos-cement products to the end user are durability, resistance to weathering attack and cost effectiveness. The noncombustibility of the products is significant, but is often of secondary importance.

SUBSTITUTES FOR A-C PRODUCTS

Various currently available materials are used as substitutes for asbestos cement in many of its diverse applications Cladding panels are frequently manufactured from Glass-Reinforced Plastic (GRP) or various thermoplastics although these materials do not possess the fire resistance of asbestos cement and their combustion can lead to the evolution of toxic fumes Metals, notably aluminum, are also widely used in this application. GRP or GRP-wound concrete pipes are often suitable for use in corrosive environments and the traditional cast iron sewage pipe performs satisfactorily. Most of these materials are more expensive than asbestos-cement products, although certain thermoplastics may be cost-competitive in specific applications.

In general, however, none of these materials can be fairly considered to be a universal replacement for asbestos cement and the most promising route to achieve this objective at present is the development of glass-reinforced cement technology Conventional E-glass fiber (which is commonly used in glass-reinforced plastics) cannot be used in conjunction with cement since the severely alkaline conditions produced during the setting of conventional Portland cement degrade the fibers and the resultant composite material rapidly loses its favorable mechanical properties. However, within the last ten years a high-zirconia, alkali-resistant glass fiber has been developed at the Building Research Establishment, Garston, England. This fiber is marketed by Pilkington Brothers Ltd , of St Helens, England, under the name "Cem-FIL" for cement reinforcement purposes. Glass-reinforced cement usually contains between 3% and 7% of fibers, and typically one would expect a material containing 5% of fibers to have a modulus of rupture similar to that which would be expected from asbestos cement containing 15% of fibers (about 35 MN/m^2). Additionally, the glass-reinforced cement is considerably more impact resistant than asbestos cement of comparable strength. The "green" boards have wet strength and can be molded, and large bore pressure pipes can be produced. The final products perform adequately in preventing fire penetration. However, several drawbacks exist in the use of this material.

1) The fiber is approximately four times as expensive as the asbestos used in cement-based products and this, coupled with the less favorable economics of the production process results in a price for glass-reinforced cement some 70% greater than asbestos cement even allowing for the smaller fiber content.

2) The drainage characteristics of a cement-water-glass fiber mix are poor and do not permit the manufacturing process for asbestos cement to be used in an unmodified form. Glass-reinforced cement is usually made by a process referred to as "spray suction." In this process, a special spray head sprays a mixture of chopped glass fiber bundles a few centimeters long with a fine cement slurry onto a porous bed. When spraying is complete, a vacuum is applied to the underside of the bed to remove excess water. A similar procedure is used to make pipes, the spray head being directed onto the inside of a rotating tubular form with the excess water being similarly removed. Consequently, the manufacture of glass-reinforced cement is relatively costly and requires a high capital investment.

However, the manufacturers of glass-reinforced cement are expending considerable effort on attempts to make the material on minimally-modified asbestos cement plants. The impetus for this effort was the result of Japanese legislation about two years ago whereby asbestos was placed in the "dangerous chemical" category of materials. Consequently, severe restrictions apply to any product sold in Japan containing more than 5% asbestos, which includes standard asbestos-cement products. It was found that the standard asbestos cement plant could produce a good quality board from a cement slurry containing both glass and asbestos fibers in suitable proportions, so as to keep the asbestos content below 5%, thus producing glass-reinforced asbestos cement (known as "GRAC"). The research effort is presently concentrated on eliminating the asbestos content completely and this has been achieved by suitable plant modifications. It is likely that this equipment will shortly become available in the United Kingdom, eliminating one of the principal drawbacks to the use of glass-reinforced cement.

3) Some attack of the glass fiber by the setting cement is necessary to achieve good fiber bonding and this requirement has raised doubts concerning the long-term durability of glass-reinforced cement. The product is too new for really long-term data to be available but manufacturers(findings for a seven-year period indicate that the strength of glass-reinforced cement when wet stored (the worst situation) drops to half its initial value in approximately two years, and then stays constant. An additional safety factor of 3 is recommended, i.e. the quality control initial strength should be at least six times the design working stress. Most existing uses of glass-reinforced cement have been restricted to non-load-bearing components (e g. cladding) but the more demanding structural applications are gradually being attempted as knowledge of, and confidence in, the material grows. It is likely that the uses for glass-reinforced cement will increase since it allows interesting concepts that are impractical with asbestos cement. A good example is the use of continuous glass fiber roving to filament wind large diameter pipes that are much lighter, due to the thinner wall required, than a steel-reinforced concrete pressure pipe of comparable strength and price.

FRICTION MATERIALS

Asbestos-based brake and clutch linings are in widespread use, particularly, but not exclusively, in the automotive field. The asbestos performs a complex function in these applications which is not completely understood. Chrysotile asbestos is used exclusively and stiffens and strengthens the filled phenolic resin matrix. The fibers maintain these properties at the high temperatures generated during, for example, braking and clutch slipping. The friction and wear characteristics of the asbestos fibers and their thermal decomposition product, forsterite, are thought to be responsible for the good braking efficiency and service life properties of these materials. Forsterite is a non-fibrous silicate and is not thought to constitute a health hazard. Investigations have established that the dust produced from the wear of asbestos friction materials does, in fact, contain only 1% to 2% of asbestos fibers. Repeated exposure to this dust is a potential hazard for personnel such as garage mechanics. While this wear debris is not thought to constitute a significant health hazard for the general public, much effort has been concentrated in searching for substitutes for asbestos in this application.

Various substitute materials have been investigated but they all have drawbacks. Sintered metals, ceramics and metallized bonded products have been available for many years. However, the high thermal conductivity of these materials creates a risk of boiling brake fluid which can cause erratic performance. Carbon fiber/carbon composite brakes have been used successfully on racing cars and aircraft such as the "Concorde." They perform better than asbestos materials under the high service temperatures in these applications but are so expensive that their use can only be justified in specialized circumstances. A considerable volume of work is currently underway on using the existing asbestos-based manufacturing technology and incorporating either steel or glass fibers into the mix to replace the asbestos.

Vehicle trials are underway in the United States with these products and it is estimated that asbestos substitutes are available for about 30% of the friction products market, the exception being in the heavier-duty applications such as disc brake pads where high temperature surface conditions are encountered.

Steel fibers were first used in friction materials in Germany, prior to and during World War II, due to difficulties in obtaining asbestos fiber. It was found the brakes worked well with little loss of efficiency when wet, but the wear debris was abrasive and severely damaged the counterface. Glass fiber-based friction materials also produce a very abrasive wear debris, with corresponding damage problems. Further, at high temperatures the glass can melt. This can produce a sudden, undesirable loss of friction since the sliding surfaces can be effectively lubricated by the molten glass. Both steel and glass fiber-based materials tend to be considerably noisier in vehicle braking applications than their asbestos counterparts. Both glass and steel fibers can be incorporated into friction materials using standard processing, but steel fibers have been found easier to handle. The steel fiber is usually of the fine steel wool type and is about four times more expensive than the asbestos used in friction materials. Conventional E-glass fiber is approximately half the price of the steel wool. Non-asbestos-based materials use proportions of fiber comparable to the conventional product and are hence more expensive.

Thus, although asbestos-based friction materials are technically and economically preferable at present for the majority of applications, it seems probable that these may eventually be replaced by the non-asbestos-based materials as a result of concern over the health hazards involved with asbestos.

CONCLUSIONS

It is apparent in the two applications which have been considered that one factor common to both is that substitute materials will be more expensive than the asbestos product it is desired to replace. The two case histories, however, highlight notable discrepancies:

1) The health hazards involved in the handling of asbestos-cement products during machining and demolition operations are greater than those associated with the handling of friction materials, where the dangers are confined to manufacture and the cleaning of brake drums and linings.

2) Research has led to the development of technically acceptable substitutes for asbestos-cement products, whilst inferior products are likely to be accepted as substitutes for friction materials.

The arguments put forward here therefore mitigate against a total ban upon the use of asbestos products and would suggest that in some cases it would be preferable to ensure the observation of adequate safety precautions during their manufacture and maintenance than to accept inferior products. In addition, the potential health hazards involved with the use of alternative fibrous materials, including glass, should not be overlooked

COPIES STILL AVAILABLE!

RECOMMENDED WORK PRACTICES—Five manuals published by the Asbestos Information Association/North America include "Recommended Work Practices for the Fabrication and Use of Asbestos Paper Products," "Shop and Field Fabrication of Asbestos Sheet Products," "Molding and Fabrication of Asbestos Containing Plastic Products," "Fabrication and Use of Asbestos Friction Materials," and "Use and Handling of Asbestos Textile Products." [$1 35 each plus postage, order from AIA/NA or through ASBESTOS Magazine]

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