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Utilization of Indian Asbestos: Part II—Asbestos-Cement Systems Containing Chrysotile & Tremolite Asbestos

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Asbestos-cement systems containing chrysotile and tremolite (Mysore) asbestos and portland cement have been studied with a view to utilizing Indian tremolites for the production of asbestos-cement sheets.

It is suggested that the low strength of sheets made with tremolite asbestos is due to weakness of the continuum (glassy phase or gel structure) and not because of the low tensile strength of the tremolite fibres. The weakness of the gel structure may be removed and the strength of sheets improved either by adding a material which can remove the calcium ions from the system before gel formation starts or by improving the tensile strength of glassy phases or a combination of both.

THE low tensile strength and the short length of tremolite asbestos fibres are usually considered to be the main causes of the low transverse strength of asbestos-cement sheets made from tremolites. The function of asbestos fibres in asbestos-cement sheets is to act as a reinforcement. Obviously such short fibres cannot act as a reinforcement in the normally accepted meaning of the term. What may possibly act as reinforcement are fibres held together by intervening cementing material and the combination functioning as a chain. The chain may be irregular in size and shape, but it must run from one end to the other end of the sheet. The strength of the sheets will depend upon the strength of these chains. The strength of chains will depend upon (i) tensile strength of fibres, (ii) bond strength between the fibres and the continuum (i.e. cementing material) and (iii) strength of the continuum.

It is considered that the lack of tensile strength of the continuum is responsible for the low strength of asbestos-cement sheets made from tremolites. Evidence to support this view is given in this paper.

Experimental procedure

Processing of raw material — Mysore tremolite was processed by keeping it immersed in 10 per cent brine solution for 24-28 hr. The sticks were crushed under rollers, repeatedly washed and dried. The length of the fibres was $\frac{5}{16}$ in. and less.

The milled fibres of Canadian chrysotiles were used. The length of the fibres was 0·5 in. and less.

The set products were examined by X-ray diffraction. Compressive strengths of cubes made up of 85 per cent cement and 15 per cent asbestos (of either variety) mixtures were determined under different conditions.

Tensile strength of fibres — Two silk threads of unequal lengths were attached by hot rosin at the two ends of the fibre. A light pan was attached to the free end of the shorter thread. The longer thread was allowed to pass over a smooth pulley and was attached to a support below. Weights were gradually placed on the pan until the fibre broke.

The diameter of the fibres was measured with a micrometer screw gauge. The tensile strength of the fibres was calculated from the breaking loads.

Bond strength between fibre and cement mortar — One end of asbestos fibres of suitable length and diameter was attached with silk threads with hot rosin. The fibres at their free ends were inserted into fine holes of a specially designed mould to secure straight contact. Cement mortar of normal consistency was poured in the mould avoiding any load normal to the fibre length. Fibres were put to the same depth in the mortars. With the fibres in vertical position, the threads were allowed to pass over a smooth pulley. A light pan was attached to the free end of the thread and weights were gradually placed on it to pull out the fibres, after allowing suitable setting time. The weight of the pan was noted when either the fibre slipped out of the mortar or was broken. The total weight at the end of the fibres divided by the area of the fibre in mortar was

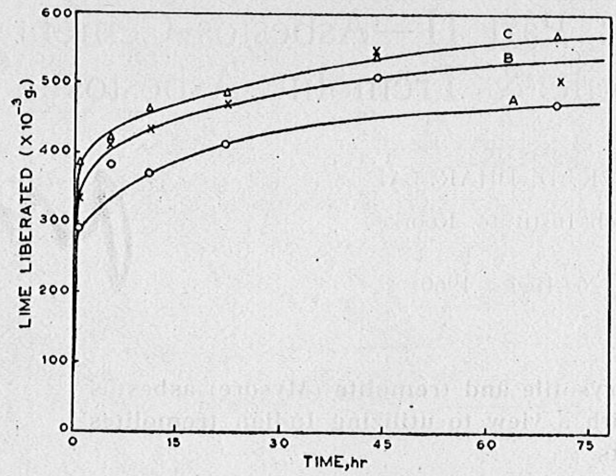

Fig. 1 — Liberation of lime in asbestos-cement-water systems [A, chrysotile-cement-water; B, tremolite-cement-water; and C, cement-water]

taken as the bond strength between the fibre and the mortar.

Absorption of cement — The method of Hayden[1] was modified as follows in this test. A weighed quantity of asbestos was mixed with 100 times its weight of cement and sufficient water was added to make it into thin slurry. The slurry was shaken for a given time in a vessel and then poured on a 200 mesh sieve. The mass retained on the sieve was carefully removed and dried at 110°C. for 24 hr and weighed. From these data the amount of cement absorbed by a given mass of asbestos was determined.

Lime liberated in asbestos-cement systems — The free lime content of chrysotile and tremolite was 0·002 and 0·005 per cent respectively which is negligible when compared to lime liberated during setting of cement.

Estimation of lime liberated was done in the following mixes at 25-30°C.: (A) 3 g. of chrysotile + 10 g. of cement + 250 g. of distilled water, (B) 3 g. of tremolite + 10 g. of cement + 250 g. of distilled water and (C) 10 g. of cement + 250 g. of distilled water. The mixes were shaken (in different batches) for 1, 5·5, 11, 22, 44 and 60 (or 70) hr under similar conditions. In Fig. 1 are given the lime liberation curves.

Results and discussion

X-ray powder diagrams of fibres show that Canadian asbestos is in a finely divided state and the processed Mysore tremolite consists of relatively perfect large crystals. This shows that chrysotiles are much more fibrized than the tremolites.

The tensile strength of chrysotile and the tremolite fibres was found to be 135,000 and 8000 lb./sq. in. respectively. The tensile strength of cement products such as sand and portland cement mortars is of the order of 300-500 lb./sq. in. and that of commercial asbestos-cement sheets is of the order of 2000-3000 lb./sq. in. The presence of chrysotile asbestos in commercial asbestos-cement sheets, therefore, improves the tensile strength of set cement.

The transverse strength of sheets made from mixes containing 15 per cent chrysotile asbestos and 85 per cent cement is usually 1·25-2·5 times that of sheets having the same composition but made with tremolite fibres. If the tensile strength of fibres had any decisive effect on the transverse strength of sheets, the ratio of transverse strengths could not have been so low as the ratio (17: 1) of tensile strengths of the two fibres. The disparity in length of the fibres is also not large enough to be of any significance.

The compressive strength of cubes made from mixes containing 15 per cent asbestos and 85 per cent cement (after 28 days' curing) is only about 60 per cent of that of chrysotile cement cubes prepared under identical conditions. It appears that the lower compressive strength of asbestos-cement sheets is not due to the breakdown of the fibres under compression, which is the case with tremolite asbestos fibres compressed under high pressures (12000 to 15000 lb./sq. in.), and no disintegration of the fibres was detected either visually or by X-ray diffraction.

The bond strength in the case of chrysotile fibres was found to be of the order of 4000 lb./sq. in. after setting for 5 hr. The bond strength of tremolite fibres appears to be high (at least as high as the tensile strength of the fibres), but it could not be determined as the fibres broke (not slipped) when the weights were placed on the pan.

The average absorptive capacities for cement of chrysotile and tremolite fibres determined by the above method were 6·13 and 2·50 respectively showing that, mass for mass, the absorptive capacity of the latter is about 40 per cent that of the former.

The decrease in free lime concentration in cement-chrysotile-water system compared to cement-water system is due to adsorption of part of $Ca(OH)_2$ (formed during setting of cement) by chrysotile fibres[2]. The amount of lime liberated with tremolite is more than that with chrysotile but less than that in cement-water system (Fig. 1). This means that tremolite also absorbs $Ca(OH)_2$, and for equal mass, its absorptive capacity is less than that of chrysotile.

X-ray diffraction patterns of set products from asbestos-cement system with the two types of fibres were found to be practically identical. This shows that the nature of the set products is nearly the same in both the systems.

It is well known that the calcium ions set free during the setting of cement are loosely held in the body of the gel[3], and that the extraction of calcium ions in small amounts has an adverse effect on the strength of the cement mixes, presumably due to the holes (imperfections) created in the gel as the loosely held calcium ions leave it. As chrysotile fibres have higher absorptive capacity, these remove larger number of calcium ions from the system than when tremolites are used, leaving a less number of calcium ions to be trapped in the gel. Consequently, the defects in the gel structure in an asbestos-cement system with chrysotiles are less than those observed with tremolites. It, therefore, seems probable that the lowering of strength of asbestos-cement sheets using tremolite fibres may be the result of increased state of imperfection of the gel structure. In asbestos-cement sheets the defects are partly caused by the 'holes' left by calcium ions as these leave the gel. This, however, should not be interpreted to mean that the use of cements, which do not liberate lime, will improve the strength. In all probability it will not, as there may be other types of defects produced.

The methods to be used to improve transverse strength of asbestos-cement sheets should then be primarily directed to improve the tensile strength of gel structure of the glassy phase by eliminating 'defects' in it. The problem then becomes essentially similar to that of improvement of tensile strength of glass. In asbestos-cement system the simplest way to eliminate the defects caused by the removal of calcium ions during curing would be to prevent the calcium ions from getting trapped in the gel structure. This may be achieved by trapping the calcium ions on the asbestos surface by activating the surface or by adding a material which can absorb these ions before gel formation starts. Methods employed for improving the tensile strength of glasses may also be applicable. Perhaps a combination of both will be necessary.

That the strength of asbestos-cement sheets depends on the strength of the gel is supported by the fact that when the sheets from chrysotile fibres are exposed to cycles of alternate heating at 50°C. and immersion in cold water, their transverse strength increases[4], though heat treatment has an adverse effect on the tensile strength of chrysotile fibres[5]. Further, fibrization of chrysotiles improves the strength of the sheets from such fibres. Since fibrization results in increased adsorption of $Ca(OH)_2$ through increased surface area, the increase in the strength of sheets on fibrization lends support to the above view that calcium ions should be removed for improving the strength of sheets.

The role of asbestos fibres in strength development in asbestos-cement sheets thus appears to be two-fold: (i) the tensile strength of fibres gives additional strength to the chains and (ii) because of their absorptive capacity, the fibres are able to trap the calcium ions and prevent them from getting into the gel structure. Tremolites have low absorptive capacity and because of this they do not fulfil the second role satisfactorily.

Summary and conclusion

1. Chrysotile fibres used in the manufacture of asbestos-cement sheets are in a fine state of division. Tremolites processed in the laboratory consist of relatively large and perfect crystals.

2. The tensile strengths of chrysotiles and processed tremolite fibres are of the order of 135,000 and 8000 lb./sq. in. respectively. The bond strength between fibre and cement mortar is fairly high with both types of fibres.

3. Mass for mass, the absorption of cement by tremolite fibres is *c.* 40 per cent of that by chrysotile fibres.

4. During setting of asbestos cement, the quantity of lime liberated depends on the nature of the fibres present. For equal masses of fibres, the amount of lime liberated in a system with tremolites is more than that with chrysotiles.

5. It is suggested that the low strength of the asbestos-cement sheets from tremolites is due to the imperfect state of the gel produced by the escape of calcium ions loosely held in the body of the gel. Chrysotile asbestos with its higher absorptive capacity removes larger number of calcium ions from the gel so that the imperfections created by the escape of the ions trapped in the gel are less compared to the imperfections in gel structure formed when tremolite asbestos is used. The improved strength of sheets with chrysotile asbestos is the result of the more perfect state of the gel structure.

6. The strength of asbestos-cement sheets can be improved by removing calcium ions from the system before the gel formation starts or by improving the tensile strength of glassy phases by a combination of both.

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