MILITARY TECHNICAL COLLEGE

CAIRO - EGYPT

PERFORMANCE OF ASBESTOS-FILLED RESIN COMPOSITES

PART I: MECHANICAL PROPERTIES

By

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ABSTRACT

Brake linings for modern saloon cars are formulated from asbestos fibres as a reinforcement, phynolic formaldehyde resin as a binder, and different fillers to modify the different properties of the linings.

To study the effect of every constituent on the mechanical properties, different formulations were produced with different asbestos-resin content ratio and the mechanical properties, mainly, the ultimate tensile strength, impact strength, hardness, and the compressive strength were measured.

Definite dependency of the mechanical properties of such formulations on the asbestos-resin weight ratio was noticed.

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INTRODUCTION

One of the pr incipal requirements of modern friction materials is their high resistance to frictional heating. Friction materials must have an appropriate and stable value of the coefficient of friction. Other recommendable properties are: running-in ability, absence of seizure, corrosion resistance, non-inflamability, adequate mechanical strength, good wear resistance, high thermal conductivity and high thermal capacity. Metallic and non-metallic friction-materials are used. They may be classified as follows:

1. Metallic: grey cast iron is used as friction material in railway brake shoes. Grechin [1] suggested the use of shoes made of alloyed cast iron. Slinko and Elemin [2] proposed chromium bronze shoes for heavily stressed brakes.

2. Asbestos rubber composites: they are used mostly in automobile brakes and for clutch linings in tractors and automobiles.

3. Asbestos-filled resin composite: Kragelski et al [3] has discussed the suitability of asbestos-filled resin for use in air-craft brakes. Lazarev and Troyanouskaya [4] developed an asbestos-filled resin with commercial name "Retinax". They claimed that "Retinax" can stand temperatures upto 1000°C.

4. Metal ceramics: These are basically powdered metal ceramic based on both copper and iron. The use of metal ceramics as friction materials is suggested by Naradov [5].

As power, speed and safety in modern car design have become increasingly demanding, asbestos-filled resin has become the most used friction material. Kragelski [6] suggested, for heavy duty application and when high operating temperature is likely, that the resin may be reinforced with metallic chips (turnouts) or metallic powder. Moulded asbestos linings are produced by heating under pressure a mixture of asbestos, fibres, organic resin and modifiers [7]. The fibres may be short or long fibre asbestos or a mixture of both. Binders may be simple resin, rubber or a mixture of subber and resin. Fillers are used as performance modifying agents. Three common types of fillers are commonly used. Inorganic fillers such as barytes, China clay, slate powder, silica and matallic oxides of iron and/or copper. The second type of fillers is metal particles which include copper, zinc and brass. The third type of fillers is organic such friction dusts.

The object of this investigation is to carry out a systematic study of how the main constituents of moulded asbestos-filled resin affect the mechanical and tribological properties

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of the friction composite. In the first phase of this study a mixture of short and long fibre asbestos with phenol-formaldehyde as binder is used to formulate a friction composite. Constituents of the composite are varied in proportion and their effect on the mechanical properties is investigated.

TEST PROCEDURE

Test specimens are prepared from essentially shaped and cured mixtures of asbestos fibres and phenolic formaldehyde resin as binding agent. The chemical constitution of asbestos is 3 Mg 0.2 $SiO_2.2H_2O$, and the macromolecule consists of parallel sheets of brucite-silica layers. If the H_2O part is driven off the molecule (e.g. by heating), asbestos looses its fibrous structure and is reduced to powder. The resin is usually as the condensation product between phenol and formaldehyde in the presence of acidic catalyst.

Asbestos is defibrized and then mixed with resin in a laboratory tumbling mixer of 5 kg capacity. The mixture is then cold pressed at a pressure of 5 M.Pa. to the required shape. The mould is then hot pressed under pressure of 12 M.Pa. and at temperature of 150°C to 160°C. During the hot pressure cycle, it is generally necessary to breath the mould to allow valatile products to escape and to ensure round samples. After hot pressing the mould is post cured in an oven at temperature of about 150°C for four hours. For each type of mixture-mould twelve to fifteen samples of test specimens are produced. Test specimens are produced according to CZN Checoslovakian specification of standards for friction materials. Test specimens are used to perform the following tests:

1. Tensile breaking strength.
2. Hardness.
3. Impact strength.
4. Ultimate compressive strength.

Fig.1a.shows a sketch of test specimen used to carry out tensile tests on standard tension compression testing apparatus, of 40 tons capacity. The same specimens were used to carry out hardness test using Brinell-Hardness tester with a ball diameter of 10 mm and a load of 5000 N. Test specimens which are used to carry out impact energy tests are shown in Fig.1.b. Impact tests are carried out using low energy impact tester of mass of 1.61 kg and impact velocity of 2.6 m/sec. Specimens used for compression tests are cut off impact test specimens with dimensions of (20 mm x 15 mm x10 mm),Fig.1.c.

Mechanical properties are tested for nine types of friction composites. The ratio of asbestos to resin is varied in steps of 10% and the effect on mechanical properties of test samples is tested. Asbestos is added as friction and heat resistant agent mainly but results show that it is also a reinforcing agent in the friction composite. Elements concentration is measured in weight fraction. Results show that there is definite dependency of mechanical strength and elements concentration . Discrepancy due to manufacturing errors is overrided by carrying out increased number of tests for each type of mixture. Inconsistent results were disregarded and the plotted results are those of consistent test results.

Mechanical tests were carried out for a number of test samples ranging from seven to fifteen for each particular mixture moulding. Mathematical averages are calculated to represent material properties.

TEST RESULTS AND DISCUSSION

In discontinuous fibre reinforced composite, the load transfer function of the matrix is more critical than in continuous fibre composites. Properties of randomly distributed discontinuous fibre reinforced composites are generally assumed isotropic. However, there is substantial evidence that fibre orientation occurs through the moulding and it varies greatly according to flow within the mould. Darlington et al. [8] and Kain et al. [9] showed that the moulded part properties vary from section to section according to local fibre orientation which had occurred during the moulding process.

1. Tensile Breaking Strength:

It may be seen from Fig.2.a that the increase of asbestos percentage causes some increase of the breaking strength of the composite. This observation confirms the theory of the strengthening effect of the short fibre asbestos. The low measured value of tensile breaking strength for the composite with 10% resin and 90% asbestos may be attributed to the small amount of resin present. The little amount of resin results in weak bondage of the composite constituents. The composite becomes therefore brittle and fails easily under load. Fig. 3 shows that the composite with 10% resin and 90% asbestos always fail to achieve the lower permissible limit as specified by standards for friction materials. The presence of 20% resin at least ensures that the composite satisfies the lower limit of most mechanical properties. The strengthening effect of asbestos in tension is nevertheless, evident and may be attributed partly due to sharing of loud with the matrix and partly by restraining the deformation of the matrix between fibres. Breakage of test samples was seen to be a characteristic of

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2. Hardness:

It may be seen from Fig.2.b.that test samples of composites of asbestos to resin ratios ranging from 80% : 20% to 40% : 60% satisfy the permissible limits of brinell hardness values for friction materials. In general, there is an agreement between tensile breaking strength and hardness test results except for the composite with 80% asbestos. Hardness test results depend to a great extent surface condition which is directly related to mixing of constituents. Though the B.H.N. and the ultimate tensile strength are related for most metals, it is not necessary to apply the same principle to friction-composites.

3. Impact Strength:

It may be noted from Fig.2.c.that the impact strength of the friction composites improves with the increase of asbestos content. The increase of asbestos generally improves the tensile strength of the composite and consequently increase its toughness. The composite formed with 40% resin gives the highest measured impact strength. A further increase of asbestos percentage, which occurs on expense of resin may render the composite brittle. Therefore, addition of asbestos improves the tensile impact energy of the friction composite up to a point whereafter loss of ductility limits the elongation of the matrix and thus further addition of rigid fibres reduces toughness of test samples. Lee [10] has studied the mechanical properties of randomly oriented short glass reinforced polyethylene. The weight percentage of glass fibres were increased in steps of 10% upto 40%. Elastic modulus and tensile strength are increased significantly by increase of fiber percent. The Izod impact energy of the polyethylene also increases. This was explained as due to addition of fibres to a brittle matrix can increase toughness because of evack blunting, branching and arrest effects. Results of Lee, however did not show peak values for impact strength as is shown in this investigation and this may be due to the limited amount of fibre inclusions of less than the 40%.

4. Comptessive Strength:

Test samples of different composites were compressed and results are shown in Fig.2. d. Though, all other mechanical tests show some optimum characteristics, the compression test does not give an optimum composite in compression. The compressive strength continually improves as the asbestos content is reduced. Experimental investigation by Collings [11] with carbon fibre reinforced plastics indicates that when the composite is subjected to transverse compressive loads, there is evidence that failure is percipitated by failure of fibre resin bond. In case of discontinuous fibre reinforced composites, an additional factor that influence failure is the large stress concentration in the matrix produced as a result of fibre ...

The effect of stress concentration is to lower further the compressive strength. Short fibres which are randomly distributed in a composite under compressive load represents weak regions within the matrix. Therefore, an increase of fibre content reduces the overall compressive strength of the composite as is shown in Fig. 2.d.

CONCLUSION

There is definite dependency of mechanical strength of the friction composite on the weight ratio of asbestos to resin in asbestos filled resin. Asbestos is not only friction and temperature resistant agent but also a reinforcing agent. Optimum formulations for different mechanical properties are not always compatible. Practical limits set by the manufactures of friction materials shown that there is a wide range of feasible formulations as for as mechanical properties are concerned. Mechanical tests have long been considered as quality control tests but investigation has shown that some formulations may lead to unacceptable weak products which are likely to break in operation when subjected to the complex stress state experienced in braking.

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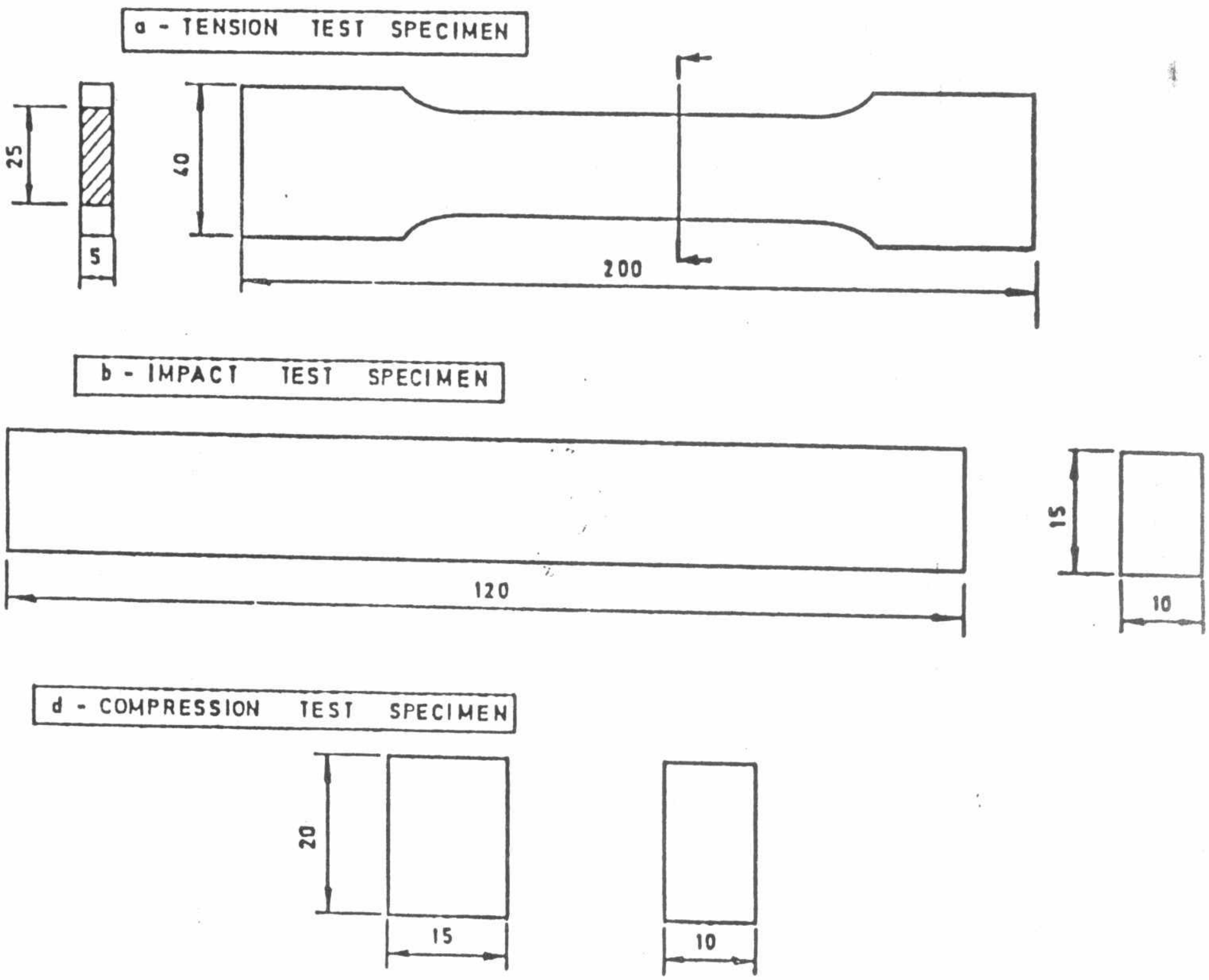

FIG. 1- MECHANICAL PROPERTIES TEST SPECIMEN

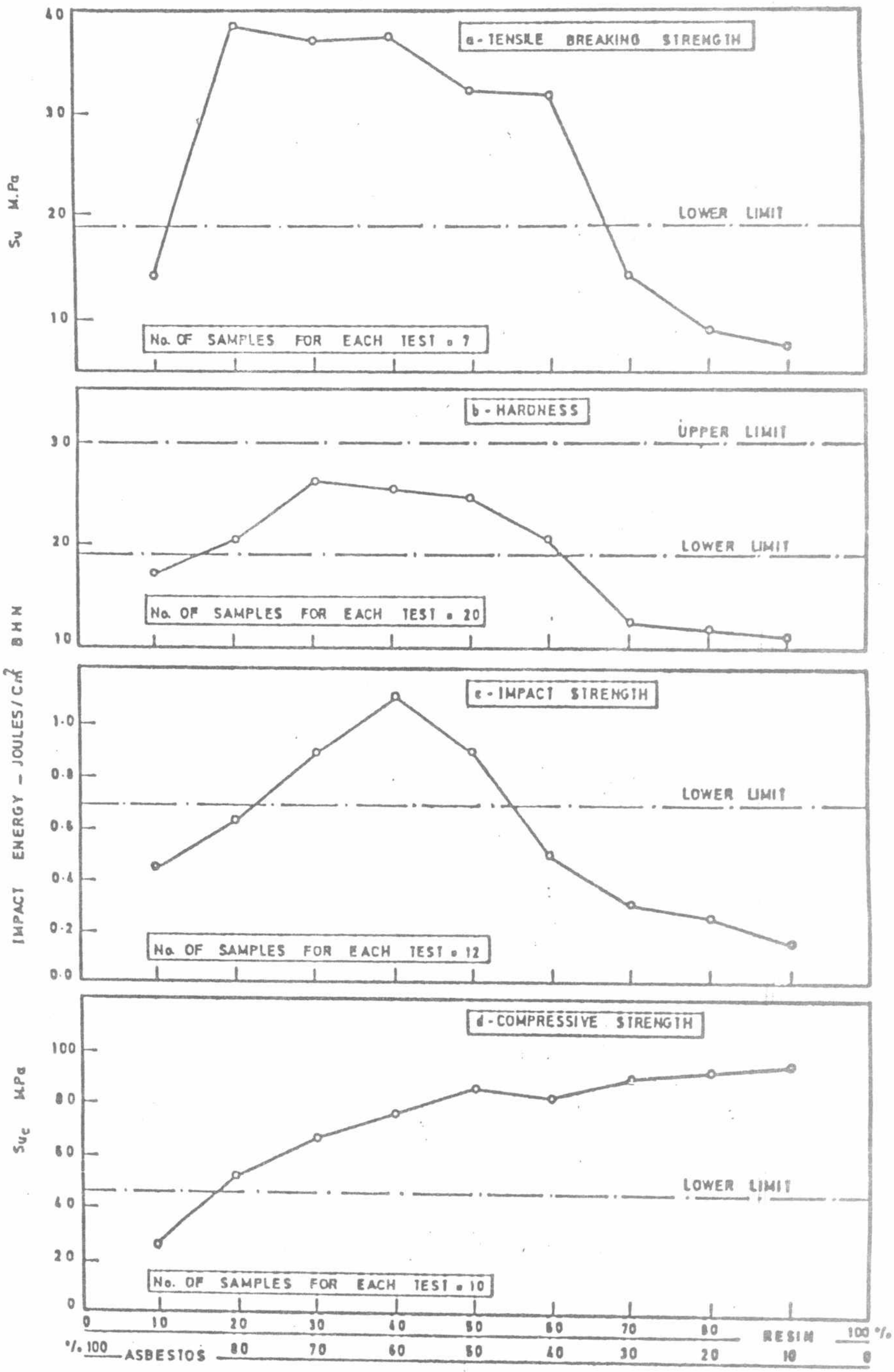

FIG.2 - EFFECT OF RESIN / ASBESTOS CONTENT ON MECHANICAL PROPERTIES OF ASBESTOS FILLED RESIN FRICTION COMPOSITE