EFFECT OF MINERAL FILLERS ON THE COMPRESSIVE STRENGTH OF GLASS REINFORCED PLASTIC COMPOSITE

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ABSTRACT

The Glass Reinforced Plastic (GRP) composite materials were made by simple hand lay-up technology (open-mould process) whereby Calcium Carbonate and Talc mineral fillers were added each in the following proportions: 5%, 10%, 15%, 20% and 25%. The materials were tested for compression strength, since the material is intended to be used in construction industry especially in cladding panel form. It was found that GRP samples with fillers of Calcium Carbonate composite material had higher compressive strength than those with fillers of Talc. This higher compressive strength was attributed to the features of the differences in the structural build up of the two mineral fillers.

Keywords: Glass Reinforced Plastic Composite, Hand Lay-up Technology, Mineral Fillers.

INTRODUCTION

Among other objectives, material science and engineering seek to identify and produce engineering materials that are both cost effective and of standard quality. For example, finely-ground wood or silica or chalk are added to plastic moulding materials largely to make them cheaper. Crushed rock aggregate is used in concrete partly to reduce the cost per unit weight of the material and partly to improve its compression strength. Powdered magnetic alloys of high coercivity are blended with rubbery polymer to make non-conducting flexible magnets (Harris, 1986). The blending of air or gas with metals, with plastics, or with cements, results in foamed products of low density. The purpose in each case is to optimise materials properties by the process of combination. In engineering practice, as indeed in nature, it is a common principle that two or more components may be profitably combined to form a composite material so as to make best use of the more favorable properties of the components while simultaneously mitigating the effects of some of their less desirable characteristics (Harris, 1986). The principle applies to all kinds of properties, physical, chemical and mechanical. A concomitant benefit of making composites is that the density and perhaps the cost of the product are often lower (Harris, 1986).

Most composite materials consist of a selected filler or reinforcing material and a compatible resin binder to obtain the specific characteristics and properties desired. Usually, the components do not dissolve in each other and can be physically identified by an interface between the components. Composites can be of many types. Some of the predominant types are fibrous (composed of fibers in a matrix) and particulates (composed of particles in a matrix).There are many different combinations of reinforcements and matrices used to produce composite materials.

Two outstanding types of modern composite materials, used for engineering applications are fiber glass-reinforcing material in a polyester or epoxy matrix and carbon fibers in an epoxy matrix (Smith, 1990). Glass is the most widely used fiber for fiber-reinforced composites. It can be very strong, it is relatively inexpensive, and of major importance, it has a higher elastic modulus than do the polymetric matrixes (Vanvlack, 1989). The E-glasses are used as fiber reinforcement, which were designed originally for electrical applications. They are mostly

Calcium Aluminoborosilicate glasses that contain no Na ions. All glass-fiber products must have their surfaces coated to give protection from surface damage and loss of strength. They are also to provide a transition between the fiber and the matrix.

Fillers in general can be used to modify and regulate certain properties of GRP composites for suitability to specific applications. The use of filler also affects the setting and hardening duration during production. The filler used must be compatible with both the matrix and the reinforcing fibres. It must be able to stick to fibres and matrix so as to resist the accompanying shear stresses. Fibrous fillers are especially effective for adding strength to a product. These fillers may be glass fibers, organic textile fibers or fiber from mineral sources (Vanvlack, 1989). It has been reported by Smith (1990) that polyvinyl chloride (PVC) products have been added with fillers such as calcium carbonate in order to lower the cost. Adding fillers into the composite especially the mineral fillers have beneficial effects.

Also, by combining the fibers of the Chopped Strand Mat (CSM) glass with materials of different characteristics such as plastics result in composite materials with improved properties. In this case, the fibers offer a number of advantages reinforcing fillers in the plastic composities, such as high specific strength and /or stiffness, low weight, low cost, and lower abrasion to the processing equipment (Schneider et al 1995).

The range of possible composites and their application is enormous. For example, carbon-fiber-epoxy composite material is used for the wings and engines of C-17 transport planes (Smith, 1990). Another example of the use of composites is glass-reinforced polyphenylene sulfide (PPS) for oil-field fittings. This application utilizes the excellent corrosion resistance of this material. Therefore, composite materials can meet the demanding requirements for construction and transportation industries, namely for motor vehicle components (Kumer and Ramani, 2000).

The aim of this work is to do a comparative study of the effect of mineral fillers on the compressive strength of Glass Reinforced Plastic (GRP) composite .The composite material is intended to be used in the construction industry in form of cladding panels where compressive strength is of great importance.

MATERIALS AND METHOD

The materials used consist of Chopped Strand Mat (CSM), release agent, polyester resin (Gelcoat), catalyst, accelerators, wood pattern with a flat surface and mineral fillers such as calcium carbonate and talc.

Production of the Composite

The hand lay-up technique (Smith, 1990) was used to produce series of samples of the GRP composite. Some samples of GRP were produced without fillers and the others were made with fillers in the following order:

Series I; with 5%, 10%,15%,20% and 25% of Calcium Carbonate; and

Series II; with 5%, 10%, 15%, 20% and 25% of Talc.

Four layers of chopped strand mat were made each in resin matrix with the percentage of the needed filler. After hardening, the samples were demoulded and set aside to cure. The curing takes four days at room temperature.

Compression Test

The mechanical behaviour of the composites were examined by compression test. The Hounsfield Monsanto Tensometer material testing machine with a loading capacity of 30KN, was used for the compression test at room temperature. In each sample, each test was repeated five times, and an average was taken at the end of the test. The dimensions for all the test samples were the same, i.e length – 40mm, Breadth – 4mm and Height – 20mm. Table 1 shows the percentage combination of the production samples.

RESULTS AND DISCUSSION

The results were analysed by statistical method. The production involving 25% filler combination with 25% of chopped strand mat (CSM) in 50% of resin matrix increased the curing, setting and hardening times. Eventually, during compression test of the sample, it failed at low force and the mat was distinctively separated from the matrix. This gives a very negative mode of failure, which can be detrimental for any application. This combination which may be recommended for 25% filler content and 25% chopped strand mat (CSM) did not seem feasible in such a composite.

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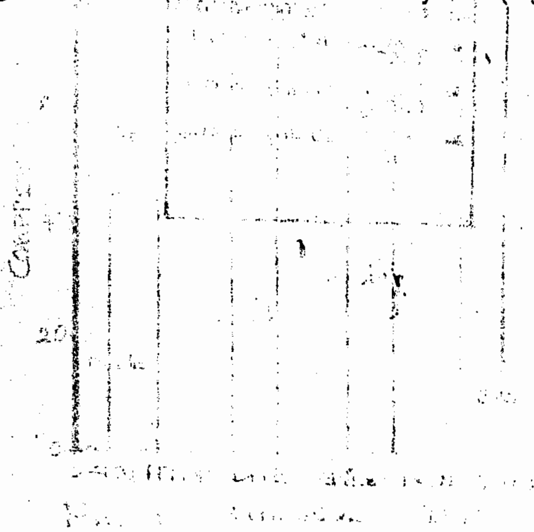
Therefore, the results and discussion herein are limited to 20% filler content, since in this percentage showed a promising result of composite.

Table 1: The percentage combination of the fillers, mat and resin used for the production of the samples

Filler	Mat	Resin
5% (7.2g)	25% (36g)	70% (100.8g)
10% (14.4g)	25% (36g)	65% (93.6g)
15% (21.6g)	25% (36g)	60% (86.4g)
20% (28.8g)	25% 936g)	55% (79.2g)
25% (36g)	25% (36g)	50% (72g)

During deformation, as the composite spreads over the compression anvils to increase its diameter, frictional forces oppose the outward flow of the material. This frictional resistance occurs in the part of the sample in contact with the anvils, while the material at sample mid-height can flow outward undisturbed. This leads to a barreled sample profile, and internally a region of undeformed material is created near the anvils surfaces. As reported by Dieter (1981), as these cone-shaped zones due to undeformed regions approach and overlap, they caused an increase in force for a given increment of deformation and the load-deformation curve bends upward as noted in Figure 1. The result showed that the samples of composite that contained no filler, had the least compressive strength. However those samples that contained filler had their compressive strengths increased depending on the amount of filler added. This was not surprising. Fine ground particles possess more surface area per unit volume than one without filler. Therefore, they increased the hardness of the composite more substantially for a given addition (Smith, 1990). Mineral fillers are especially effective for adding strength to the composite (Van Vlack, 1989).

In comparative studies of the compression strength of two mineral fillers used namely Talc ($Mg_3Si_4O_{10}(OH)_2$) and Calcium Carbonate ($CaCO_3$), Figures 2-4 showed that Calcium Carbonate ($CaCO_3$) was more effective as a strengthening agent than talc ($Mg_3Si_4O_{10}(OH)_2$). Table 2, shows the comparative compression strengths of Calcium Carbonate and Talc. The explanation of the differences in the compression strengths between Calcium Carbonate and Talc fillers in the composite lies in their structurally build up.



Talc, $Mg_3Si_4O_{10}(OH)_2$ (Hydrous magnesium silicate), has a three-layer sheet structure. Two silica tetrahedral layers enclose an octahedral layer in which all octahedral positions are filled with Mg ions (trioctahedral). The bonds between the sheets are weak (Sorrel and Sandstrom, 1982). As a result of this, the hardness of talc is 1 moh's scale, cleavage is perfect in one direction, fracture irregular, with specific gravity of 2.58-2.83. Also weakness of Talc could be ascribed to the stacking of successive layers which are not regular. It may also be due to small atomic space containing only a small amount of substitute element like Aluminum (Al) or Titanium (T_i), which could have raised up its hardness.

The structure of Calcite can be described by Calcite group like $CaCO_3$ (Calcium Carbonate) which has a structure similar to that of halite, where Na and Cl ions are replaced by Ca and CO_3 ions respectively (Sorrell and Sandtrom, 1982). The unit cell is distorted by compression along a triad axis to give a face-centred rhombohedral cell (Deer, et al., 1966). The distortion of the cube is necessary to accommodate the large planar CO_3 groups which contain a carbon ion at the centre of an equilateral triangle of oxygen (Sorrell and Sandstrom, 1982). The specific gravity of Calcite, is raised by any of the usual substituent ions entering the structure. The specific gravity is 2.6-2.8, while the hardness is 3 on Moh's scale, but varies from 2 ½ on {0001} to 3½ on a surface parallel to the z axis (Dudu and Rejl, 1986). The main lamella twinning in calcite is that on $\{0_1T_2\}$, which gives rise to striate parallel to the edges and to the long diagonal of the cleavage rhomb (Deer et al., 1966). These features might have contributed to more compression strength of $CaCO_3$ as a filler than Talc in composite.

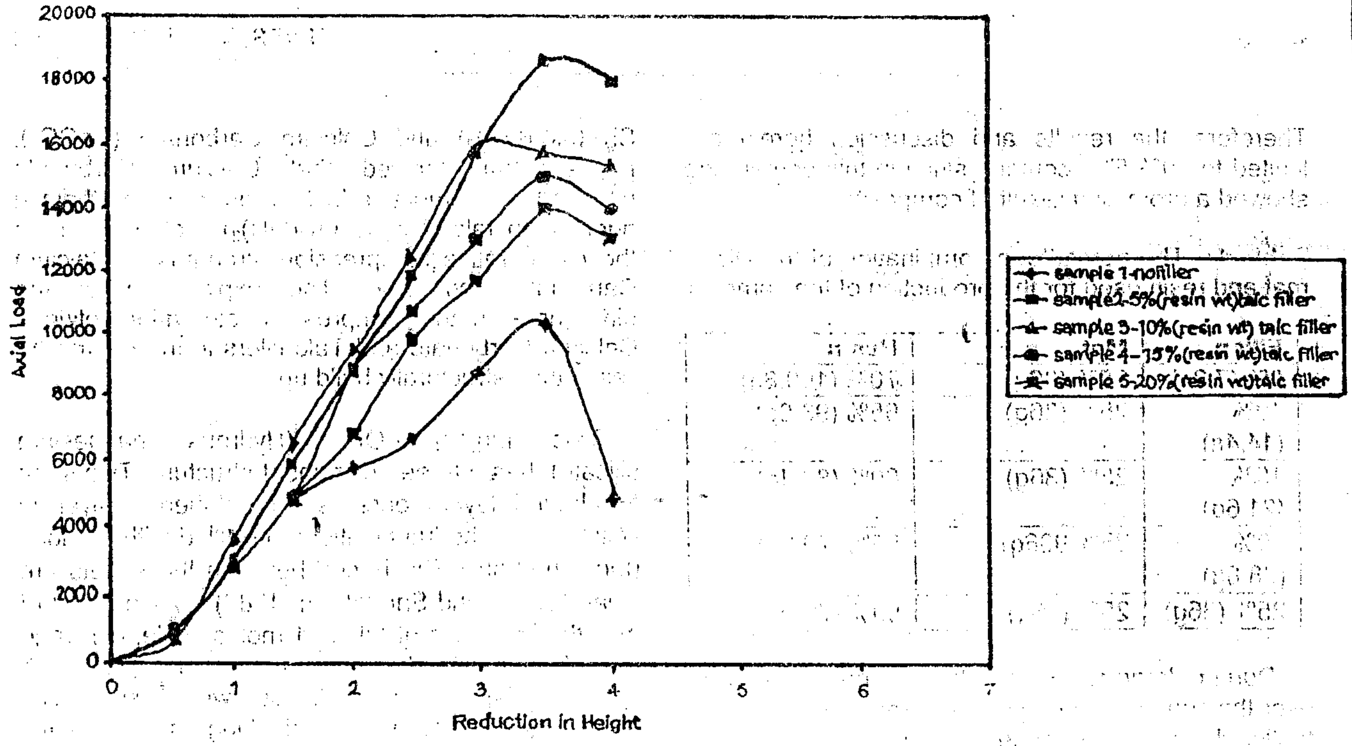


Fig. 1. Load-Deformation Curves for compression test

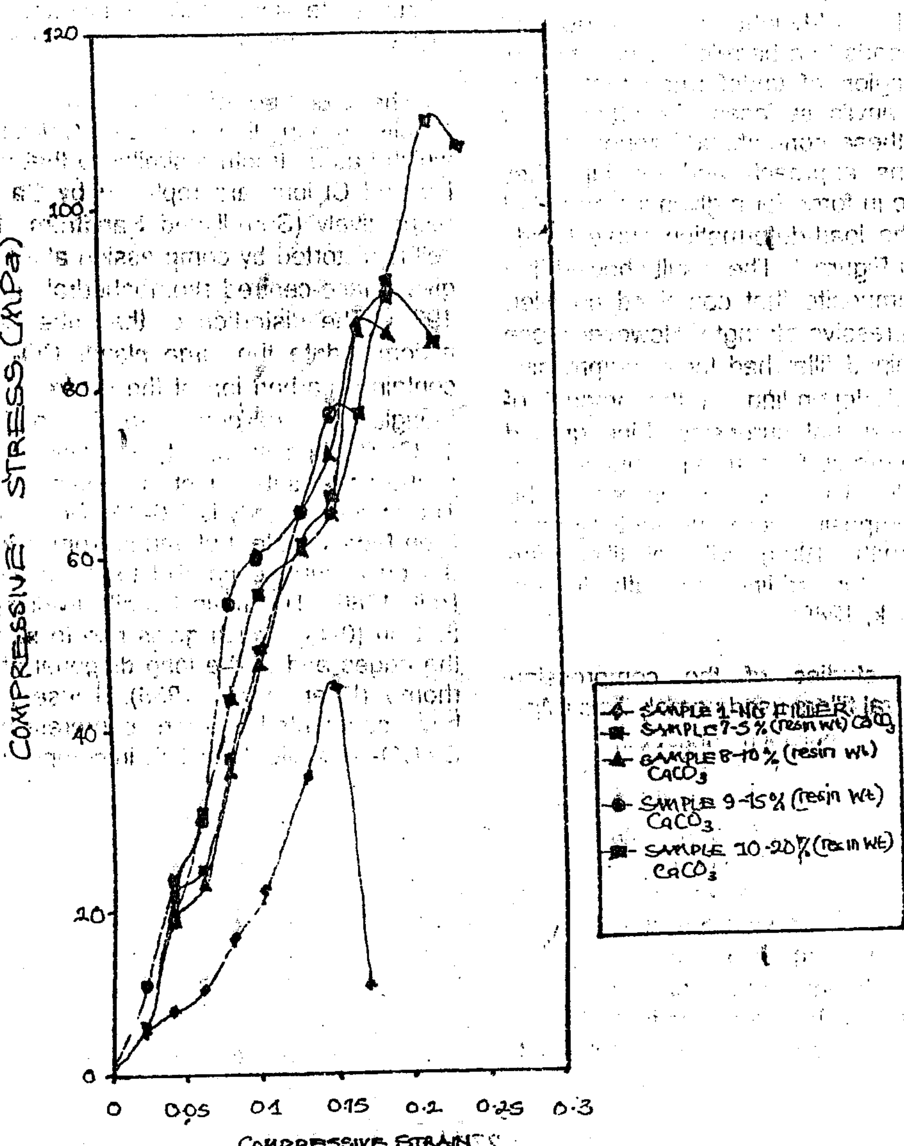


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Fig. 2. EFFECT OF $CaCO_3$ FILLER ON COMPRESSIVE STRENGTH OF

Table 2: Comparative Study of Calcium Carbonate and Talc fillers on the Compressive Strength of Composite.

S/No	The Mineral Filler	Added Percentage of filler	Compressive Strength (Mpa)
1	No filler	-	44.81 + 10.45
2	Calcium Carbonate	5%	109.75+ 14,14
3	Talc	5%	98.00 + 14.14
4	Calcium carbonate	10%	87.00+ 16.08
5	Talc	10%	88.00+ 11.34
6	Calcium Carbonate	15%	77.13+ 5.38
7	Talc	15%	67.38 + 13.58
8	Calcium Carbonate	20%	89.88 +18.57
9	Talc	20%	74.63 + 15.52

CONCLUSION

The actual strength values of a fibre composite material depend on the details of production methods, the type of fibre glass used, their combination and also on the type of mineral fillers. In this work, reference was only made to the effect of fillers on the compressive strength, since the material is intended to be used in cladding panel for construction, where compression strength is of paramount importance.

It can therefore be concluded that mineral fillers increased or improved the compressive strength of GRP composite. The fillers consisted of ground particles of Talc and Calcium Carbonate added separately to the samples up to 25% (Resin wt) content. However, it was found that the use of filler must be limited to 20% (Resin wt) filler content. This is because above this percentage, there is the possibility of negative effects on the responses of the composite, such as tremendous increase in curing, setting and hardening times, and prernature failure during the testing of the sample.

Improvement in compression strength was generally higher with Calcium Carbonate fillers than with Talc at the same percentage. These were attributed to the differences in the structural build up of the calcium carbonate and talc fillers that were used to produce the composite.

RECOMMENDATIONS

Since engineering composite materials industry is still at its infancy stage in Nigeria, it is necessary to make the following recommendations to create awareness of this material:

(I) It is high time the government and the private sectors started to venture into this "tomorrow" engineering materials. This is because the conventional engineering materials, like metals, plastics and ceramics, have their limitations in design and production of products for high-technology engineering applications. In order to bridge these gaps, the use of composite materials has become very necessary.

(II) The production of composite materials can start from the simple technology of hand lay-up process (which is open-mould process) to closed-moulding compound (SMC) process.

(III) The products of composite engineering materials company can be used in these areas:- aerospace, automotive engineering, bioengineering, chemical engineering, civil/structural engineering, marine engineering and others.

(IV) The compressive strength of a composite material can be improved with the use of appropriate mineral fillers like Calcium Carbonate.

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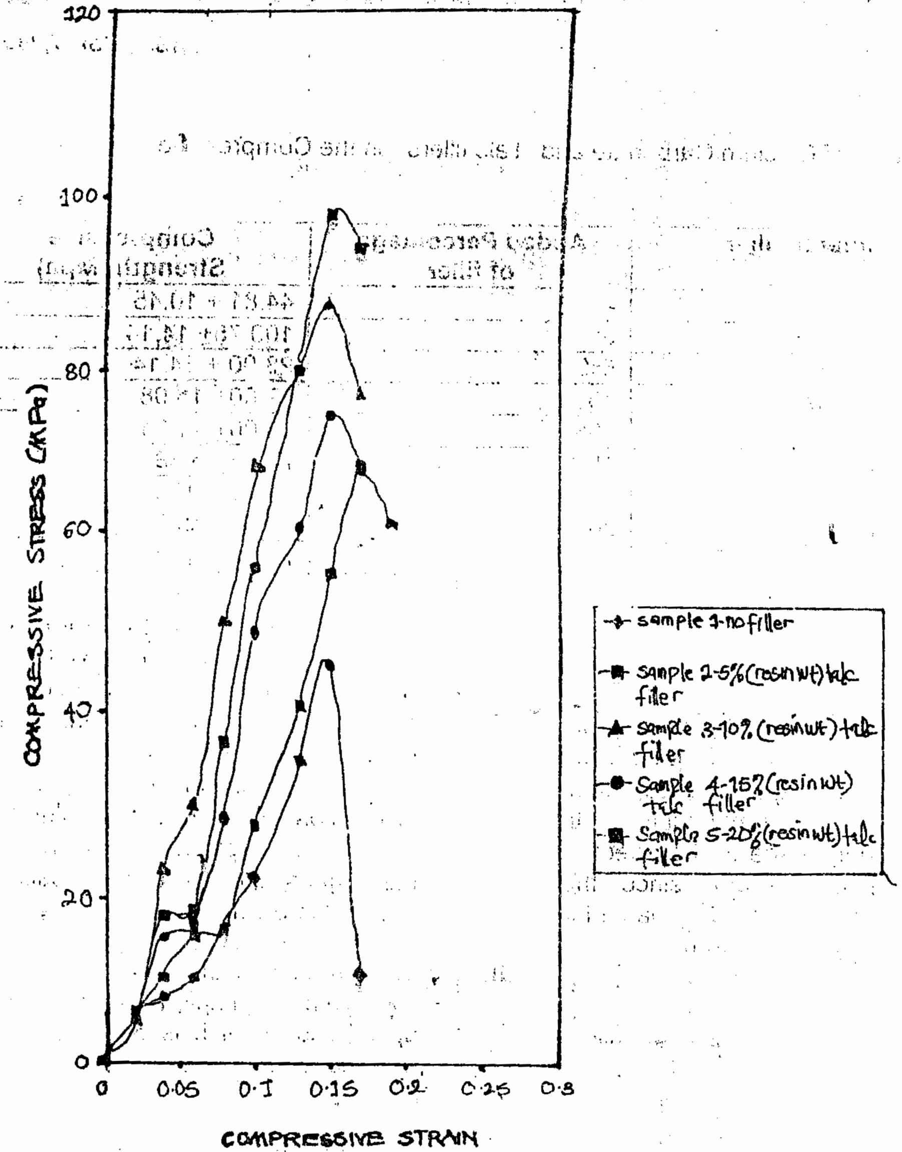

FIG. 3. EFFECT OF TALC FILLER ON COMPRESSIVE STRENGHT CHOPPED STRAND MAT GRP COMPOSITE

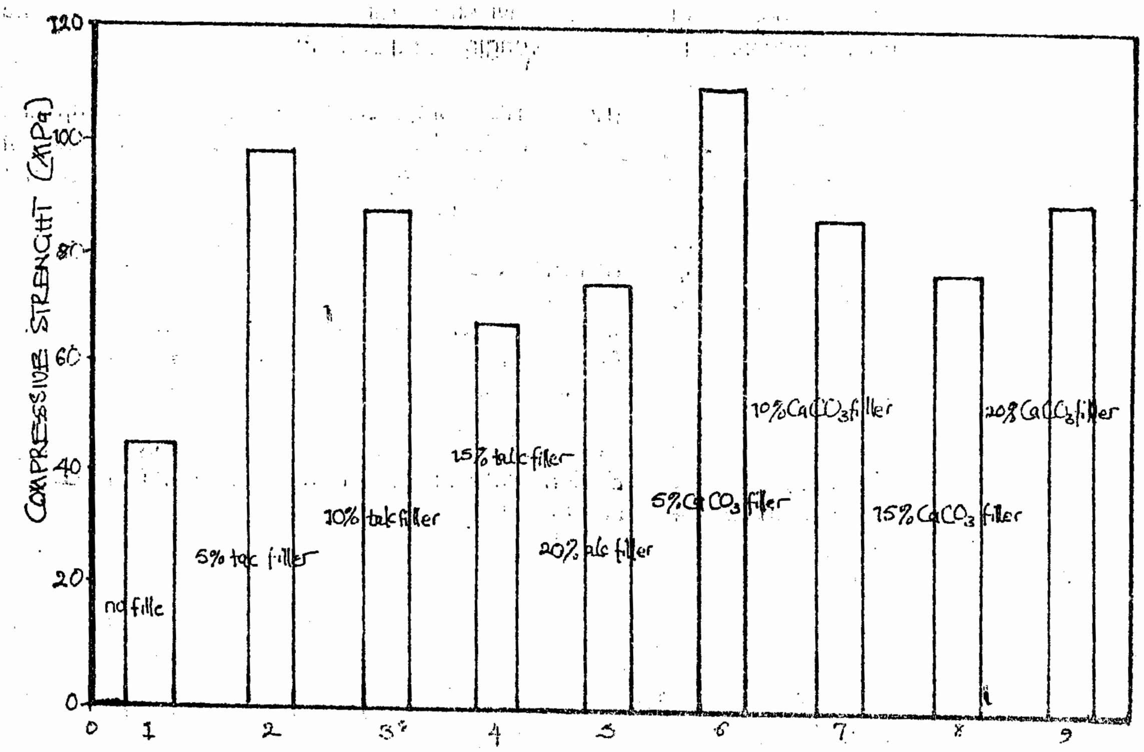

FIG. 4 EFFECTS OF TALC FILLER ON COMPRESSIVE STR...