
DEVELOPMENT AND INVESTIGATION OF THE CORROSION BEHAVIOUR OF Al-Cu-Mg/ COCONUT SHELL ASH PARTICULATE COMPOSITE IN 0.5M HCL.

Mahdi S. U^{1*}, Ige A.R² & Ahmed A.M²

1. Department of Metallurgical and Materials Engineering, Waziri Umaru Federal Polytechnic, Birnin Kebbi, Nigeria.
2. Department of Pure and Applied Chemistry, Kebbi State University of Science and Technology, Aliero, Nigeria.

Corresponding email: *Snmahdi31@gmail.com

ABSTRACT

In this research, Al-Cu-Mg/Coconut Shell Ash particulate (CNSAp) composite was developed using the stir-casting method, the morphology of the developed composite was studied using the scanning electron microscope and the tensile strength and hardness were investigated using the universal tensile testing machine and the Rockwell hardness tester respectively. The corrosion behavior of the composite in 0.5M hydrochloric acid was also investigated using the gravimetric mass-based (weight-loss) method of corrosion testing. The morphology showed distribution of the reinforcement in the matrix which became more pronounced as the amount of the reinforcement was increased. The hardness increased from 40.73 to 56.60HRV in the control sample and 6% reinforcement respectively while the tensile test showed an increase in value from 1735N/mm² in the control sample to 1968.67N/mm² at 8% reinforcement. The result of the gravimetric-based weight loss corrosion test showed a decrease in the corrosion rate in each composition after the selected hours which is an indication of passivation in the coupons and there was a decrease in the general corrosion rate after 120hrs from 0.00070mmpy in the control sample to 0.00006mmpy at 8% reinforcement.

KEYWORDS: Matrix, Reinforcement, CNSAp, Composite, reinforcement, morphology.

1. INTRODUCTION

Composite materials, plastics and ceramics have been the dominant emerging materials in many industries over the last decade. The motive behind the use of Metal Matrix Composite (MMCs) components in the automotive, agriculture and mining sectors is based on requirements for weight reduction, pursuit of high efficiency and performance materials. The automotive industry is subjected to increasingly strict fuel economy requirements by consumers, demanding improved comfort and safety. To meet these requirements, automotive manufacturers are turning to light weight and improved efficient products. The possibility of taking advantage of particular properties of the constituent materials to meet specific demands is the most important motivation for the development of composites (Aigbodion & Hassan, 2007).

A composite is a material that is produced via a physical combination of pre-existing constituent materials to obtain a new material with unique properties when compared to the monolithic materials. The term “matrix”, as often used in composite materials, refers to the percolating “soft” phase (which has general excellent ductility, formability and thermal conductivity) in which are embedded the hard “reinforcements” (high stiffness and low thermal expansion). The reinforcements can be continuous or discontinuous, orientated or disorientated (Aigbodion & Hassan, 2007).

Metal-Matrix Composites (MMCs) have emerged as a class of materials capable of being utilized in advanced structural, aerospace, automotive, electronic, thermal management and wear applications. The performance advantage of Metal Matrix Composites is in their tailored mechanical, physical and thermal properties, high thermal conductivity, high abrasion and wear resistance (Aigbodion & Hassan, 2007). The ever-increasing demand for low cost reinforcement stimulated the interest towards production and utilization of by-products from industry as reinforcements since they are readily available at affordable cost (Aigbodion, 2007).

To improve the ductility and fracture toughness of the traditional composites, the new class of materials known as Metal Matrix Nano composites (MMNCs) is developed by reinforcing particles in the nanometer scale. MMNCs are the advanced materials prepared by combining two or more materials in which tailored properties are analyzed. The reinforcement of micro/nano particles in the AMCs has improved mechanical properties due to the reinforcement of high strength and high modulus particles like Nano sized SiC, Al₂O₃, B₄C, ZrO₂, Graphite, FeTiO₃. Aluminium Metal Matrix Nano Composites (AMMNCs) are widely used for high performance applications such as automotive, military, aerospace and electrical industries. The three production methods of these composites can be categorized into: solid state methods, semi-solid state methods and liquid state methods. The solid state methods can be divided into powder metallurgy, mechanical alloying and diffusion bonding methods. It allows essentially a wide range of materials to be used as the matrix and reinforcement. Also, separation effects and intermetallic phase formations are less for these processes (Rajesh & Yohan, 2016).

Corrosion is a time-consuming with progressive deterioration of a metal's properties such as its exterior look, its surface aspects, or its mechanical properties under the effects of the surrounding environment, atmosphere, water, sea water, various solution and many more (Santhosh, 2015). Each and every metals and alloys subjected to corrosion through chemicals, environment, or electrochemical alteration show some level of destruction. The driving force is free energy withdrawal of metal to build up; a metal oxide. Considering corrosion counterbalance take place over metal outer surface, called as interfacial action.

Corrosion presents itself at metal medium phase boundary where heterogeneous response in network of metal surface has essential function. Metallurgical aspects that might alter corrosion in alloy consist of crystallography, grain size together with shape, grain heterogeneity, impurity inclusions and also residual stress due to cold work (Aigbodion *et al.*, 2011). This study examines the corrosion behaviour of Al-Cu-Mg/ coconut shell ash particulate composite in 0.5M Hydrochloric acid.

2. MATERIALS AND METHODS

2.1 Materials/Equipment

The materials that were used in this research are pure Aluminium wire obtained from NOCACO, Copper, Magnesium shavings, Coconut shell, thread, 0.5M Hydrochloric acid, grit papers, polishing cloth and the equipment used are Crucible furnace, Electronic Universal tensile testing machine model WDW-100KN, Rockwell hardness tester, analytical weighing balance, beaker, polishing machine, dessicator, scanning electron microscope (SEM), and moulding box.

2.2 Method

The Coconut shells were dried and heated at 1000°C for 10 hours to burn off all carbonaceous and volatile matter leaving only the particulate then it was ball milled for 6 hours then sieved to a size of 64µm. The composite was developed by measuring the appropriate amount of material that will formulate the Al-3.5% Cu-0.8% Mg/Coconut Shell Ash particulate composite with 2, 4, 6, 8% reinforcement and a control sample with no reinforcement. The Aluminium and Copper metals were melted initially in the crucible furnace then the Magnesium shavings were added. The reinforcement was preheated, added to the melt and stirred before it was poured into the green sand mould pattern with diameter 23mm and 176mm length then allowed to solidify and cool to room temperature. The tensile behavior of prepared samples was determined at room temperature using Universal testing machine in accordance with ASTM D638-10. Test specimens were machined to dimension of length 180x2.5 mm. The specimen was loaded between two manually adjustable grips of a 200 KN computerized Universal Testing Machine (UTM) with an electronic extensometer. Each test was repeated three times and the average value was taken to calculate the tensile strength of the composites.

The Hardness test was carried out using the Indentec Universal hardness testing machine (model number 8187.5LKV). Rockwell Hardness tester with HRC Scale was used to measure the hardness of the material according to the ASTM E18-20. Cast samples were ground, polished and mounted with Bakelite to provide support. The samples were placed one after the other on the machine. A minor load of 10 KN was initially applied and this would take up the slack in the system and the dial indicator was set to zero. A major load of 150 kN was applied and when the major was taken off, the hardness value was displayed on the dial indicator. The hardness test was carried out on three different spots on each test piece. Three readings were obtained for each of the test sample compositions and the average values were recorded as the Hardness value accordingly. The same procedure was replicated for each of the test sample of other compositions.

A total of 30 coupons (5 for each composition) 10mm x 15mm in dimension were made according to the ASTM G1 standard. The surface will be prepared by mechanical grinding and polishing of the surface using grit papers of different grades to obtain a mirror-like finish. The samples were then degreased using acetone at room temperature, weighed using a weighing balance then stored in a desiccator. A thread was used to hang them in the electrolyte.

50 cm³ 0.5M HCl was poured into six beakers according to the ASTM D1141-98 standard. Five weighed samples of each composition of the composite including the control sample were suspended using a thread in the solution by completely submerging them. After every day (24 hours) one sample was removed from each beaker, washed in running tap water, dried with clean cloth and then weighed again. The initial and final weights of the coupons were used to calculate the corrosion rate using the formula below:

$$\text{Change in weight (W)} = W_2 - W_1 \dots \dots \dots 1$$

Where W_1 = Initial weight

W_2 = Final weight

$$\text{Corrosion Rate (W)(mmpy)} = \frac{87.6W}{DAT} \dots \dots \dots 2$$

Where D = Density of Steel (7.9g/cm³)

A = Surface area (cm)

T = Time (hrs)

3 RESULTS AND DISCUSSION

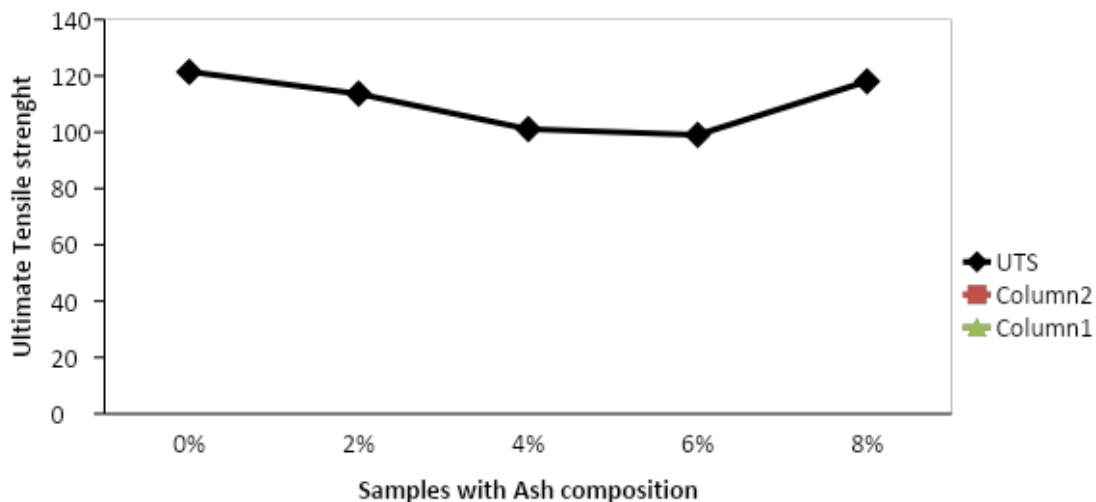


Figure 1. Plot of the variation of the Ultimate Tensile strength against the reinforcement in the Al-3.5% Cu-0.8%Mg/CNSAp composite.

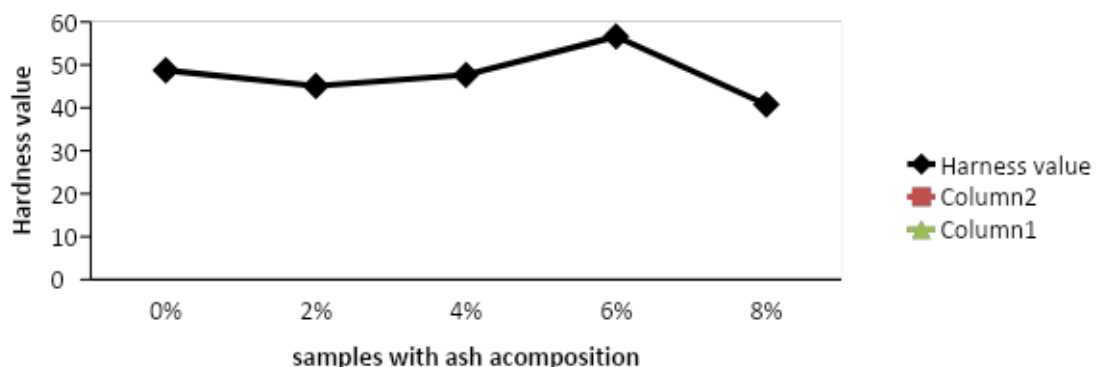


Figure 2. Plot of the variation of the Rockwell Hardness value against the reinforcement in the Al-3.5%-Cu 0.8%Mg/CNSAp composite.

From the charts above, it can be seen that the Ultimate Tensile strength for the material decrease from 121.45 N/mm^2 at 0% to 99.02 N/mm^2 at 6% before increasing to 118.12 N/mm^2 at 8% which when calculated against the strain produced showed an increase in stiffness from 1735 N/mm^2 at 0% to 1968.67 N/mm^2 at 8% reinforcement as shown in the figure 1 below. Figure 2 shows the plot of the Rockwell hardness against the reinforcement, there is an increase in hardness of the material from 48.73 HRB at 0% to 56.6 HRB at 6% which is the highest result obtained from the test.



Plate 1: Microstructure of as-cast Al-3.5%Cu-0.8%Mg alloy (control sample) x300

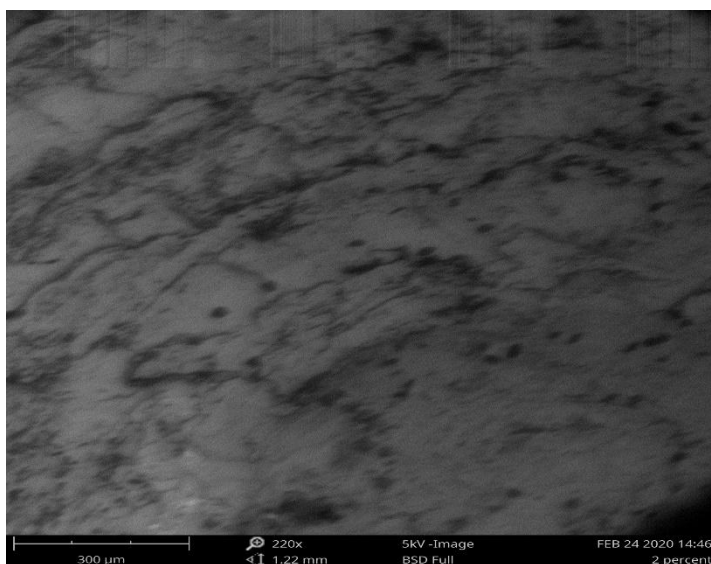


Plate 2: Microstructure of as-cast Al-3.5%Cu-0.8%Mg/CNSAp composite with 2% reinforcement. x300

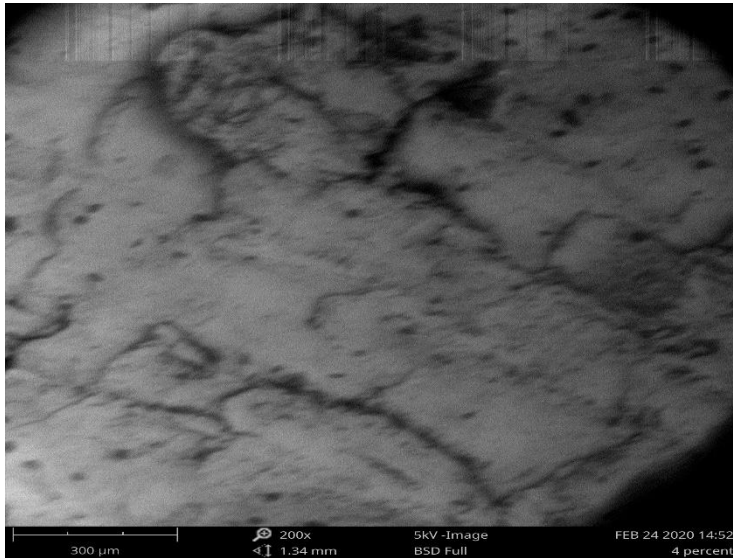


Plate 3: Microstructure of as-cast Al-3.5%Cu-0.8%Mg/CNSAp composite with 4% reinforcement.x300

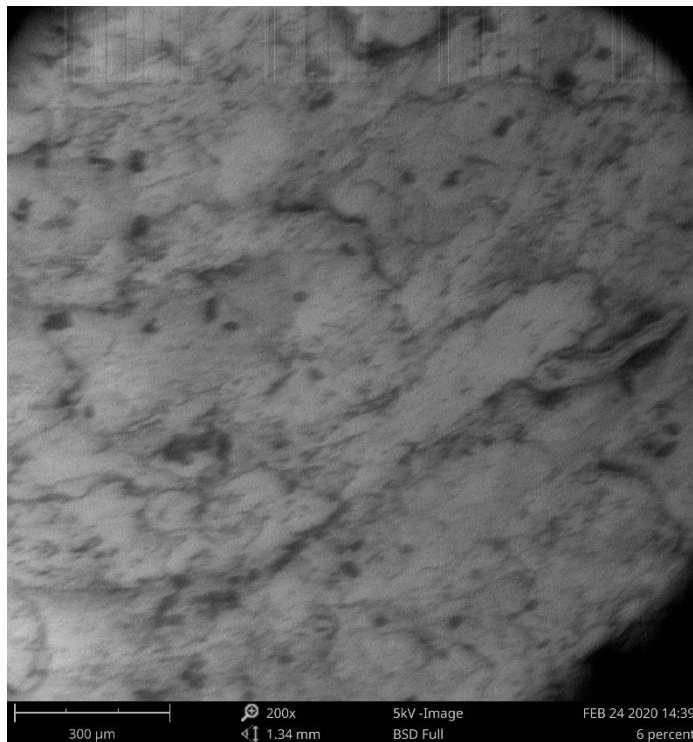


Plate 4: Microstructure of as-cast Al-3.5%Cu-0.8%Mg/CNSAp composite with 6% reinforcement.x300

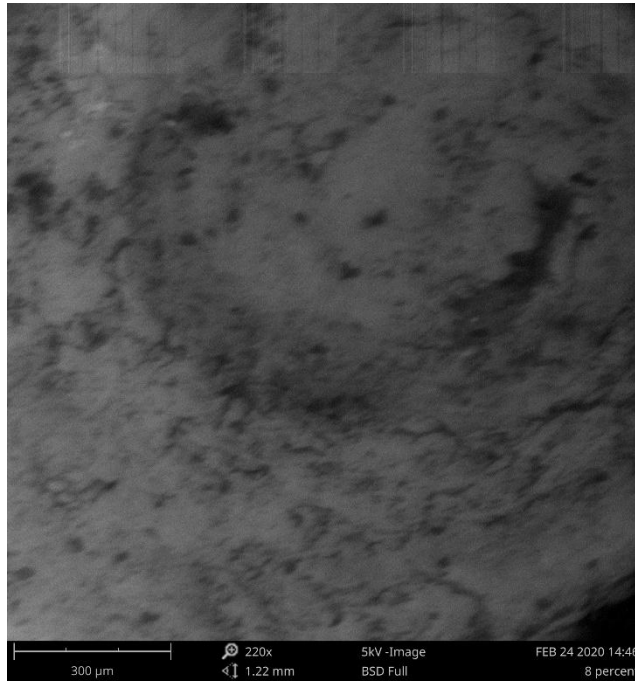


Plate 5: Microstructure of as-cast Al-3.5%Cu-0.8%Mg/CNSAp composite with 8% reinforcement.x300

The Scanning Electron Microscopy performed on each of the compositions of the composite shows the presence of the reinforcement (dark) in the matrix and an increase in the presence of the reinforcement as the amount increased as shown in the plates 1, 2, 3, 4 and 5 which correspond to the morphology of the composites with reinforcement 0 to 8% respectively. This account for the increase in the strength of the material as the reinforcement create more grain boundaries and obstructions in the matrix making it stiffer and stronger as reported in the research by Li *et al* (2019).

Table 1: corrosion test result for 0% CNSAp

S/N	Initial weight (g)	Final weight (g)	Change weight (g)	in	Corrosion rate	Time of Exposure (hrs)
1	4.145	4.133	0.012		0.00092	24
2	4.372	4.353	0.019		0.00073	48
3	4.364	4.356	0.008		0.00020	72
4	4.680	4.608	0.072		0.00138	96
5	4.026	4.016	0.01		0.00015	120

Table 2: corrosion test result for 2% CNSAp

S/N	Initial weight (g)	Final weight (g)	Change weight (g)	in	Corrosion rate	Time of Exposure (hrs)
1	5.014	5.009	0.005		0.00038	24
2	4.781	4.736	0.045		0.00173	48
3	4.628	4.593	0.035		0.00089	72
4	4.431	4.381	0.05		0.00096	96
5	4.548	4.502	0.046		0.00070	120

Table 3: corrosion test result for 4% CNSAp

S/N	Initial weight (g)	Final weight (g)	Change weight in (g)	Corrosion rate	Time of Exposure (hrs)
1	4.492	4.490	0.002	0.00015	24
2	4.336	4.303	0.033	0.00127	48
3	4.567	4.513	0.054	0.00138	72
4	4.051	3.998	0.053	0.00106	96
5	4.357	4.342	0.015	0.00023	120

Table 4: corrosion test result for 6% CNSAp

S/N	Initial weight (g)	Final weight (g)	Change weight in (g)	Corrosion rate	Time of Exposure (hrs)
1	4.539	4.525	0.014	0.00107	24
2	5.024	4.989	0.035	0.00134	48
3	4.907	4.867	0.04	0.00102	72
4	5.029	4.984	0.045	0.00086	96
5	4.577	4.525	0.052	0.00080	120

Table 5: corrosion test result for 8% CNSAp

S/N	Initial weight (g)	Final weight (g)	Change weight in (g)	Corrosion rate	Time of Exposure (hrs)
1	4.847	4.835	0.012	0.00092	24
2	4.806	4.803	0.003	0.00011	48
3	4.293	4.289	0.004	0.00010	72
4	4.620	4.617	0.003	0.00005	96
5	4.521	4.517	0.004	0.00006	120

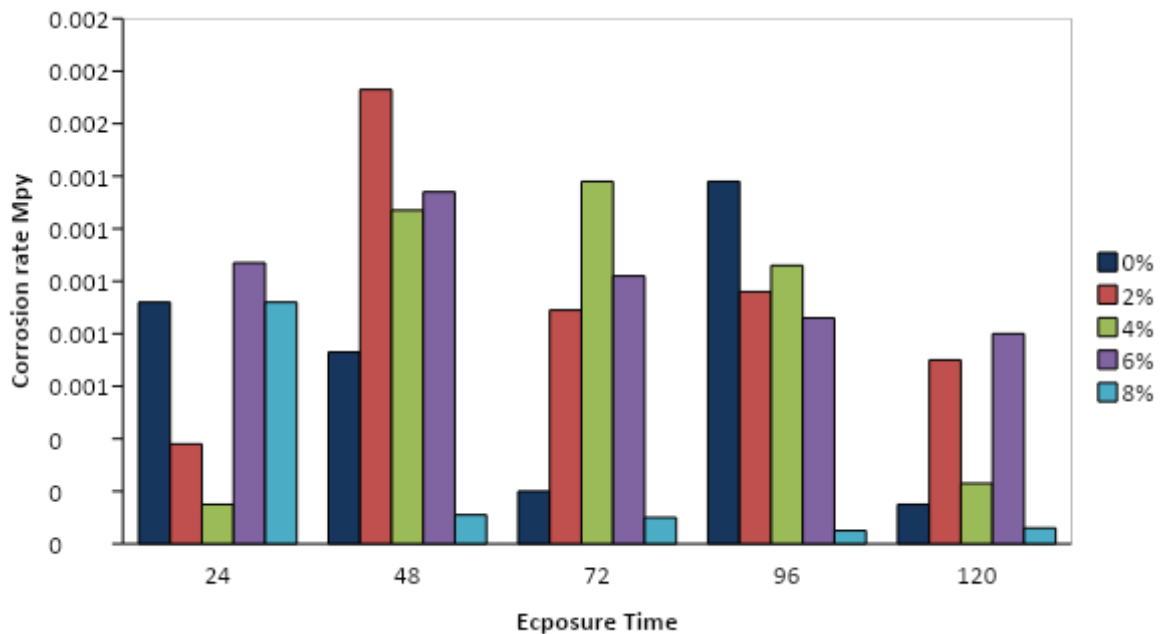


Figure 3. Graphical representation of the corrosion rate against exposure time.

The results on Tables 1 to 5 show the results obtained from the gravimetric based weight-loss corrosion test which shows after 24 hours the composite with 6% had the lowest corrosion rate with 0.00107mmpy among the 5 compositions after 48, 72, 96 and 120 hours, the 8% composition has the lowest corrosion rate at 0.00011mmpy, 0.00010mmpy, 0.00005mmpy, 0.00006mmpy respectively. It is noteworthy that generally the composites exhibit a reduction in corrosion activity after 120hours which could be explained by the passivation phenomenon which is exhibited by Aluminium and its alloys.

4 CONCLUSIONS

Coconut shell ash can be used to develop Al-3.5%Cu-0.8%Mg/CNSAp composite using stir casting. Addition of Coconut shell ash particulates increase the tensile strength and hardness of the composite within the scope of this investigation.

Addition of the CNSAp to the Al-3.5% Cu-0.8%Mg alloy increases its corrosion resistance as seen in the result where after 120 hours the corrosion rate reduced from 0.00015mmpy in the control sample without reinforcement to 0.00006mmpy in the composite with 8% reinforcement.

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