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Investigation on Curing days of Concrete Waste Particle Reinforced Aluminium Matrix Composite

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Abstract: Particulate reinforced aluminium matrix composites (AMCs) are employed as major structural materials in aviation and automobile components. AMCs are materials that have ductile metallic alloys reinforced with hard particles, resulting in attractive properties. The solid-state technology is used in this work to explore the influence of waste concrete as a reinforcing agent in aluminium matrix composites since it has significantly lower operation costs and energy than standard recycling by casting. The effects of concrete reinforcing on mechanical and physical characteristics were explored. Recycled aluminium chip AA7075 was reinforced with 2.5 %, 5%, 7.5 %, 10%, and 12.5% concrete with varied cure days of 7 and 28 days for each reinforcement composition. The current study identified density, apparent porosity, water absorption, micro-hardness, compression, and microstructure investigation of aluminium matrix composites. The finding reveals that range density of the specimen in g/cm³ between 2.3 and 2.6 only. For sample 1 which is 100% Aluminum shown that density gain until 2.5489 which is obtained the porosity of 2.7648% and water absorption 1.7531%. Aluminum matrix composites reinforced with 5% concrete achieved the maximum microhardness test result of 55.33 Hv after 7 curing days. The availability of reinforcing concrete has increased the hardness of aluminium matrix composites. For the highest microhardness was achieved in the specimen with 87.5% aluminum and 12.5% of concrete 28 curing days. The composition of 95% aluminium with reinforced concrete has the greatest young's modulus when compared to the others, with the reinforced 7 curing days being 13.24 MPa/m2 and the reinforced 28 curing days being 19.39 MPa/m2.

Keywords: AMC, Waste Concrete, Zinc Stearate

1. Introduction

Aluminium recycling is one of the methods for reusing scrap aluminium in other products once it has been manufactured. The most frequent method for recycling aluminium is to simply re-melt it. Although the use and industrial-scale production of aluminium metal is just a century old, the

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industry has evolved to the point that aluminium metal is now second only to steel and iron among metal producers, as shown in Figure 1. Recycled aluminium is widely used in the automobile industry. It was revealed in a comprehensive study on automotive aluminium recycling that, despite concerns about climate change, the use of aluminium in automotive applications with the notion of light weight is expected to rise gradually (Cui& Roven, 2010). Aluminium scrap obtained as secondary aluminium is recycled. Due to the high energy consumption of aluminium mining and melting, exchanging a portion of the metal through recycling of industrial waste such as aluminium chips promise lower manufacturing costs, does not harm the environment, and conserves primary aluminium resources, thereby achieving the current industrial society's goals.

Because of the qualities of diverse aluminium alloys, aluminium is used in a variety of sectors shipping, packing, and food preparation, to name a few energies, architecture, and electric transmission. Based on research on aluminium-reinforced rice husk ash composites, it appears that adding amorphous silica to metal matrix composites can improve material behaviour applications of the next generation (Mohd Joharudin et al., 2019). The AMCs are a high-tech material that is employed in a variety of engineering applications. In comparison to polymer composites, AMC are employed in flywheel applications. This is because the alumina fibre reinforced AMC improves the mechanical qualities of the material, allowing it to rotate at high speeds while maintaining its perfect shape (Surappa, 2003).

Particulate reinforced aluminium matrix composites (AMCs) are being used in aircraft and vehicle components as key structural materials. AMCs are materials in which ductile metallic alloys are reinforced by hard particles, resulting in appealing characteristics. Aluminium matrix composite is increase of the demand in a variety of industries due to its low density and good mechanical properties, as is the case with most metal matrix composites. The characteristics of the composite can be considerably improved by adding reinforcement materials such silicon carbide, aluminium oxide, and boron carbide, which are easy to mix into metal matrix composites (Joharudin, Latif, Mustapa, & Badarulzaman, 2020). Aluminium matrix composites have physical and mechanical qualities that are appealing to the aerospace and automotive industries, such as low density, high strength, great wear resistance, and exceptional high-temperature performance (Huang et al., 2021).

Metal matrix composites (MMCs) are a type of material that combines a metal and another component. Physically and chemically, these two components are at separate phases. The base material is a metal matrix, with fibres or particles acting as reinforcing material. The goal of developing such a material, as with other metal matrix composites, is to increase the metal matrix's mechanical properties. The goal of 3 matrix composites is to increase the metal matrix's current attributes by adding reinforcing features such as high strength, high heat resistance, and other unique traits (Chawla et al., 2013). As new manufacturers create these materials, the list of metal matrix composites may change from time to time. However, in metal matrix composites (MMCs), aluminium metal matrix is one of the most commonly utilised materials. Aluminium matrix composites (AMCs) are promising materials for a number of applications due to their excellent physical and mechanical properties.

The provision of shelter, sanitation, and healthcare is critical to safeguarding the world's rising population, hence global demand for buildings and infrastructure is quite strong. Concrete is the chosen construction material to meet this need, but its manufacture is causing overexploitation of natural gravel and sand, resulting in an environmental disaster in areas where these materials are mined in an unsustainable manner. Waste concrete is widely available around the world, particularly in areas where the built environment is rapidly expanding and in areas where concerted attacks, earthquakes, or extreme weather events have occurred (Marsh et al., 2022). Beneficiation technologies for total re-recycling of waste concretes, particularly the fine fractions produced after crushing, have also been hampered by a lack of expertise and practical hurdles. Despite these challenges, it is widely acknowledged that fully utilising waste concrete provides unique prospects for supply chain stability, reduced natural resource use, and the transition to a Circular Economy.

The research work involves the experimental studies about to improve characteristics reinforcement between aluminium matrix composites with waste concrete. The main objective is to increase strength of the material which can be later be used to various application.

2. Materials and Methods

2.1 Aluminium

Transportation (automotive, aeronautical, shipbuilding), aerospace, and biomedical are just a few of the areas where this is in high demand. Aluminium alloys, the most widely used lightweight alloy, have also entered into many industrial fields for its applications. Table 1 shows the general chemical composition of the Aluminium AA7075 used is this study.

Table 1. Chemical of Aluminium AA7075

Al	Zn	Cu	Si	Cr	Others
87.18	9.49	2.59	0.31	0.28	0.15

2.2 Waste Concrete

Recycling concrete to provide a source of recycled materials and so minimize the demand for primary construction mineral extraction has been identified as a way to address these challenges. The concrete as reinforcement of this study have been divided into 6 compositions which are 0%, 2.5%, 5%, 7.5%, 10% and 12.5%. Table 2 shows the general composition of the waste concrete in the study.

Table 2. Chemical composition of Waste Concrete in sample

Compound	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2
Conc 7 days (%)	0	1.83	11.24	42.97	0.59	1.87	0.2	2.62	34.19	0.51
Conc 28 days (%)	0	1.12	12.09	60.37	0.61	0.96	0.26	3.91	17.63	0.26

2.3 Preparations of Chip AA7505

The recycled aluminium chip was prepared using a variety of ways. Each stage ensures that all of the specimens used in the experiment are properly made, which contributes to the accuracy of the results. The aluminium alloy AA7075 was the primary raw material employed in this research. The starting step of this experiment is chip preparation which was produced through high speed milling machine at machining laboratory. Table 3 shows the parameter of the milling machine to produce the uniform size of aluminium chip.

Table 3. Specification of Chip Production

Tool	10 mm diameter, 2 flute carbide
Operation	Drying cutting without coolant
High cutting velocity	345.5 m/min
Depth of cut	1 mm
Feed, f	11000 mm/min

2.4 Waste Concrete Preparation

The cube concrete was provided to this study as the initial phase in the concrete preparation process. The crushing technique is used to reduce the size of the concrete by using Ball Mill Machine. Manual Crusher had been used by using hammer, but the concrete had not completely turned to powder, so the researcher had to do sieving process until completed.

2.5 Mixing and Compaction process

The mixing method and the cold compaction process were both used to prepare the specimens. Each stage ensures that all of the specimens used in the experiment are correctly created, which helps to ensure that the results are accurate. All of the examples were made from AA7075 recycled aluminium chips, concrete, and zinc stearate.

To carry out the mixing method, a compaction process was employed. This machine was used to blend all of the powdered components. This mixing procedure may combine three components in a random order: aluminium chips, concrete, and zinc. Table 4 illustrates the various amounts of aluminium chip and concrete utilised in the mixing procedure for six different samples. In AMC, several concrete compositions of 7 days and 28 days (at grade 30) are used as reinforcement: 0 percent, 2.5 percent, 5 percent, 7.5 percent, 10 percent, and 12.5 percent, with a total sample size of eleven and one without reinforcement. Mixing, cold compaction with a pressure of 9 tonnes, and sintering in a tube furnace at a temperature of 552°C are used to create AMC specimens. To improve the structural stability of AMC, 1% zinc stearate is employed as a binder during the mixing process.

Table 4. Composition of experiment sample

Sample	1	2	3	4	5	6
Aluminium chip AA7075 (%)	100	97.5	95	92.5	90	87.5
7 days of curing days Concrete (%)	0	2.5	5	7.5	10	12.5
Sample		7	8	9	10	11
Aluminium chip AA7075 (%)	-	97.5	95	92.5	90	87.5
28 days of curing days Concrete (%)	-	2.5	5	7.5	10	12.5

2.6 Sintering Process

The sintering method was used to minimise porosity and boost characteristics like as strength. This is due to the fact that the sintering process alters the microstructure of particles that are close together. The specimens were placed inside the tube furnace, and the argon gas was switched on for 1 hour to guarantee that the tube is completely filled with gas and no air is present. The tube furnace operates in accordance with the control programme schedule, which is based on the sintering profile shown in Figure 1. The sintering process takes 7 hours.

The temperature was kept constant for 30 minutes to eliminate the binder, which is zinc stearate. At the same heating rate, the temperature was gradually raised to sintering temperature. Following that, the same temperature was maintained for 1 hour. Finally, the sample was cooled to room temperature at a rate of 5° C/min.

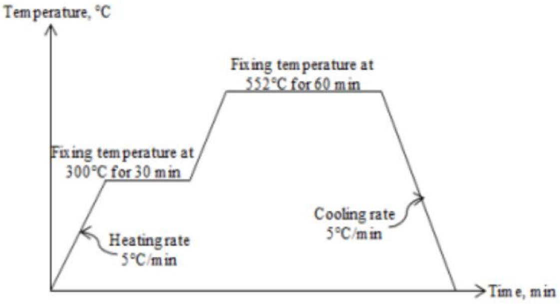

Figure 1. Sintering profile (Joharudin, 2020)

2.7 Physical Test and Micro-Hardness Test

In this study, physical tests such as density, water absorption, and porosity were performed and analysed. An optical microscopic examination of the microstructure of the chosen specimen was also carried out. The purpose of this physical examination was to determine the specimen's condition. The Micro-hardness of the material was determined utilising a micro-hardness test. In this experiment, a Vickers tester with a load of 980.7 mN and a period of 10 s with eight repetitions was employed.

2.8 Compression Test

The compression test was used to assess the specimen's ultimate compressive strength. The connection between stress and strain is same when the specimen is exposed to compressive loading and when the specimen is subjected to tensile loading. The specimen behaved elastically up to a particular amount of stress. When the value was surpassed, plastic deformation began. The compression test will be performed with the help of a Universal Tester Machine with a maximum load of 50KN.

3. Results and Discussion

3.1 Physical Properties

Using the Archimedes principle, physical testing was done to assess the connection between density (g/cm3), apparent porosity (percent), and water absorption (percent) of metal matrix composite samples. The density test was performed using a Mettler Toledo weighing machine. The sample must be boiled in distilled water for three hours before resting for twelve hours. This test is required for the density, apparent porosity, and water absorption tests. Table 5 displays the physical test results for both waste concrete grades. Figure 4 depicts the Density test results for both waste concrete 7 days and 28 days.

Table 5. Physical test for Waste Concrete Grade 40 and 30

Samples of concrete 7 days	Density (g/cm^3)	Water Absorption (%)	Porosity (%)
1. Al 100%	2.5489	1.7531	2.7638
2.Al 97.5 % + Concrete 2.5 %	2.3637	8.8505	13.2413
3.Al 95% + Concrete 5%	2.5068	2.5186	3.8930
4. Al 92.5% + Concrete 7.5%	2.3927	1.1290	1.5903
5. Al 90% + Concrete 10%	2.4316	0.8152	1.1766
6. Al 87.5 + Concrete 12.5%	2.4113	4.4422	6.5607

Sample of concrete 28 days			
1. Al 97.5 % + Concrete 2.5 %	2.4139	2.8936	4.2130
2. Al 95% + Concrete 5%	2.2489	2.5121	3.2182
3. Al 92.5% + Concrete 7.5%	2.4479	3.3223	4.9756
4. Al 90% + Concrete 10%	2.5043	1.1058	1.6821
5. Al 87.5 + Concrete 12.5%	2.3511	1.2918	1.7682

Table 5 shows that density of the specimen for different composition is not too big difference between sample. However, the water absorption and Porosity of the specimen is related when the result shown that when porosity increases, the more percentage of the water absorption is recorded. The finding reveals that range density of the specimen in g/cm³ between 2.3 and 2.6 only. Sample 1 which is 100% Aluminum shown that density gain until 2.5489 which makes the porosity to 2.7648% and water absorption 1.7531%. The range for density of 5 specimens with different composition of aluminum and concrete grade 30 and 28 days is about 0.25 g/cm³ which quite small of differences. The result shown that specimen with composition Al 87.5 of aluminum and 12.5 % concrete can achieve for 2.3511g/cm³, meanwhile for the water absorption and porosity which are 1.2918% and 1.7682 respectively.

3.2 Microhardness Test

The test was carried out with a load of 980.7 N and was repeated eight times in around ten minutes. The test was carried out in accordance with ASTM E384. Specimen without concrete 7 days that shown in table 4.2 is the smallest value of microhardness (Hv), meanwhile aluminum matrix composites with reinforced with 5% concrete 7 curing days is the highest microhardness test which is 55.33 Hv. Table 4.2 shows that the highest microhardness is the sample with the most percentages of the reinforced concrete 28 days. Comparison chart in figure 4.6 shows the pattern of the microhardness test of the specimen between 7 days and 28 days reinforcement. The blue color which is 7 days shows uneven and fluctuating microhardness value. Meanwhile, for 28 days reinforcement results shows more the existence of the reinforcement in the specimen, microhardness of the specimen increases. The highest microhardness value is the specimen with 87.5% aluminum and 12.5% of concrete 28 curing days.

Table 6: Micro-Hardness Vickers test results for concrete

Specimen with 7 days concrete	Composition	Hardness, Hv
A	Al 100%	35.21
B	Al 97.5% + Concrete 2.5%	45.00
C	Al 95% + Concrete 5%	55.33
D	Al 92.5% + Concrete 7.5%	46.30
E	Al 90% + Concrete 10%	50.29
F	Al 87.5% + Concrete 12.5%	28.23
Specimen with 28 days concrete		
G	Al 97.5% + Concrete 2.5%	41.69
H	Al 95% + Concrete 5%	42.03
I	Al 92.5% + Concrete 7.5%	42.32
J	Al 90% + Concrete 10%	49.14
K	Al 87.5% + Concrete 12.5%	73.19

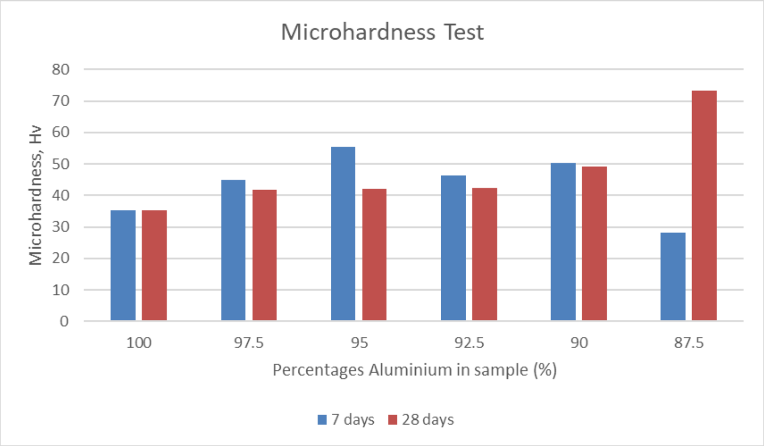

Figure 2: Microhardness test comparison chart between reinforced concrete 7 days and 28 days

3.3 Compression Test

The compression test was conducted to determine and quantify the ultimate compressive strength of the specimen. The compression testing machine was set at 1mm/min speed rate and the result can observe is Young's Modulus of the specimen. Stress and strain value which are obtained in this compression test can show the Young's Modulus of the specimen. The composition of 95 % Aluminium with reinforced concrete shows the highest young's modulus. The reinforced 7 curing days is lower which is 13.24 MPa/m² meanwhile for the 28 curing days is 19.39.

Table 5. Young's Modulus test of AMC with reinforced concretes

Composition of sample (%) of 7 days concrete	Young's modulus (MPa/m²)
100 Al	11.31
97.5 Al + 2.5 Concrete	12.75
95 Al + 5 Concrete	13.24
92.5 Al + 7.5 Concrete	10.05
90 Al + 10 Concrete	9.45
87.5 Al + 12.5 Concrete	10.13
Composition of sample (%) of 28 days concrete	
97.5 Al + 2.5 Concrete	12.03
95 Al + 5 Concrete	19.39
92.5 Al + 7.5 Concrete	14.79
90 Al + 10 Concrete	11.48
87.5 Al + 12.5 Concrete	10.05

The results shown in figure 4.8 is the strain against stress for the reinforcement of concretes 7 days. The composition of aluminium of the sample which has the highest incline line is 90%. Meanwhile, for the 95% composition of aluminium content in one specimen is the lowest of the strain which mean it is difficult to deform. The lower the strain, the more the strength of the specimen. When the surface area becomes more resistant to plastic deformation, the hardness increases.

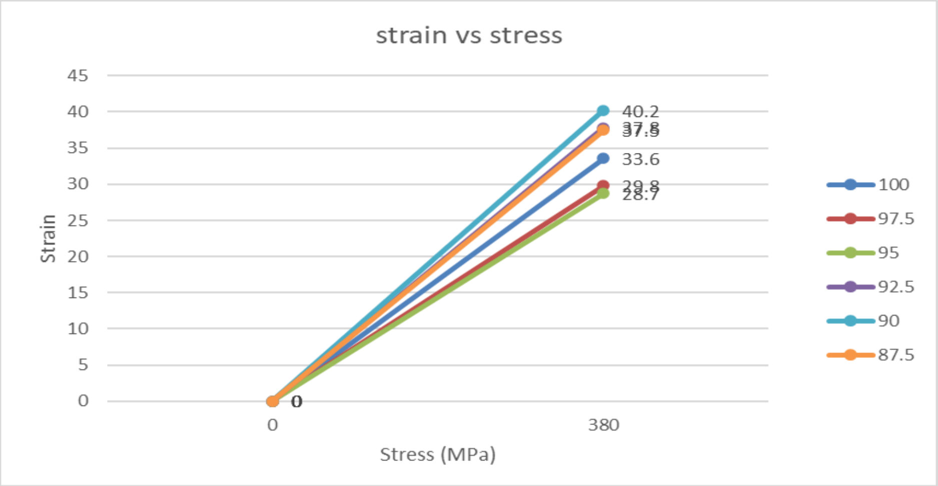

Figure 3. Strain against stress chart for reinforcement concretes 7 days

4. Conclusion

In conclusion, the summarized of current study is as follows:
Aluminum recycling and waste concretes is a way of reusing waste material in other goods after it has been created. Waste concrete and Zinc stearate can be used as aluminum matrix composites reinforcing agent and binder. When grain sizes are reduced, the hardness strength increases because of an increase in surface area. The best result for this investigation is one that is 95 percent aluminum with 5 percent waste concrete reinforcement for 28 days and contains Zinc striate as a binder

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References

[1] Jirang, C. U. I., & Roven, H. J. (2010). Recycling of automotive aluminum. Transactions of Nonferrous Metals Society of China, 20(11), 2057-2063

[2] Chawla, K. K. (2013). Ceramic matrix composites. Springer Science & Business Media.

[3] Baradeswaran, A, Perumal, AE. Study on mechanical and wear properties of Al 7075/Al2O3/graphite hybrid composites. Compos Part B: Eng 2014; 56: 464–471

[4] Krishnan K. Sankaran, R. S. (2017). Metallurgy and Design of Alloys with Hierarchical Microstructures. Aluminum Alloys.

[5] Mohd Joharudin, N. F., Abdul Latif, N., Mustapa, M. S., Mansor, M. N., Siswanto, W. A., Murugesan, J., & Yusof, F. (2019). Effect of amorphous silica by rice husk ash on physical properties and microstructures of recycled aluminium chip AA7075. Materialwissenschaft Und Werkstofftechnik, 50(3), 283–288. https://doi.org/10.1002/mawe.201800229

[6] Joharudin, N. F. M., Latif, N. A., Mustapa, M. S., & Badarulzaman, N. A. (2020). Effects of untreated and treated rice husk ash (RHA) addition on physical properties of recycled aluminium chip AA7075. International Journal of Integrated Engineering, 12(1), 132–137. https://doi.org/10.30880/ijie.00.00.0000.00.0000

[7] M. Samuel. A new technique for recycling aluminium scrap, Journal of Materials Processing Technology 135; 2003: 117-124.}

[8] Huang, X., Zhang, J., Miao, J., Cinkilic, E., Wang, Q., & Luo, A. A. (2021). On the interactions between molten aluminum and high entropy alloy particles during aluminum matrix composite processing, (xxxx).