INVESTIGATING ON THE EFFECT OF PARTIAL REPLACEMENT OF FINE AGGREGATE WITH ALUMINIUM DUST IN THE PRODUCTION OF CONCRETE.

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ABSTRACT

This experimental investigation was performed to evaluate the viability of using aluminium by-product (waste) in the production of low strength concrete. Aluminium waste dust is obtained from the use of aluminium alloys in construction industry. It typically comes in the form of thin, flexible and small strips that can be used in concrete production. The effects of incorporation of Aluminium waste dust on the properties of fresh and hardened concrete were experimentally investigated. The study evaluated the density, swelling, compressive strengths and workability properties of concrete mixtures to which aluminium waste dust was added in different proportions (0%, 2%, 4%, 6%, 8%, 10% and 20%) by weight of cement. Compression strength tests were carried out to evaluate the strength properties of hardened concrete. Workability and swelling of fresh concrete were also monitored and recorded. The test results indicate that Aluminium waste dust reacts with cement hydration products, causing considerable decreases in workability, compressive strength and density of plain concrete with the addition of Aluminium waste dust. The reduction in density of concrete due to hydrogen gas released from the reaction of aluminium with alkaline cement paste solution can be positively viewed to produce lighter concrete. The results also indicate that the strength of concrete with Aluminium waste dust can still be considered sufficient for some applications. Overall, the results of this study demonstrate the viability of using Aluminium waste dust in the production of low-strength and lighter concrete and can help toward a more sustainable construction.

Keywords: Aluminium dust, Low strength concrete, Compression strength, Workability

INTRODUCTION

Concrete is a mixture of paste and aggregates, the paste comprises of cement and water, this coats the surface of the fine and coarse aggregates. Through a chemical reaction called hydration, the paste hardens and gains strength to form mass known as concrete. Within this process lies a key to a remarkable trait of concrete; it is plastic and malleable when newly mixed, strong and durable when hardened. These qualities explain why concrete can build skyscrapers, bridges, sidewalks and super highways, houses and dams. The key to achieving a strong, durable concrete rests in the careful proportioning and mixing of ingredients.

Concrete is the most widely used man-made construction material in the world. They are used in constructing buildings, bridges, roads and dams. Its uses ranges from structural applications, kerbs, pipes and drains. The characteristics of concrete, in particular compressive strength, durability, porosity, fire resistance thermal and acoustic insulation properties, impact resistance varies and is determine by the aggregate or cement use or by the method used to produce it. For ordinary structural concrete, water cement ratio is the deciding factor with a lower water content resulting in a stronger material. However, this decreases the concrete workability which can be assessed using the slump test. The rating, form, texture and aggregate proportion may have similar impact as well. Concrete strength is express in pounds per square inch or kilogram per square centimeter by the force needed to crush it. Various variables including humidity and temperature can affect power. According to BS 882-1992, aggregates are of two types, the fine and the coarse aggregate. Fine aggregates are usually lesser than 4.75mm (i.e. passing through the No. 4 sieve) while the coarse aggregate is usually greater than 4.75mm (i.e. retained on NO.4

sieve). Properties like size, shape, texture, moisture content, gradation etc. of aggregates do influence the properties of concrete.

The reuse of waste material represents a means of relieving some of the problems of solid waste management and pollution. The reutilization of waste is important from different point of view. It helps to save, sustain natural resources that are not replenished and decrease pollution in the environment. Waste and industrial by-products should be considered as potentially valuable resources merely awaiting appropriate treatment and application. Aluminium wastes are among these wastes; their disposal has harmful effects on the environment due to their long biodegradation period, and therefore one of the logical methods for reduction of their negative effects is the application of these materials in other industries. Concrete plays an important role in the beneficial use of these materials in construction. Although some of these materials can be beneficially incorporated in concrete, both as part of the Cementous binder phase or as aggregates, it is vital to realize that not all waste materials are appropriate for such use.

Aluminium alloys are widely used in engineering structures, where light weight or corrosion resistance is required. The use of aluminium alloys in engineering applications, primarily in residential building components, such as: facades, sidings, windows, doors and guard rails, results in a tangible waste that poses an environmental problem and thus needs management and recycling. The aluminium by-product waste (ALBP) typically comes in the form of small size, thin and flexible particles as can be seen in Plate 1. The intent of this study is to evaluate the potential use of this waste in concrete applications. Under normal circumstances, aluminium does not react with water, as an impermeable protective layer of aluminium oxide (alumina) forms on the surface of aluminium particles, preventing water from coming into direct contact with the aluminium metal. However, in a cement-based solution, which is highly alkaline, the reaction of aluminium proceeds to form aluminium hydroxide and hydrogen gas. Aluminium hydroxide goes into the solution in the presence of reaction promoters, such as: alkalis, calcium oxide and hydroxyl ions.

Plate 1.2 Aluminium waste dust

Lightweight concrete can be defined as a type of concrete which includes an expanding agent in that it increases the volume of the mixture while giving additional qualities. It is lighter than the conventional concrete. The main specialties of lightweight concrete are its low density and thermal conductivity. Its advantages are that there is a reduction of dead load, faster building rates. Lightweight concrete (LWC), with its reduced weight and improved durability, enables longer spans, fewer piers, and longevity for bridge structures. Aluminium dross is a mixture of free metal and non-metal substances (e.g., aluminium oxide and salts). (Manfredi et al. 1997). The use of by-products in concrete has been continuous research over the last five decades. Efforts has been made to use industry by- products such as aluminium waste, fly-ash, silica fume, ground granulated blast etc. in civil engineering construction. Attention is focus worldwide on preserving and safeguarding the environment but re-using of waste (by-product) from our industries and human daily activities. One of the by-products, particularly use in concrete is recycled by aluminium. Aluminium has been part of our daily life, ranging from aluminium windows, doors, roofs etc. and thus generate into waste. Solving the disposal of these large volume of aluminium material leads to re-used as an aggregate in concrete work. The use of aluminium waste is presently uneconomical, but the gains to the environment are unquantifiable.

Liu *et al.* (2017) suggest that Aluminium dust should be treated before landfilling. The treatment according to the authors involves aqueous dissolution at 60°C for 48 h to reduce its reactivity. This combined hydrolysis and heat treatment can convert dross to inert material. Further stabilization can be accomplished with gypsum. It is of researchers' view that the quantity of dross generated is a function of the type and quality of raw material, operating condition, type of technology and furnace used.

Shinzato and Hypolito (2005) evaluated engineering properties of concrete blocks produced with up to 33% replacement of sand with Aluminium dust. Their findings indicate that the blocks blended with Aluminium dust at a limit satisfied dimension, humidity and absorption tests but failed compressive strength test. However, their results revealed that one of the constituents of Aluminium dust accelerated the strength development of samples occasioning to the decrease in working time.

Elinwa and Mbadike (2011) analyzed the compressive and flexural strengths of concrete produced with dross at 5%, 10%, 20%, 30% and 40% replacement intervals by cement weight. Their results showed 10% optimal replacement of Aluminium dust with cement when compared with the control mechanical properties. Reddy and Neeraja (2016) investigated the compressive, split tensile, flexural strengths, sorptivity, water absorption and rapid chloride in concrete blended with Aluminium dust. At 15% replacement of Aluminium dust with cement, the evaluated samples showed a better result in all the tests performed against control. The study proposes the blending of Aluminium dust in concrete matrix for production of paver blocks, refractory bricks and for normal strength concrete.

Mailar *et al.* (2016) examined the mechanical and durability properties of concrete mixed with Aluminium dust in hot weather condition. At 20% replacement with cement, the investigated samples exhibit superior mechanical and durability properties than the normal concrete. Dai and Apelian (2017) investigated the use of two types of Aluminium dust (primary and secondary) as a refractory material reinforcement in mortar. The investigation characterized compressive and flexural strengths of the design samples. The results indicate 40% increase in flexural strength and 15% increase in compressive strength at 10% replacement with sand under primary Aluminium dust.

Javali *et al.* (2017) studied the use of Aluminium dust and granular iron slag as partial replacement for sand and cement respective toward producing eco-friendly concrete. They evaluated the compressive strength and durability properties of M4 grade concrete at 5%,10%,15%, 20% substitution of cement and 10%, 20%, 30% and 40% substitution of sand. At 5% and 20% substitution of Aluminium dust and iron slag with cement and sand, compressive strength and durability properties were found to comply with conventional concrete. Further result on toxicity analyses reveals less significant effects of salts and gasses on the concrete mix.

López-Alonso *et al.* (2019) found aluminium waste at controlled amount to be a suitable aggregate in road construction when mixed with recycled aggregate and mixed recycled aggregate. They found improved mechanical behavior when aluminium waste is mixed with recycled aggregate in road construction. Elinwa and Mbadike (2011) manufactured recycled aggregate and mixed concrete by substituting various aluminium waste percentages of cement. The results found that the compressive and flexural strengths of concrete were similar to those of conventional concrete with replacement rates of 10% to 15% of aluminium waste. The other discovery was that aluminium concrete retards the setting times of concrete that are beneficial in hot weather conditions.

Rana Shabbar *et al* (2017) investigated the behaviour of aerated concrete with different Aluminium powder content under monotonic loads. The proportion of aluminium powder was kept 0%, 0.25%, 0.5%, 0.75% and 1% by weight of cement content. The mixture was a cement mortar mix with one part cement and two parts sand and different proportions of aluminium powder. The test results showed that with increase in aluminium content, the dry density decreased also the compressive, flexural strength and modulus of elasticity of the specimens declined according to the increase of the content of the aluminium powder. (Wilson and Kosmatka, 2011) The consequences of this examination show that aluminium dust can be utilized as a fixing in the scope of specific points of confinement to enhance extended concrete/mortar and to enhance the erosion resistivity of concrete/mortar. The most fascinating finding was that aluminium dross quickens the setting time of concrete/mortar. In light of these discoveries it is recommended that aluminium slag included concrete/mortar might be utilized as a part of the assembling of structures subfloors, boards, squares and so on

(Unger and Beckmann, 1992). Aluminium dross has been added to cement weight by 5%, 10%, 15%, 20% and 30%. At that point utilizing this concrete cubes were casted. It is discovered that 7 days compressive test has been expanded when contrasted and 3 days compressive test for 5% substitution. In any case, for rest of the substitutions (10%, 15%, 20%& 30%), 7 days compressive test has been diminished when contrasted and 3 days compressive test. Subsequently, 5% substitution is best. The consequences of this examination show that aluminium dross can be utilized as a fixing up to 5% to enhance extended concrete/mortar. (Manfredi, *et. al.,* 1997). From the trial mixes done it was discovered that the setting time of recycled aluminium dust concrete is 30 minutes when replaced at 20%. This property of reused aluminium waste solid renders it to be reasonable for sweltering climate cementing conditions. In light of the outcomes got, the supplanting of concrete with 20% of Aluminium waste yields predominant mechanical and toughness attributes.

(Shreyas, *et. al.,*2015). An examination was made by absolutely replacing aluminium waste and reused total aggregate as opposed to natural sand and smashed independently. Mix layout for M30 assessment was finished utilizing 0.2% and 0.4% of steel fiber with view point proportion 60. Quality tests were done at 7, 14 and 28 days. Exploratory examination indicated satisfactory outcomes when appeared differently in relation to conventional cement. (Vijayalakshmi & Rajeswari, 2018) The objective of this work is to limit waste and rather utilize the misfortune in a trademark cycle by using it as a manufactured material and besides to make a light weight concrete. Substitution of aluminium powder and dross (5, 10, and 15 %) by weight of bond are utilized to deliver circulated air through (gas) concrete. The outcome got demonstrates that ideal of 10% Aluminium dross can be supplanted with bond to get required compressive quality and split elasticity for concrete. Gugliemir *et al*. (Guglielmi *et al.*, 2010) studied the influence of Aluminium content on porosity, density and compressive strength of autoclaved clayey cellular concrete. The results showed that the porosity increased by increasing Al powder up to 0.4% and then decreased significantly

Rihan Maaze, *et al* (2016) studied the influence of marble powder and aluminium powder on the performance of bricks. For this three different series of mixtures was made along with Black Cotton Soil, Red Soil and fly ash. The first mixture had only marble powder, the second had only aluminium powder and the third had a combination of both marble powder and aluminium powder. The proportion of marble powder was kept to be 5%, 10% and 15% by weight of Red Soil and for aluminium powder was kept 1%, 2% and 3% by weight of Black Cotton Soil. The bricks manufactured from only marble powder showed only 30-70% increase in compressive strength, from only aluminium powder showed 10- 20% increase in compressive strength and from the third mixture which was a combination of both marble powder and aluminium powder no improvement in compressive strength but the bricks were lighter, thus decreasing its dead load.

Raj and John (Raj and John, 2014) studied the influence of Aluminium content (0.1, 0.2, 0.5, 1, 2 and 5%) by cement weight on dry density and compressive strength of aerated concrete at 3, 7 and 28 days. The results showed that the dry density and compressive strength decreased by increasing the Al content. This reduction was caused by an increase in tiny bubbles which were formed by the Al powder. (Şahin *et al.*, 2003) studied the density, compressive strength, modulus of elasticity and water absorption of lightweight concrete with pumice aggregated (PA). Pumice at 25%, 50%, 75% and 100% replacement was used in place of normal aggregate. It caused a decrease in the density of up to 41.5% when compared to the control samples which is probably due to the porous structure of PA. However, the compressive strength decreased by increasing the PA content and the lowest value was obtained at 100% PA replacement of normal aggregate. Furthermore, the slope of stress–strain curves decreased dramatically when PA content increased. This could lead to a decrease in a stiffness of lightweight concrete.

(Gopienko, 1999). To increase the safe usage of Al, it is recommended to use coarse Al with the grain size from 0.1mm to 0.5 mm with the percentages between (0.2 and 0.5) by cement weight to the mixing ingredients. (The Aluminium Association, 2006). Al was divided to the three classifications according to the method of manufacture; granules, atomized and flake. The ground Al has a granular appearance with edges and points appearing quite sharp (under manification). Atomized particles have their length, width and thickness approximately the same order whereas with flaked particle the length or width maybe several hundred times its thickness. (Ramesh 1999).Valuable aluminium metal, oxides, salts, and other materials have been wasted because of the lack of viable processing technologies to convert this material to useful products. Lucheve *et al.* (2005) Drosses may be classified by means of their metal content and drosses with a high metal content (white, or wet, dross that is rich in free metal) typically occurs when scrap is re-melted with salts in an open – hearth furnace. This black, or dry, dross is usually granular with a high metal content in the coarse fraction and chiefly oxides and salt in the fines. The possibility for non-waste utilization of aluminium dross and converting it into commercially useful products.

Materials and Method

The materials used for concrete were sourced locally. The fine aggregate was washed river sand free from impurities and the granite are quarry crushed with 20mm as average size. Ordinary Portland Cement (OPC) was obtained from Dangote brand of cement having 42.5N strength, with properties conforming to BS 12 (British Standards Institution, 1971). The Aluminium waste dust (Plate X) samples were gotten from Aluminium Village in Dopemu, Ikeja, Lagos state, Nigeria.

Plate 3.2.5 Aluminium dust

The particle size distribution of both the fine aggregate and the Aluminium waste dust is presented in Figure A.

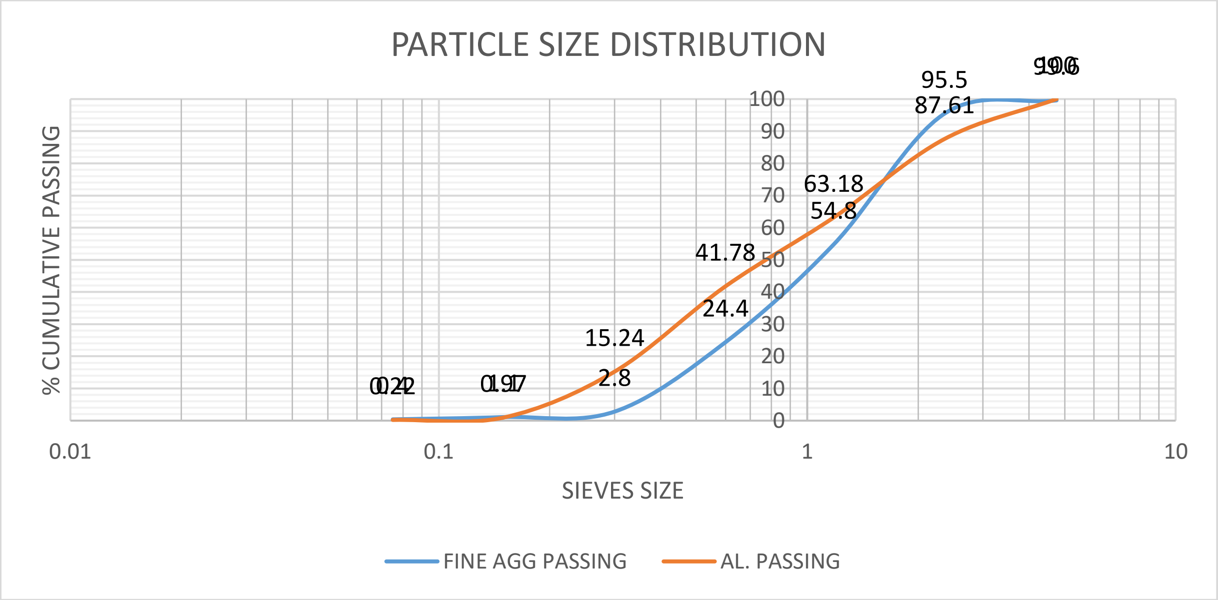

Figure 1: Particle Distribution Graphs of Fine Aggregate and Aluminium Waste Dust

Figure A shows the result of particle size distribution test conducted on fine aggregates and the Aluminium waste dust. The maximum size of the fine aggregate 4.75 and the fineness modulus is 2.78 while the maximum size of the Aluminium waste dust is 4.75 and the fineness modulus is 3.09. From the coefficient of curvature (0.90), the value lies between 0.5 and 2 (well graded) in accordance with BS1377. This implies that the fine aggregate is of good quality and can be recommended for use. From the coefficient of curvature gotten (1.18), the value lies between 0.5 and 2 (well graded) in accordance with BS1377. This implies that the aluminium waste dust is of good grade and can be recommended for replacement.

The result of particle distribution test conducted on coarse aggregates is presented in Figure B. The maximum size of the coarse aggregate is 19mm while the fineness modulus is 2.58

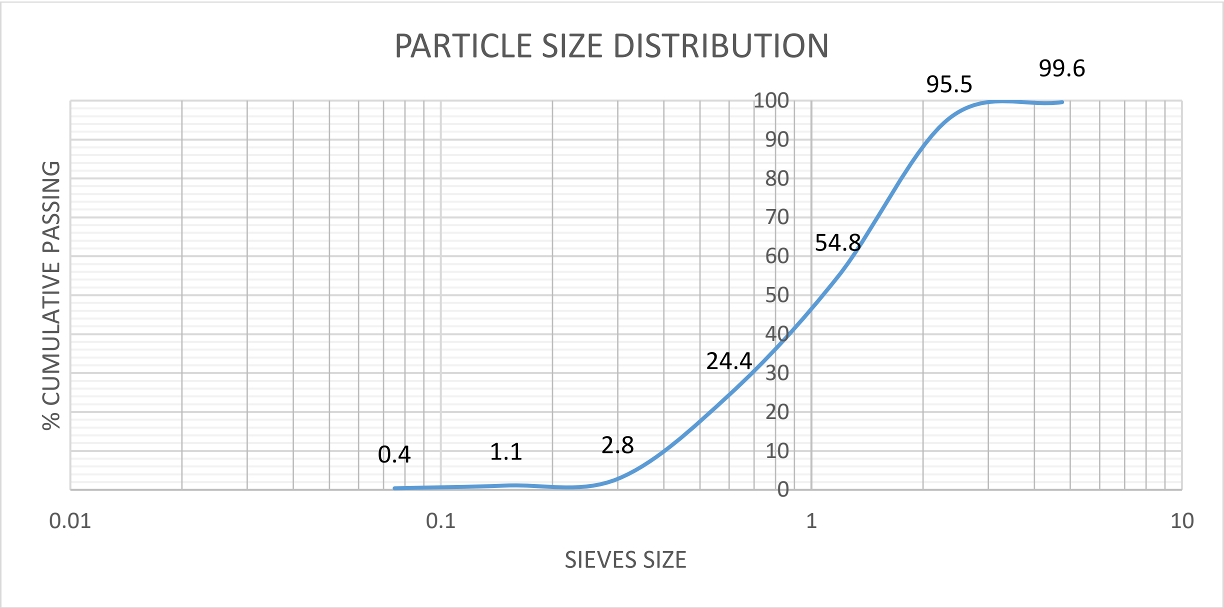

Figure B: Particle Size Distribution Graph for Coarse Aggregate

The concrete mix design of 1:2:4 was developed and adopted using DOE method. Workability test was conducted on the fresh concrete. The concrete matrixes (fine and coarse aggregates, cement, and water) were mixed in an open space. The fine aggregate was first mixed thoroughly with cement in the mixing machine and after that, coarse aggregate is added and followed by water. Loss of water by evaporation was avoided. Water-cement ratio was maintained at 0.6. After a consistent mix has been gotten, a workability test was conducted. The fresh concrete was placed in the frustrum shaped mould 300 mm (12 in) of height, 300mm and 100mm base and top diameters respectively (Plate B). The resulting fall is shown in Place C. The decrease in height of concrete to that of mould was measured to the nearest 5 mm.

Plate

The fresh concrete is then poured into prepared 150mm x 150mm x 150mm mould. The concrete samples were allowed to set for 24 hours. After 24 hours, the samples were demoulded and put in curing tank for a period of 7, 14 and 28days. After the curing period, the samples were brought out and tested for compressive strength within 1 hour from removing from water.

The compressive strength test of the hardened concrete was performed on a Universal Testing Machine (UTM) with crushing piston moving at 5mm per minute. Nine cubes were cast for each replacement (0%, 2%, 4%, 6%, 8%, 10% and 20%) with w/c ratio of 0.6 for all samples. The samples were placed in the appropriate location in the test machine in such a way that the load was applied to the face, perpendicular to the direction of casting.

Plate 4: Placing the Concrete Cube in the UTM

Results and Discussion

The results of compressive strength carried out on the cube at 0%, 2%, 4%, 6%, 8%, 10% and 20% aluminium waste dust are presented Figure 3.

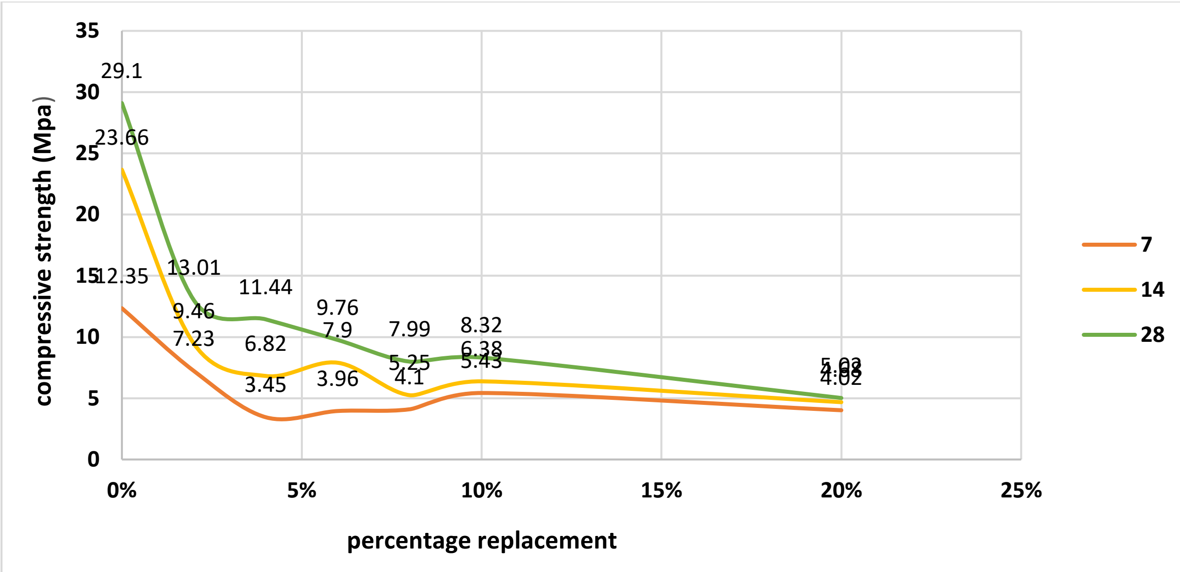

Figure 3: Graph of compressive strength against percentage replacement of Aluminium waste dust.

The compressive strength at 28 days for convectional concrete is 29.10MPa. For the modified concrete, at 2% replacement, it decreases to 13.01MPa. At 4%, it decreases to 11.44MPa and at 6%, it decreases to 9.76MPa. At 8%, it decreases again to 7.99MPa. At 10%, it increases again to 8.32MPa. At 20%, it decreases again to 5.02MPa. It can be deduced from above explanation that the modified concrete attained optimum strength at 2% replacement

Conclusions

The investigation on strength characteristic of concrete made with substituting fine aggregate with Aluminium waste dust and replaced at 0%, 2%, 4%, 6%, 8%, 10% and 20% in the production of concrete using a mix ratio of 1:2:4. The results show that the compressive strength at 28days for modified concrete (2% and 4% replacement) with w/c of 0.6 were 13.01 N/mm^2 and 11.44 N/mm^2 compared to control concrete (29 N/mm^2) at 28days. The strength of concrete decreases as replacement of fine aggregate with Aluminium waste dust increases. Because of this low strength, the concrete made with aluminium waste dust can be used where low strength concrete is required and this can serve as an alternative solution of safe disposal of Aluminium waste dust.

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