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# INCORPORATION OF ADMIXTURES IN RECYCLED AGGREGATE CONCRETE: A REVIEW

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**Abstract**—**The huge amount of annual concrete production poses significant harmful environmental impact. The demand for construction and concrete production consequently results in a huge demand for natural aggregate thereby causing great concerns for aggregate availability. Recycling waste concrete which often times end up in landfill is one of the major solutions to reduce its environmental effects. Waste concrete are crushed to desired sizes and used as replacement for natural aggregate to a certain degree in the production of new concrete. A reduction in strength has been reported after various researches with most recommending an optimum replacement percentage of 30% beyond which are decline in strength properties is evident. Thus, it becomes necessary to improve this performance and increase the amount of concrete waste reduction. To produce high-performance concrete, early researchers altered the water-cement ration to achieve the desired results. Thereafter, they employed the use of chemical and mineral admixtures alongside specialised production process. In addition to performance improvement, Mineral admixture will function to substitute or reduce the consumption of Portland cement leading to a low impact, less energy consuming building material. This paper reviews the effect of admixtures on the mechanical properties of recycled aggregate concrete and possible areas for future research were identified and recommended.**

Keywords: **Mineral Admixture, Recycled aggregate concrete, $CO_2$, Global warming**

## I. INTRODUCTION

The impact of the unprecedented increase in human population, industry and their adverse effects on the environment has resulted to the pursuit of sustainable technologies over the past few years. Therefore, it becomes significant to carry out research on the recycling of waste construction materials which is gradually increasing with the increase in urban development and human population. In today’s concrete, sustainable construction has become one of the major requirements. [10]

Many investigation and analysis has been shifted towards recycled aggregate because it is easy to obtain as well as cheaper compared to virgin aggregate. Thus, recycled aggregate has been steadily introduced in a wide range of construction and civil engineering applications as a partial replacement of virgin aggregate in concrete [2]. In recent years, recycled aggregate concrete is adopted as one of the most promising solutions to decrease the amount of demolition and construction waste which often ends up in landfill. Construction and demolition waste has considerably increased over the last decades in response to increased construction activities as well as demolition and restoration of old buildings. Also, a natural resource, especially natural aggregate (which makes up 70% of the total concrete volume) has been used extensively to meet the increased demand of new construction [10].

Globally, there is a significant increase in the utilization of natural aggregates for construction due to construction and infrastructure development. This contributes to the global annual demand for construction aggregates of more than 26.8 billion tons [8]. In other developing countries, laws have been placed to restrict construction and demolition waste in the form of special taxes and prohibitions. Concrete, sand, bricks, mortar and tiles residues are among the heaviest materials found in construction and demolition wastes with concrete making up to half of the total waste weight [1]. The causes of material waste in construction sites include change of design, poor material quality, poor site supervision, defective materials, unskilled labor, poor storage facilities, and poor handling process. Also, lack of sustainable waste management plan, inadequate contribution of non-regulatory sectors in waste collection, inadequate valuation of waste usually starting from the design processes, and poor implementation of a sustainable procurement system are major players influencing waste generation in the country.[3][4].

The challenges of the construction industry are also caused more as a result of the production of Portland cement. Therefore, a most suitable and effective remedy is the utilization of less amount of Portland cement through replacement with supplementary cementituous materials, especially industrial waste. From the various efforts made to reduce this environmental drawback of concrete, it is believed that the adverse effect of CO2 emission, cement, may be controlled if mineral admixtures are employed. They will reduce cement consumption, cost and energy. In eco cement, up to 70% of Portland cement clinker is replaced by additives such as, sand, pozzolanic materials, fly ash, granulated blast furnace slag, and ceramic waste. [14] [17]

There is a growing recognition in the significance to improve the recycling process of waste concrete and properties of recycled concrete which will consequently improve environmental conditions as well as contribute a quota towards the issue of Global Warming. This paper will review the properties of recycled concrete with the incorporation of various admixtures and identify areas for further research and recommendations.

## II. ADMIXTURES

The utilization of industrial by-product and wastes led researchers to incorporate admixtures partially replacing cement. Thomas et al.(2012) and Thomas (1996) reported that the utilization of mineral admixtures is highly advantageous towards reducing environmental damage and improvement of the durability of concrete. The improvement is as a result of pore structure alteration in the concrete which results in reduction of permeability, thus increasing resistance to water related deterioration and water penetration. [18]

The effect of several admixture such as; of limestone, silica fume (SF), Fly Ash (FA), Slag (steel, lead,copper),rice husk ash(RHA),carbon black, sand stone, Waste paper sludge ash(PSA), Metakaolin(MK), polypropylene imitation steel fibers (PPTF) and stone waste powder on the mechanical properties of recycled concrete has been taken into consideration by researchers overs the years.

### A. Effect on Compressive And Tensile Strength

Bui et al in (2018) investigated the effect of fly ash (FA), Silica Fume (SF), Metakaolin (MK) and waste paper sludge ash (PSA) ; on the properties of recycled aggregate concrete containing 100% recycled aggregate through replacement and addition method. The results obtained after various tests at 500 °C displayed that the residual Compressive strength of heated recycled concrete aggregate increased by 38.45% and 35.23% with a 5% and 10% addition of fly ash. They reported a superior resistance of recycled aggregate concrete to elevated temperature through addition method compared to the replacement method. The researchers concluded that the residual compressive strength of the heated recycled aggregate concrete was improved significantly more by fly ash in comparison with the other additives considered in their research (silica fume, PSA and MK). Although at 20°C, concrete made with fly ash showed a lower compressive strength improvement compared to others.

A recent study reported an 11% decline in the compressive strength of concrete made with recycled aggregate at 30% replacement compared to that of natural aggregate after 28 days. Furthermore, rice husk ash (RA) and bagasse ash (BA) was incorporated at 5%, 10%, and 15% to study the behavior of the recycled aggregate concrete. A 9% strength increase was recorded in the RAC when rice husk ash was incorporated at 10%. At 15%, the strength increment was approximately 2% and 13% with respect to the Natural aggregate concrete and recycled aggregate concrete. The results for bagasse ash are very similar to those of rice ash. The recorded strength increment at 15% BA addition was 2.5% and 13% with respect to Natural aggregate concrete and recycled aggregate concrete respectively. [16]

In an effort to investigate the effect of admixtures on (fine recycled aggregate concrete)FRAC, Ju et al, (2020) reported a strength decline of about 12% in comparison with conventional concrete (0% recycled aggregate) when 50% and 100% fine recycled concrete aggregate (FRCA) was used in concrete. This strength decline was improved by mineral admixture 0% and 50% FRCA replacement regardless of the dosage or type. The admixtures considered in their research are fly ash (15% and 30%), silica fume (2.5% and 5%), and ground granulated blast furnace slag (20% and 40%). At 100% FRCA replacement, a progressive decline was recorded for the normal dosage of the mineral admixtures. The effects on the concrete splitting tensile strength from the various additives follows very similar pattern to the compressive strength. However, there was no increasing strength effects recorded for 100% FRCA.

Wang et al, (2014) investigated the strength and optimal mix design for recycled aggregate thermal insulation concrete with mineral admixtures. The mineral admixture considered are nanosilica (NS), ultrafine slag (UFS) and nanocalcium carbonate (NCC). The study results revealed an improved compressive strength for cement repacement by 1% NS and 10% US. However, a decline in mechanical performance surfaced 1.5% NCC addition.

Silica fume was incorporated in recycled concrete and the behavior of the samples was assessed. When the percentage of recycled aggregate replacing natural aggregate increased from 0% to 100%, the compressive strength decreased from 30.85 Mpa to 17.58 Mpa which is a 43% decrease as compared to natural aggregate concrete. A 10% addition of silica fume (SF) resulted in a compressive strength of 29.2 Mpa (65% increase) for concrete samples containing 100% recycled aggregate. [7]

The concrete compressive strength for M25 recycled aggregate concrete (RAC) at 50% fine recycled concrete aggregate (FRCA) containing fly ash initially displayed a lower strength by 4.1% and 5.0% for RAC at 100% FRCA after 7 days. However at 90 days, the strength increased by 26.18% for RAC at 50% FRCA and decreased by 3.5% for RAC at 100% FRCA. Pramod et al, (2018) attributed the strength increase to pozzolanic reaction in concrete due to the presence of fly ash. The concrete compressive strength for RAC containing ground-granulated blast-furnace (GGBS) initially displayed a higher strength by 50.16% after 7 days and 25.59% after 90 days. The tensile strength of the RAC concrete at 50% and 100% FRCA containing fly ash both displayed an initial lower strength. On the other hand, the tensile strength of the RAC concrete at 50% and 100% FRCA containing GGBS both displayed higher initial strength in all days.[15]

A maximum compressive strength of 54.07 Mpa for 7 days water curing was reported in a study by El-Harwary and Nouh,(2017) where they investigated the effect of limestone filler on the mechanical properties of recycled concrete. The mixture contained 10% limestone by weight of cement and 10% recycled coarse aggregate by weight of natural aggregate. At 28 days, a strength decline was realized which can be due to the presence of water in the pores at the 28days curing as it was tested immediately removing the samples from the curing tank. A study by Voglis et al (2005) observed a higher early strength for cement containing limestone than those containing fly ash or pozzolana at 7 days.

Jian et al (2017) recorded better performance when fly ash, silica fume and Polypropylene imitation steel fiber (PPTF) was incorporated into recycled pervious concrete. The reported a compressive strength which is positively proportional to the increment in admixtures. The admixtures were incorporated at; 7% and 14% for fly ash, 5% and 10% for silica fume, 3kg / m3, 5kg / m3, 7kg / m3 and 9kg / m3 for PPTF. The strength increment for silica fume, fly ash, and PPTF are 74.3%, 61.2% and 206.8% respectively.

### B. Effect on Water Absorption

Water absorption values are generally higher in ordinary RAC mix and this was confirmed by Ransinchung et al, (2016). They reported values of water absorption values for RAC mix 9% higher than those for NAC mix. The addition of the mineral additives (bagasse ash and rice husk ash) in the RAC mix at 15% resulted is water absorption values 4.29% and 6.09% higher than those of NAC mix. When the parameters of RAC mix containing admixtures was compared with values of RAC mix without admixtures, a decreasing water absorption value was found.

Djelloul et al, (2018) incorporated ground granulated blast-furnace slag (GGBS) at 15% and 30% by weight of cement in self-compacting concrete made with fine and coarse recycled aggregate. The results displayed a decrease in water absorption and depth of water permeability for the recycled concrete aggregate mix.

## III. MOST EFFICIENT ADMIXTURES

Mineral admixtures have been compared by some researchers and some have been outlined to perform better than others based on experimental results obtained.

A study incorporated ultrafine slag, nanosilica and nano calcium in recycled aggregate thermal insulation concrete. They and reported that with respect to compressive strength, the addition of 1% nanosilica and 10% ultrafine slag improved significantly the mechanical performance of the concrete. 1.5% nano calcium on the other hand alongside thermal insulation particles resulted in a decline in the concrete compressive strength. [22]

Bui et al, (2018) in their research to study the properties of recycled aggregate concrete containing mineral admixture under high temperature, reported that fly ash (FA) performed better to improve the residual compressive strength of the heated recycled aggregate concrete followed by metakaolin (MK), waste paper sludge ash (PSA), cement and silica fume (SF). The percentage increase with 5% and 10% Fly ash in recycled aggregate concrete are 38.45% and 35.23% respectively. However, under normal conditions, a study conducted by Jian et al (2017) showed that concrete containing silica fume performed better than fly ash in terms of compressive strength. PPTF with an increment of 206.8% at a dosage of 5kg/m3 displayed superior performance compared to silica fume (74.3%) and fly ash (61.2%). However as the dosage of PPTF continues to incline, the strength consequently declines.

The performance of ground-granulated blast-furnace (GGBS) on compressive strength of fine recycled aggregate concrete (FRAC) was shown to be superior followed by fly ash then silica fume in a recent study. There was a 17.4% strength increase when 50% FRCA and 40% ground-granulated blast-furnace slag was incorporated in concrete giving an average value of 36.9 ± 0.8 Mpa. In a similar comparison by Pramod et al, (2018), they reported that better compressive strength performance 20 – 25% higher than fly ash at 28 day. With respect to tensile strength on the other hand, Ju et al, (2020) reported a better performance for Silica fume with a strength increment of 20.3% (4.45 ± 0.09 MPa for 50% FRCA) followed by GGBS and fly ash. [11]

Berndt, (2009) investigated the properties of recycled concrete with fly ash and slag as additives. Overall better performance was realized for concrete mixes containing 50% slag. Slag reduces strength loss and was beneficial for concrete containing recycled aggregate.

## IV. CONCLUSION

This paper reviews the utilization of different mineral admixtures in recycled aggregate concrete to enhance concrete quality and consequently reduce the harmful environmental impact. The following conclusions are based on the results and findings of previous research.

- Mineral admixtures such as limestone, silica fume (SF), Fly Ash (FA), Slag ,rice husk ash(RHA), Waste paper sludge ash(PSA), Metakaolin(MK), polypropylene imitation steel fibers (PPTF) ,stone waste powder e.t.c have been shown to improve concrete performance. Each minerals displays significant characteristics in binder blends and the compressive strength, tensile strength, early age or late hardening have been investigated over time by researchers. However, more detailed research are needed where different (5-10) admixtures are incorporated into recycled concrete and compared under similar conditions and exposures to determine. This will provide accurate data for comparison and maximum strength effects displayed by the admixtures
- More research are required to cover the effect of mineral admixtures on properties of recycled aggregate concrete like brittle behavior, shrinkage, crack formation, CO2 absorption, permeability, resistance to sulphate attack, alkali-silica reaction, carbonation, Chloride ion resistance, resistance to freezing and thawing, Abrasion resistance, fire resistance, and resistance to acid
- More agro-waste minerals or industrial by-products should be considered. The incorporation of more chemical and mineral admixtures might result in the substitution or reduction of Portland cement in the concrete industry leading to a low impact, less energy consuming building material.

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