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Experimental Study of Concrete Modified with Medium Carbon Steel Fine Particles

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ABSTRACT- Medium carbon steel fine particle is waste from steel fabricated informal industries in Ghana and are readily available. In this paper, effect of medium carbon steel (Fe_3O_2) fine particles was studied. Medium carbon steel with size less than 20 nm was added at different percentages 1%, 2%, 3%, 4%, 5% and 6%) to concrete. The concrete were tested for mechanical and physical properties at different curing ages of 7, 14, 21, and 28 days. Water absorption of concrete were also studied. Experiments results indicated that the flexural and compressive strength of hardened concrete increased with the addition of Fe_2O_3 fine particles at all the curing ages and the optimal content of Fe_3O_2 fine particles was 5%. It is clearly that the water absorption for the modified concrete specimens was lower than the control concrete samples. The results of this studies support the conclusion that medium carbon fine particle could be used to enhance concrete up to a level of 5% addition. This paper is limited to strength and physical properties of Fe_2O_3 fine particles in concrete but disregarded the long term durability properties of Fe_2O_3 fine particles concrete. Hence this paper recommends further studies in the long term durability of concrete with Fe_2O_3 fine particles.

Keywords- Carbon steel, compression, flexural, Fine particle, Strength

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I. INTRODUCTION

Recently, metal particles have attracted great interests due to their four major effects including size effect, quantum effect, surface effect and interface effect. Due to the high cost of steel re-bars , the use of metal waste is of increasing interest. The rational use of metal waste is also an important area of the environment protection. Research of new building materials with iron waste, in particular, perforated steel tape, percussion caps, dust waste from filters and metal powders [1,2] have shown the feasibility of its use in concrete. Positive factors are low price, the possibility of effective utilization, as well as obtaining products with new properties. Metal-cement composites with small-sized metal fillers have a high wear resistance, high temperature resistance and low shrinkage. [3]. Industrial wastes from the steel industry such as iron ore tailings and iron powder wastes from steel production can be hazardous to the environment. Stockpiling these materials close to production sites can result in soil and ground water contamination.

By adding metal particles into cement, the performance and properties of materials could be improved. The use of fine metal particles can improve the mechanical properties of concrete due to accelerated hydration and the formation of small-sized crystals (such as Ca(OH. [4] evaluated the effects of iron fillings on the compressive and tensile strength of concrete. Metal waste particles could improve the flexural and compressive strength of concrete. A study by [5] indicated that both the compressive strength and tensile strength increased with the addition of iron fillings to the concrete. [6] demonstrated that the setting time of fresh cement paste could be shortened by SiO_2 and Al_2O_3, powder and the initial setting time and the final setting time became shorter with the increase of the particles content.

Meanwhile, [7] found that the hydration degree of cement could also improved with the addition of Al_2O_3 particles.

Fine metal particles can also improve the durability of cement-based composites due to filling very small pores. The size of fine metal particles is important as it has to be compatible with the pore structures of cement [8,9]. Metal particles are used either to replace part of cement, inducing ecologic profile concrete [9] or as an admixture in the cement pastes or concrete [10]. In both cases, the addition of fine-scale particles improves the performance of cement matrix.

The present study focuses on the properties of concrete when adding Medium carbon steel waste (Fe_3O_2)- fine particles as reinforced admixtures in different percentages and the associated compressive strength, flexural, and split tensile strength of concrete have been evaluated. Medium carbon steel waste is industrial byproduct resulting from the informal steel fabricated industries all over Ghana. Recycling of this byproducts and using them in concrete will reduce the health hazard and their impact on the environment.

II. MATERIALS AND METHODS

2.1 Materials

Ordinary Portland cement was used throughout the current study. Medium carbon fine particle (Fe_2O_3 fine particles) was prepared under laboratory condition. The properties of Medium carbon fine particle are presented in Table 1

Table 1. PROPERTIES OF FINEPARTICLE

Purity	Average particle size	Specific surface area	Colour	True Density
98%	≤ 20nm	200m^2/g	Dark grey	4.5g/ cm^3

2.2 Sample preparation

Fe_2O_3 fine particles was added to Portland cement at various levels namely:1%, 2%, 3%, 4%, 5% and 6%, by weight of cement as admixture. The Medium carbon fine particle mixed with cement in a dry condition, and the dry mixtures were sieved several times for a proper dispersion of the Fe_2O_3 fine particles The water-cement ratio (W/C) used was 0.5. Cement paste cubes of 100 mm size were cast and vibrated on a table vibrator. The specimens were demoulded after 24 hours of casting then cured in tap water until testing.

2.3. Test methods

a) Compressive strength**:** The compressive strength test was determined using universal testing machine. An electrical digital universal tester can provide a consistent testing on a wide range of specimens through a hydraulic pump and a digital readout system.

b) Splitting tensile strength: Splitting tensile test was performed according to BS 1881. The determination of the splitting tensile strength was done by conducting the splitting tensile test on the cylindrical specimens of diameter 150mm and height of 300mm. The concrete specimens were placed horizontally between plates of the testing machine. In order to support the testing specimens, narrow strips of plywood were required to interpose between the specimens and the plates. The strips were 3mm thick and a 25mm width as per BS1881.

Figure 1 compression and split tensile strengths setup

c) Flexural strength: The flexural strength tests were conducted on 100*100*300 mm prism specimens in conformity with BS1881. The prism specimens were subjected to three-point loading. The flexural strength of the cement paste was tested at ages of 7, 14, 21, and 28 days. The average of three specimens was recorded for each testing age. Flexural strength was calculated by using the following equation:

Sf = 0.25Pl (1)

Where: Sf: Flexural strength (MPa), P: Total maximum load (N). and l length of beam

d) Water absorption:

Water absorption tests were conducted on the control concrete specimens and the concrete modified with the fine particles. The test was carried out in accordance to ASTM C (642-1997). In the test procedure, the specimens were dried in an oven at (100-110°C) for 24 hours, and then their masses were measured. Next, the specimens were fully immersed in a water tank for 24 hours, then they were taken out. Their surfaces were dried with a cloth and finally their weights were measured again. The test was conducted on the specimens with different curing ages of 7, 14, 21, and 28 days, and the percentage of water absorption was calculated from the following equation:

Water absorption (%) = (W2-W1)/W1 × 100 (2)

Where: W1: The average weight of dry sample (g), W2: The average weight of the wet sample (g).

III. RESULTS AND DISCUSSION

3.1. Compressive strength

The Compressive strength is the most important property of the concrete that is considered in the structural designs. The compressive strength results of the concrete with different Fe_2O_3 fine particles percentages (2%, 3%, 4%, 5% and 6%) at a curing times of 7, 14, 21 and 28 days are presented in Table 2. It can be seen from Table 2 that all the specimens of the concrete modified by the fine particles had higher compressive strength than the control specimens' at all curing periods.

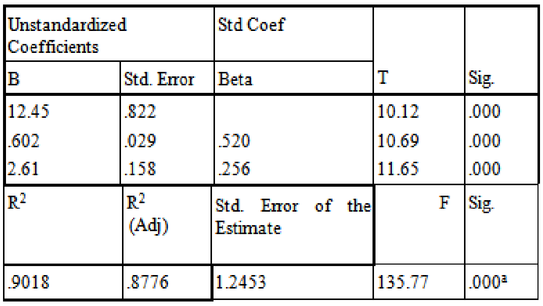
It is clearly seen that the compressive strength of control specimen was lower than the samples reinforced by the fine particles. This in the opinion of the present author might be due to the fine particles that were packed into the concrete pores provided resistance to compressive forces. Also the tiny fine particles size efficiently fill the void of concrete mixtures making the concrete resistance to the applied compressive force. The maximum compressive strength of concrete samples was achieved by adding 5% Fe_2O_3 at curing time 28 days. The compressive strength increased with increasing the curing period for all concrete mixtures. It can also be seen that the concrete specimens with Fe_2O_3 fine particles had the highest strength at all curing periods, and the compressive strength of the concrete increased with increasing the percentage of fine particles up to (5%). The early effect of the fine particles may be due to its influence on accelerating the pozzolanic transformation of C3S, C2S and CH into the C-S-H gel which was responsible for the strength improvements of the cement matrix. The concrete with 5% Fe_2O_3 fine particles were the highest in gaining early strength at all curing periods, due to its smaller particles, which were superior in the filling the cement matrix pores [11,12].

Table 2. Compressive strength

Specimens	**Curing Age (days)**			
	7	**14**	**21**	**28**
OPC	13	21	25	30
OPC+1% Fe_2O_3	13	21	26	31
OPC+2% Fe_2O_3	18	23	28	34
OPC+3% Fe_2O_3	21	25	30	39
OPC+4% Fe_2O_3	25	31	34	41
OPC+5% Fe_2O_3	30	33	39.3	44.2
OPC+6% Fe_2O_3	30	32	35	38

The regression analysis in Table 3,indicates that, Fe_2O_3 fine particles and curing age, had significant effects on the compressive strength of concrete and the equation generated is adequate for making predictions (F=135.77, P<0.001). The coefficient of multiple determination, R^2 (adj) shows that about 88% of the variations in the compressive strength could be explain by the curing age and the amount of Fe_2O_3 fine particles used for the concrete (R^2 = 0.9091, Adjusted R^2 = 0.8778). From the Beta values the variance in the compressive strength was more influence by the addition of Fe_2O_3 fine particle.

Table 3 Statistical analysis of compressive strength



Unstandardized Coefficients		Std Coef		
B	Std. Error	Beta	T	Sig.
12.45	.822		10.12	.000
.602	.029	.520	10.69	.000
2.61	.158	.256	11.65	.000
R^2	R^2 (Adj)	Std. Error of the Estimate	F	Sig.
.9018	.8776	1.2453	135.77	.000ª

3.2. Splitting tensile strength

The tensile strength results of the concrete with different Fe_2O_3 fine particles percentages are presented in Fig. 3. It is clearly observed that the tensile strength increased with an increase in the fine particles percentages to reach an optimum value. The tensile strength of the concrete prepared with different percentages of fine particles was higher than the tensile strength of the control cement pastes samples as presented in Figure 2. It can be clearly seen that the concrete specimen with 5% Fe_2O_3 fine particles showed a higher tensile strength than their counterparts prepared with low fine particles percentage at the curing age of 28 days.

The effect of curing ages on tensile strength of control specimen and the concrete with the different fine particles specimens is statistically presented in Table 4. It can be seen from this Table that, the tensile strength consistently increased with the increase in the curing age for all concrete specimens. It could be concluded that adding fine particles to concrete increased its tensile strength. The reason for this may be related to the large surface area of fine particles which promote the pozzolanic reaction to form C-S-H gel which in turn gives the mixture its strength [11, 12].

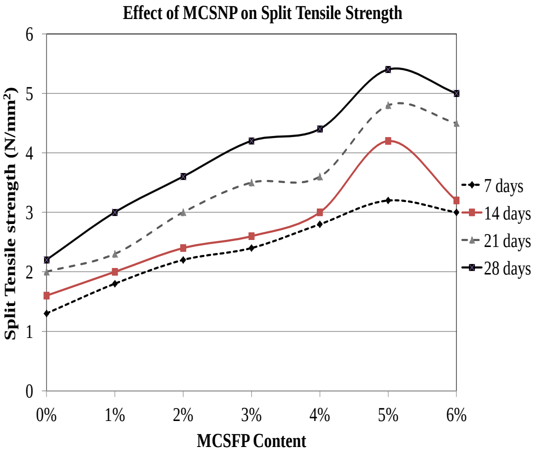


Figure 2. Effect of (Fe_2O_3) fine particles on tensile strength

From Table 4 The coefficient of multiple determination, R^2 shows that about 97% of the variations in the tensile strength could be explain by the curing age, amount of Fe_2O_3 fine particles used for the concrete (R^2 = 0.985, Adjusted R^2 = 0.971). From the Beta values the variance in the compressive strength was much influence by the addition of Fe_2O_3 fine particles.

Table 4.statistical analysis of tensile strength

Model	Unstandardized Coefficients		Std Coef		
	B	Std. Error	Beta	T	Sig.
Constant	.916	.093		9.880	.000
Curing Age	.051	.003	.495	15.387	.000
Fe_2O_3	.153	.018	.324	8.584	.000

R	R^2	R^2 (Adj)	F	Sig.
.985^a	.971	.968	312.593	.000^a

3.3. Flexural strength

The results of the flexural strength of the control concrete and the concrete samples modified by various percentages (1%, 2%, 3%, 4%, 5% and 6%) of Fe_2O_3 fine particles at different curing time (7, 14, 21 and 28 days) are presented in Figure 3. It can be clearly seen from the figure that the flexural strength increased with increasing fine particles percentages and the curing time. This behaviour was attributed to the continuity of hydration process, which induced new hydration byproducts (calcium silicate hydrate (CSH)) within the cement matrix [13, 15]. It is also observed that the maximum flexural strength could be achieved when using 5% Fe_2O_3 fine particles (Figure 3) with the concrete at curing time 28 days. The fine particles can lead to having a very dense structure, less porosity and reduce capillary voids of the cement pastes. This is because the fine particles can react with CH to induce CSH, fill the voids of the cement matrix[12]. The flexural strength of the concrete specimens increased with an increase the percentages of fine particles up to (5%). However, it is interesting to note from the flexural strength results that a little reduction in the flexural strength was associated with adding 6% fine particles. This may be related to the fact that the quantity of 6% Fe_2O_3 fine particles present in the concrete specimens were higher than the required amount to combine with the liberated lime during the hydration process [14] Thus, leading to the leaching out of excess silica and causing a reduction in strength. It may also due to poor dispersion of fine particles, which cause weak zones [14].

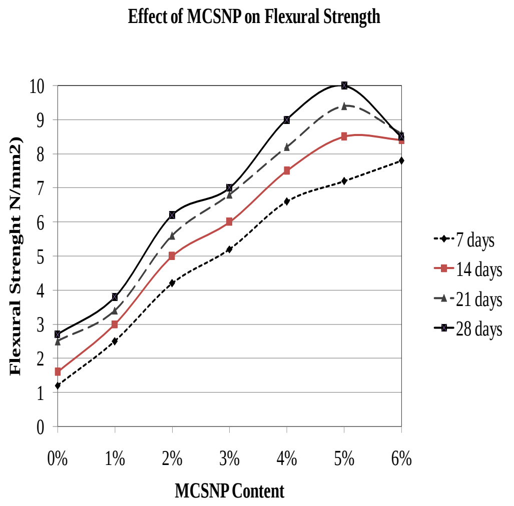


Figure 3 Effect of (Fe_2O_3) fine particles on flexural strength

3.4 Water absorption

The water absorption test was conducted in order to study the effect of mixing fine particles with the concrete. Figures 4 show the water absorption test results of the control concrete and the concrete modified by various Fe_2O_3 fine particles percentages at different curing time. It is clearly seen from this figure that the water absorption for the modified concrete specimens was lower than the control concrete samples. This figure also reveals that the water absorption decreased with increasing curing time and the fine particles percentages up to (5%). The lowest water absorption of concrete samples was associated with 5% Fe_2O_3 at curing time 28 days. The fine particles have substantially reduced the water absorption. This may be due to "the higher fineness of fine particles that led to the filling of the pores spaces and to disconnect the continuity of the capillary pores" [13]. The testing results also indicated that the absorption of the concrete modified by fine particles continuously decreased with increasing of the fine particles. This is because, the partial filling of the cement matrix pores by the hydration byproducts, reduced the capillary porosity [14]. The decreasing in water absorption may also be due to the enhancement of the concrete porosity by both the physical and the chemical mechanisms of the fine particles. The fine particles could make the pore structure of concrete more homogeneous by decreasing the number of large pores [14]. However, the absence of the fine particles can lead to "growing large crystals of CH that tend to be parallel to aggregate particles surface" [14].

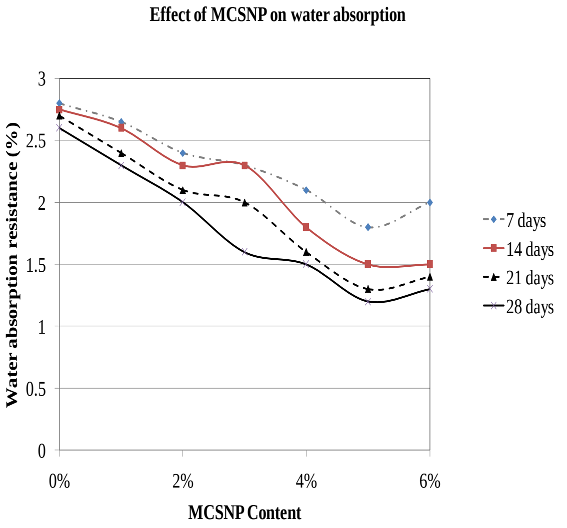


Figure 4 Effect of (Fe_2O_3) fine particles on water absorption resistance

IV. CONCLUSION

Inclusion of Fe_2O_3 fine particles improved the mechanical properties namely: the compressive strength, the splitting tensile strength and the flexural strength and the maximum values of the mechanical properties were associated with the concrete modified by 5% Fe_2O_3 fine particles at a curing time 28 days. However, an adverse trend was observed when the percentage of Fe_2O_3 fine particles was increased to 6%. The physical properties such as water absorption was also enhanced where the water absorption was substantially reduced. The result of the present study support the conclusion that some mechanical properties such as, the compressive strength, the splitting tensile strength and the flexural strength could be improved by adding Fe_2O_3 fine particles up to 5% by weight of cement. Likewise the water resistance of concrete could also be improved when concrete is modified by Fe_2O_3 fine particles.

The study recommend that deterioration test on concrete modified with Fe_2O_3 fine particles should be studied to ascertain the long term durability of this innovative material.

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