UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION- KUMASI

EFFECT OF ADDING STEEL PARTICLES ON THE PERFORMANCE OF CONCRETE

ISAAC KOBINAH ASSIEDU

OCTOBER, 2018

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A Thesis in the Department of Construction and Wood Technology Education, Faculty of Technical Education, Submitted to the School of Graduate Studies, University of Education, Winneba in partial fulfillment of the requirements for award of the Master of Philosophy in Construction Technology Degree.

OCTOBER, 2018

DECLARATION

STUDENT'S DECLARATION

I, Isaac Kobinah Assiedu, declare that this Thesis with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE: ………………………………………………………………………………………

DATE: ………………………………………………………………………………………………

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of Thesis as laid down by the University of Education, Winneba.

SUPERVISOR'S NAME: DR. PETER PAA KOFI YALLEY

SIGNATURE: ………………………………………………………………………………………

DATE: ………………………………………………………………………………………………

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DEDICATION

This Thesis is dedicated to the maker of Heaven and Earth Jehovah God, my supervisor Dr. Peter Paa Kofi Yalley, my parents and my children Belinda and Ricardrine.

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LIST OF ABBREVIATIONS

a/d	Shear Span to depth ratio
AFM	Atomic Force Microscopy
a/h	Shear span to height ratio
B/A	Binder Aggregate
B/S	British Standard
CDM	Construction and Demolition Waste
FRC	Fiber Reinforcement Concrete
FRP	Fiber Reinforced Polymers
g	gram
GHACEM	Ghana Cement
kg	Kilogram
kg/m^3	Kilogram per cubic metre
KN	Kilo newton
Lab	Laboratory
M	Metre
M^3	Cubic metre
mm	Millimeter
mm^2	Square millimeter
N	Newton
nm	Nanometer
N/mm^2	Newton per square millimeter
W_1	Average weight of dry sample
W_2	Average weight of wet sample

W/B	Water Binder Ratio
W/C	Water Cement Ratio

ABSTRACT

The industrial waste and metal by-products such as steel fibers, synthetic fibers, carbon fibers and steel particles can be used as reinforcement materials since they possess reinforcement properties. Steel particles are produced in millions of tons per year as waste material in metal shops. This enormous waste is currently not being harnessed productively in the metal shops in the Central Region of the Republic of Ghana. In most cases, they are indiscriminately dumped into the environment causing environmental Pollution that deplete the Ozone layer causing global warming. The concrete industry offers an ideal remedy to deal with the steel particles produced from the steel shops in the environment. The purpose of the study was to investigate the strength performance of concrete with steel particles. Sample of steel particles with a particle size of 20um were collected from metal shops in the Cape-Coast Metropolis. The steel particles were added at different percentages (0%, 5%, 10%, 15%, 20% and 25%) to the concrete at different curing times of 7 and 28 days. Sixty cubes and sixty beams were cast and tested using 1:2:4 mixes by weight with 0.5 water/ cement ratio. The results showed that at the 28days curing age, the compressive strength recorded 25.28 N/mm^2, 26.61N/mm^2, 27.05N/mm^2 and 25.01N/mm^2 which met the target strength of 25N/mm^2 for 0% to 15% particles. Addition of 20% to 25% performed poorer than the control specimen. 10% replacement gave the highest compressive strength, about 7% higher than the control. The flexural and tensile strengths also followed the compressive strength trend. The results for water absorption resistance for both 7 and 28 days were 6.89%, 6.91%, 6.94%, 19.10% and 11.83% when 0% to 25% particles were added. The mean values increased from 6.91% to 11.83% when 5% to 25% particles where added for both 7 and 28 days. This shows that, addition of particles increased both physical and mechanical properties content of about 60%.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

The heaviest materials found in Construction and Demolition Waste (CDW), steel shops and factories are rocks, aggregates, reinforcement bars, concrete, ceramic residues and steel particles. These make up between 70% to 80% of the approximately 5 million tonnes generated in Ghana every year of which only a very small quantity is recycled or used unlike other countries of the Europeans community (Boamah et al, 2011). According to Sang Kyu et al (2008), the construction of highways, bridges and buildings has been increasing from the beginning of the past century. Large volume of construction materials will be required to rebuild this infrastructure and support new construction. Recycling of waste materials by converting and uses of steel particles not only save landfill space but also reduce the demand for extraction of natural raw materials for new construction activities. In 2014, the Missouri Department of Transportation and Materials in the United States explained that as modern construction continues, two pressing issues will become more apparent to societies: an increase demand for construction materials, especially concrete materials and an increasing production of construction and demolition waste. To address both the concern of increasing demand for new concrete materials and increasing production of waste, many nations have begun to recognize that a more sustainable solution exists in recycling waste concrete materials for use in construction of structures. To the Missouri Department of Transportation and Materials, this will help to address the question of how to sustain modern construction demands for construction materials as well as help to reduce the amount of waste and particles that enters already over-burdened landfills that leads to environmental pollutions.

Concrete is a brittle material which consists of four components namely; coarse aggregates which form the body of the concrete, fine aggregates which fill the pores in the coarse aggregates, cement which is a binding material or matrix and water which hydrates the cement and makes it workable. Concrete produced from these constituents' materials is usually very strong in compression but has a very low tensile and shear resistance. The tensile and shear strength of concrete is about one-tenth of its ultimate strength (Adom-Asamoah, 2003).

Ujjwal and Kuhar (2017) described concrete as a material prepared by mixing various constituents like cements, aggregates, water etc. which are economically available. They went on to say that concrete is a composite material composed of granular materials like coarse aggregates embedded in a matrix and bound together with cement or binder which fills the space between the particles and glue them together. Over time, the cement forms a hard matrix which binds the rest of the ingredients together into a durable stone-like material with many uses. Concrete is used in large quantities almost everywhere mankind has a need for infrastructure. The amount of concrete used worldwide ton for ton is twice that of steel, wood, plastics and alummium combined. Concrete usage in the modern world is exceeded only by that of naturally occurring water.

In Ghana and many developing countries, concrete beams, slabs, lintels and columns are generally under-reinforced and therefore constitute brittle elements. The use of such under reinforcement concrete elements arise as a result of the high cost of reinforcement bars and lack of awareness of the suitability of recycling and using available waste materials such as waste reinforcement bars, steel fibers and steel particles for reinforcement in concrete to improve its flexural strength, shear strength, ductility and resistance to impact, fracture and abrasion (Kankam, 2003).

Construction Engineering Lab (1992) stated that the addition of reinforcement bars and steel fibers to plain concrete is intended both to improve the materials ductility and that of the structure in which it is used. Investigations into various types of fibers for structural concrete beams, slabs, lintels and columns have been made which include glass, steel, asbestos, polypropylene and other natural fibers such as coconut husk, sisal, sugar cane bagasse, jute, palm stalk and palm kernel (Aziz et al, 1984).

Steel fibers and reinforcement bars are known to increase the flexural strength of concrete beams, slabs, lintels and columns where both flexural and impact strength are important (Persson and Skarendahl, 1980). A study of the impact resistance of both plain and reinforced concrete containing steel fiber mesh and reinforcement bars has also revealed remarkable increase in energy absorption of the latter (Fiber Mesh Company, 1989).

Also, concrete reinforced with uniformly and randomly short length steel fibers and waste reinforcement bars is superior in the shear strength, tensile strength, bending strength, cracking load, toughness, shock resistance and other properties to unreinforced concrete. The technology of steel fiber and reinforcement bars in reinforced concrete thus already exists. However, in recent times, the cost of reinforcing steel bars for reinforced concrete has increased; and this has engendered the construction of concrete slabs, beams and columns with inadequate reinforcement, which usually lead to premature failures. Steel fiber and reinforcement bars for concrete slabs, beams, lintels and columns can be obtained from many sources including; steel fibers cut from wire to the required length, slit cold rolled steel sheet whose width corresponds to length of the fiber chopped by a rotating cutting edge or a pressing mill and a disc rotated on molten steel that extracts molten steel and steel fiber from discarded vehicle tyres (Rutledge et al, 2006).

There is another and cheaper source of reinforcement material in Ghana that is yet to be exploited. This can be obtained from steel shops which is steel particles, which are usually thrown into the environment indiscriminately that causes environmental pollution which can be collected and used as reinforcement materials for construction purposes.

Conversion of wastes to wealth, a process known as recycling is the new vogue all over the world; it is not only to reduce environmental pollution but also to effectively put these waste materials into good use that would be beneficial to mankind (Akindehinde & Oluwotusin, 2010). Reducing environmental pollution and alleviating poverty in less developed countries are important goals of sustainable development. The challenges that pose to engineering professions to execute projects in harmony with nature using the concept of sustainable development involving the use of high performance economic friendly materials produced at reasonable cost with lowest possible environmental impact. In the context of reinforced concrete production, it is necessary to identify less expensive component materials, especially materials that can serve as substitutes for the reinforcement bars which are most expensive input component. Thus, steel particles from steel shops that can be used are harnessed for concrete beams in Ghana will serve a dual purpose: First to produce stronger concrete beams at cheaper cost and secondly to reduce environmental pollution.

1.2 Statement of the problem

In Ghana, reinforcement bars of different sizes are obtained mainly from steel factories for building construction and civil engineering works (Sandor, 1992). A survey through the literature review indicates about ninety-five percent(95%) of buildings are constructed with cement and sand, reinforcement is used to strengthen the structure especially on the structural components such as beams, slabs, lintels, columns and foundations (Reynolds, 1972). The increasing cost of reinforcement bars for construction of structural elements such as concrete slabs, beams, lintels, columns and foundations has caused many of these elements and other purposes constructed without adequate reinforcement bars. Consequently, these structural elements most often than not, do not perform their design purposes satisfactorily since they easily fail in flexure when subjected to bending and impact loads. The quest for another and cheaper source of steel for reinforcement to reduce the cost of beams, columns, slabs, lintels and foundations construction in Ghana has been on the increase in recent times. Investigations carried out on concrete elements reinforced with steel bars and steel fibers have proved that their mechanical properties, physical performance and durability improve tremendously (Kankam, 2003). The formation and distribution of cracks in these concrete members are also generally controlled with the introduction of steel fibers and reinforcement bars (Adom-Asamoah, 2003). However, increasing cost of acquiring them from the market has engendered the need to look for another sources of reinforcing materials that could be obtained from steel particles on steel shops and factories and used in Ghana is the focus of this study.

It is this fore-knowledge which serves as the strongest motivation for the current researcher to investigate and evaluate scientifically whether the steel particles can be used as reinforcement material to perform the same function as reinforcement for reinforced concrete works.

1.3 Purpose of the Study

The purpose of the study is to investigate the strength performance of concrete with steel particles.

1.4 Specific objectives of the study

The specific objectives are:

- **I.** To determine the compressive strength of concrete with steel particles.
- **II.** To determine the flexural strength of concrete with steel particles.
- **III.** To determine the split tensile strength of concrete with steel particles.
- **IV.** To find water absorption resistance of concrete reinforced with steel particles

1.5 Significance of the study

Currently, in Ghana steel particles are not used in any productive venture, but is often disposed off as waste. Steel particles from the steel shops and other areas is a major challenge as it is indiscriminately disposed off in the natural environment causing pollution when rusting and corrosion takes place. The ever rising cost of building materials especially reinforcement in Ghana makes it difficult to provide affordable housing for the poor majority of an overall population of about twenty- eight million (28,000,000) people in the country (Ghana Population Council, 2016). However, the quest for affordable housing for insatiable infrastructure needs of a rapidly growing and urbanizing world coupled with the desire for a better quality of life of nations like Ghana suffering from a lack of availability and accessibility to world resources made focusing on wastes as inevitable option. The need for effective utilization of waste materials such as pieces of iron rods and steel particles in order to bring down the cost of reinforcement use as major structural components in concrete production to achieve a balance between economic development and protection of the environment cannot be over-emphasized. In addition, findings from this research will go to add to the knowledge that has been accumulated in this area. Industries which are into steel works will go a long way of increasing production and reducing unemployment rate in the country since more hands will be needed.

1.6 Justification of the study

Recently, there has been an increasing trend toward the use of sustainable materials. Sustainability helps the environment by reducing the consumption of non-renewable natural resources. Concrete, the second most consumed material in the world after water uses a significant amount of non-renewable resources. As a result, numerous researchers have investigated the use of recycled materials in the production of concrete such as fly ash and recycled aggregate. Unfortunately, global data on concrete waste generation is not available, but construction and demolition waste and steel particles account for around 900 million tonnes every year just in Europe, the US and Japan (World Business Council for Sustainable Development, 2012).

Under the goal of sustainability, the use of recycled concrete materials has become an important issue in the field of civil engineering and building construction works. Continuous efforts are being made to improve the mechanical properties of reinforced concrete materials as compared to normal concrete materials. There are several modes of failure in concrete structural members. Due to the fragility of concrete structures, shear failure is one of the most important and undesirable modes of failure. Shear strength of concrete depends significantly on the ability of the concrete materials to resist shearing stresses. Shear force is present in beams at sections where there is a change in bending moment along the span. It is equal to the rate of change of bending moment. An exact analysis of shear strength in reinforced concrete beams is quite complex (Pinal, 2016). According to Corinaldesi (2010), there have been many studies on the mix design, mechanical properties and durability of concrete made with recycled materials. Work on structural behaviour, structural members, strength characteristics and structural design recommendations lacks far behind research work at the material level. The flexural strength of reinforced concrete beams does not depend much on the mechanical properties of the concrete (Abdelfatah and Tabsh, 2011). The axial capacity of reinforced concrete for beams and columns can be somewhat predicted from the steel and concrete materials strengths. However, flexural and tensile strengths of concrete inside structural elements such as beams and columns is a very complex phenomenon that often cannot be extrapolated from the properties of the involved materials. Recycling concrete materials not only reduces using virgin materials but also decreases the amount of waste in landfills.

In the Central Region, construction and demolition waste (CDW) materials such as steel particles are not used in any production venture, but often disposed in landfills or are left at the steel shops and steel factories causing environmental pollution when rusting and corrosion takes place (Regional Environmental Protection Agency report, 2016). According to the Regional Engineer, about 50% of minor structural elements such as short span beams, columns, slabs, lintels and foundations in the Central Region are under-reinforced causing cracks and deformations on buildings (Ministry of Local Government and Rural Development, Regional Engineer's Report on assessment of quality construction work, 2016). Based on the above, there is the need to investigate and evaluate scientifically whether the steel particles can be used as reinforcement to perform the same function as reinforcement materials for reinforced concrete works.

1.7 Scope of the Study

The study involved the collection of steel particles from the steel shops in the Central Region and combine with cement, aggregates and water for concrete production with target strength of 25N/mm^2 for the reinforcement concrete and plain concrete. A total of 60 cubes and 60 reinforced concrete beams samples were cast to study the compressive strength, flexural strength, tensile strength and water absorption properties at 7 and 28-days respectively.

1.8 Experimental Studies

A review of related literature on the study were done from the appropriate textbooks, internets, newspapers, journals and other relevant publications. Data collected through laboratory experiments were analysed and conclusions were drawn.

1.9 Limitation of the Study

The researcher was faced with the challenge of travelling to and fro longer distances to look for information for the research work. This was especially necessary to have a better relevant literature to review. Also, conveying of steel particles from Cape-Coast Metropolis to Sunyani Technical University for experimental studies. These situations delayed the duration of the research and also increased the expenditure.

1.10 Organization of the thesis

The thesis is grouped into six chapters as follows: Chapter one deals with general introduction of the study, problem statement, purpose of the study, objective of the study, significance of the study, justification of the study, scope of the study, experimental studies, limitation of the study and organization of the study. Chapter two covers the literature review relevant to the study whilst chapter three details the experimental studies that were used to achieve the research objectives. Chapter four is devoted to the results obtained. Chapter five captures the discussions of the results. Chapter six presents on conclusions and recommendations of the study.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Concrete as a Building Material

Concrete is a constructional material which consists of a binding material, fine aggregate and coarse aggregate and a suitable amount of potable water. Good concrete is required to be hard, strong, durable, dense, impermeable and fire resistance. The soundness of concrete depends on the quality of materials, grading of aggregates, ratio mix, water content and workability. Concrete, which is too rich of cement, shrinks excessively on drying, water, if too much is used in concrete reduces the strength of the concrete and renders it weak (Chudley, 1987).

Concrete has been the most common building material for many years. It is expected to remain so in the coming decades. Most of the developed world has infrastructure built with various forms of concrete. Mass concrete dams, reinforced concrete buildings, prestressed concrete bridges and precast concrete components are some typical examples. It is anticipated that the rest of the developing world will use these forms of construction in their future development of infrastructure (Chen and Richard, 2003). Sandor (1992) reported that the reason for its popularity can be found in the excellent technical properties of concrete as well as in the economy of these materials.

2.1.1 History of concrete

In early century, some form of concrete using lime-based binders may have been used (Reed et al, 2008). History proved that in 1756, John Smeaton, a British engineer, made the first modern day concrete (hydraulic cement) by adding pebbles as a coarse aggregate and mixing powdered brick into the cements. In 1793, he built the Eddy stone lighthouse in Cornwall, England with the use of hydraulic cement, but modern concrete using Portland cement, which sets under water, dates back to mid-eighteenth century and more importantly with the patent by Joseph Aspdin in 1824 (Soroka, 1979). He made concrete by burning ground chalk and finely crushed clay in a lime kiln until the carbon dioxide evaporated, producing a strong cement. Portland cement has remained the dominant cement used in concrete production today. The other major ingredient of concrete besides cement is the aggregates. Aggregates include sand, crushed stone, slag, fly ash, burned shale and burned clay. The invention of the cement came into being when he improved upon hydraulic lime, the strongest cementing material existing at that time. The material was termed Portland cement because of its close resemblance to a Portland, limestone found in Dorset in great Britain. The raw materials used in the manufacture of Portland cement were calcium carbonate which is found in calcareous rocks such as limestone or chalk and silica, alumina, oxides of iron etc, found in argillaceous materials such as clay and shale.

The strength of the Portland cement developed by Joseph Aspdin became far greater than hydraulic lime which was the mostly used cementing material at that time. Joseph Aspdin indicated that the strength development achieved by him as compared with hydraulic lime was 27.58N/mm^2 in 6months and that of hydraulic lime for the same period was 6.89N/mm^2. The crushing strength development for 7 days was also improved from 0.69N/mm^2 for hydraulic lime up to 17.23N/mm^2 for Portland cement. However, in 1849 Joseph Monier was able to improve upon ordinary mass concrete by inventing reinforced concrete. He was a Parisian gardener who made garden pots and tubs of concrete reinforced with an iron mesh. Reinforced concrete combines the tensile strength of metal with the compressive strength of concrete to withstand heavy loads. Reed et al. (2008) however postulated that, the introduction of the Portland cement has transformed very tremendously the construction processes in this modern era, since it has revolutionized the strength of structures. He deduced that the material ensures greater strengths of structural components like columns, beams, floors, bridges and others in support of greater loads. Traditionally, concrete is a composite material consisting of the dispersed phase of aggregates (ranging from its maximum size coarse aggregate down to the fine sand particles) embedded in the matrix of cement paste. This has a Portland cement concrete with the four constituents of Portland cement, water, stone and sand. These basic components remain in current concrete but other constituents are now often added to modify its fresh and hardened properties. This has broadened the scope in the design and construction of concrete structures. It has also introduced factors that designers should recognize in order to realize the desired performance in terms of structural adequacy, constructability and required service life. These translated into strength, workability and durability in relation to properties of concrete. In addition there is the need to satisfy these provisions at the most cost- effective price in practice (Chen and Richard, 2003). Gambhir (1992) further opines that, concrete is a composite product obtained by mixing cement, water and inert matrix of sand and gravel or crush stone. It undergoes a number of operations such as transportation, placing, compacting and curing. The distinguishing property of concrete is its ability to harden under water. The ingredients of concrete can be classified into two groups namely active and inactive. The active group comprises fine and coarse aggregates. The inactive group is also called inert matrix.

2.2 Types of concrete

Bour-Frimpong (2009) described the two types of concrete as:

- Mass concrete: This is otherwise called plain concrete. It is the type of concrete without reinforcement. It can be found in pavement, slab, ground floor etc. The ratio normally used is 1:3:6 thus I part of cement, 3 parts of sand and 6 parts of stones.
- Reinforced concrete: This type of concrete incorporates the use of steel bars in its production. The ratio normally used is 1:2:4 thus I part of cement, 2 parts of sand and 4 parts of stones.

2.2.1 Proportion of concrete materials

The proportion of concrete materials is mostly influenced by the use of concrete. Concrete proportion for a reinforced concrete is different from that of a plain concrete. Therefore, these materials are proportioned to make sure that the correct materials are used for the mix. Proportioning of materials is termed as batching (Chudley, 1987). Batching is the process or method of measuring materials for concrete in their right or correct ratio. There are two types of batching, these are;

- Batching by volume: This method of batching is usually carried out by using an open bottom box called gauge box. For a 1:2:4 mix, a gauge box is filled once with cement, twice with sand and four times with stones, the top of the box being made level each time. If the aggregate is damp or wet, its volume will increase by up to 25%. Therefore the amount of sand should be increased by that amount. The increase in volume is called bulking.
- Batching by weight: This method of batching involves the use of a balance which is attached to a dial giving the exact mass of the materials as they are placed in the scales.

This method is considered the best method since it has a greater accuracy and the balance can be attached to the mixing machine.

2.2.2 Measurement of workability of concrete.

According to Bour-Frimpong (2009), various methods are used for measuring workability of concrete. These are:

- The slump test: The principle of this is that if a heap of concrete of standard size is allowed to stand on a flat surface, it will slump by an amount which varies with its workability. The concrete is placed and compacted by a standard method, 30mm into an open-ended, truncated conical mould, 300mm deep and with upper and lower diameters of 100mm and 200mm respectively. The mould is carefully removed and the vertical distance by which the top of the concrete sinks is measured.
- Compacting factor test: The slump test is not sufficiently sensitive to be used to test a concrete of low workability i.e. having a slump of less than 10mm. The principle of the test is that, if a standard container is filled with conic under standard condition of compacting, the mass of the concrete in the container varies with its workability. The apparatus used consists of two hoppers with trap, through which concrete (ml), which exactly fills the cylinder, is measured. The cylinder is then emptied and refilled with concrete under conditions which ensure maximum compaction of square metre (m^2). The compacting factor is expressed as a decimal: a typical value is the range 0.7-0.8.
- Vebe Consistometer test: This test is carried out on concrete whose workability is so low that no slump can be recorded. The principle of the test is that if a standard heap of concrete is vibrated, it will subside at a rate which varies with the workability of the concrete. The

apparatus consists of a cylinder, large enough to enclose a slump cone and supported on a base which can be vibrated. A vertical arm attached to the base, carries a funnel and a transparent plastic disc just fits inside the cylinder with the funnel on top of it. When a slump test is carried out, the funnel prevents overflow of concrete into the cylinder. The disc is then allowed to rest on top of the concrete, and a vibratory unit is switched on. A typical value of "Vebe degree" is in the 10-25.

2.2.3 Mixing of Concrete

Concrete is mixed to have all materials combine to each other and to have a uniform mix and strength of mix (Chudley, 1987). There are two methods of mixing concrete. These are:

- Hand mixing: This is carried on a prepared platform. The quantity of sand is first batched onto the platform, and spread out with the aid of a spade or shovel. The quantity of cement is also batched and poured over the sand. The sand and cement are then mixed thoroughly to have a uniform colour in the dry state. The mix is spread out. The quantity of coarse aggregate is also batched and poured over the dry mix. A quantity of suitable amount of water is poured gently over the mix. The mix is shoved for several times until a uniform paste is achieved.
- Machine mixing: Here a concrete mixer is used. The materials are batched and directed into the mixing drum.

  The mix is allowed to turn over in the mixer for at least two to five minutes after adding water. The mixing is done by revolving the drum by the use of attached motor. Machine mixing method is faster than the hand mixing method and also produces thorough mix than the hand mixing method.

2.2.4 Placing of concrete.

Placing of concrete refers to the final positioning of concrete. Concrete should be properly placed to ensure that it can be well compacted into a homogeneous mass. Improper placing results in serious defects such as segregation, bleeding and honey combing. Improper placing of concrete can also cause distortion of movement of the reinforcement. Concrete should not be dropped or poured over a height of more than one meter line. Improper handling results in the separation of the coarse and fine aggregates. Concrete should therefore be placed in the formwork close to its final position (Bour-Frimpong, 2009).

2.2.5 Compaction of concrete

Compaction of concrete is whereby the particles of the aggregates are rammed or tamped after placing so that the aggregates are closely packed more closely together so as to achieve the maximum density and strength (Chudley, 1987). Compaction of concrete also ensures that the amount of voids is reduced to a maximum. There are two means of compacting concrete. These are;

- Hand compaction: This is by ramming or tamping the concrete by the use of a rammer. It can also be done by spading or pruning by the use of spade.
- Machine compaction: This is the method of ramming or tamping the concrete with a machine called vibrator. There are two classes of vibrators. These are:
    i. Internal or poker vibrator: This has about 50 diameter tube inserted into concrete at 2 feet centres, however smaller vibrators should be used at a closer interval.

Vibration is usually said to be completed when the cement mortar is brought to the surface and air bubbles no longer appear.

ii. External vibrator: The external vibrators are usually vibrating machines which are clamped to the formwork, but there are special types used for slab and paving construction in which the vibration is applied to the top surface of the concrete (Bour-Frimpong, 2009).

2.2.6 Curing of Concrete

When the concrete has been mixed, placed in position and compacted, it must be cured at an adequate temperature and humidity to ensure that proper hydration of the cement takes place and the concrete hardens and gains its strength. Curing is therefore a means of preventing the fresh concrete from rapid drying. The fresh concrete must be protected from the influence of the sun and drying winds. Curing is done to allow the concrete to attain it maximum strength and also to prevent a rapid drying out of the concrete which may cause shrinkage and cracks (Bour-Frimpong, 2009).

2.3 Properties of Concrete

C.C.A.A. (2002) describes four main properties of concrete as follows:

- Workability: Workability means how easy it is to mix place, handle, compact and finish a concrete mix. Concrete that is stiff or dry may be difficult to handle, place, compact and finish and if not constructed properly, will not be as strong or durable when finally hardened.

- Cohesiveness: Cohesiveness is how well concrete holds together when plastic. Cohesiveness is affected by the aggregates, from large rocks to small sands. Well-graded aggregates give a more cohesive mix; too much coarse aggregate gives a boney mix.
- Strength and durability: Well-made concrete is a naturally strong and durable material. It is dense, reasonably watertight, able to resist changes in temperature, as well as wear and tear from weathering. Strength and durability are affected by the density of the concrete. Denser concrete is more watertight (or less permeable). Concrete durability increases with strength.

2.4 Compressive strength of concrete

Safuiddin (2008) opines that compressive strength is the most important mechanical property of concrete. In general, for a given set of cement and aggregates and under the same mixing, curing and testing conditions, the compressive strength of a concrete primarily depends on water/ binder (W/B) ratio, binder/ aggregate (B/A) ratio, mixture composition, and degree of consolidation. Abrams (1918) reported that the amount of water in the mix compared with the amount of cement is called the W/B ratio and the lower the W/B ratio the stronger the concrete. However, it is the W/B ratio that chiefly controls the development of compressive strength in concrete. Abrams (1918) further stipulated that, B/A ratio are the ratio of the mass of aggregate to that of cement in concrete or mortar. A high quality concrete may be possible by using lowest W/B ratio possible, using the proper size coarse aggregate practical for the job and using the optimum ratio of fine to coarse aggregate. In some instances, the same W/B ratio, concrete with a smaller maximum-size aggregate could have higher compressive strength. The rougher the surface of the aggregate the greater the bond with the cement paste, the stronger a concrete will be. Rounded particles result in lower strength than crushed aggregates. Larger size aggregates lead to lower strength concrete. Concretes containing smooth gravels beging to crack at lower compressive stresses than concretes containing coarser-textured aggregate. Gambhir (2004) says that, among the various properties of concrete, its compressive strength is considered to be most important and is taken as an index of its overall quality. This is an important property of hardened concrete which is considered in the design of most concrete mixes of various strength of concrete. The determination of compressive strength has received much attention due to the fact that concrete is primarily meant to withstand compressive stresses. Cubes, cylinders and prisms are the types of compressive test specimens used to determine compressive strength.

2.5 Constituents of reinforced concrete

2.5.1 Cement

Gambhir (1992) describes cement to be a well-known building material and has occupied an indispensable place in the construction works. There is a variety of cements available in the market and each type is used under conditions due to its special properties.

Bye (1983) explained Portland cement as a finely ground material consisting primarily of compounds of lime, alumina and iron. When mixed with water, it forms a paste that hardens and binds the aggregates (such as sand, gravel or crushed rocks) to form a hard durable mass called concrete. Portland cement has become one of the most important construction materials during the last 150 years or so, primarily because concrete can be used advantageously for so many different purposes (Sandor, 1992). From Gambhir (1992), raw materials for manufacture of cement are clay and chalk or limestone. Firstly they are taken in proper proportions, crushed and then ground to fine power. Secondly, the resulting mass is heated to about 1450^{0}C in a kiln where lime (obtained from the limestone) and alumina and silica (constituents of clay) fuse to form a mixture of calcium silicate and calcium aluminate in a clinker.

Table 2.1 Chemistry of cement

Type of oxide	Percentage
CaO	60-67
S_1O_2	17-25
Al_2O_3	3-8
Fe_2O_3	0.5-6
MgO	2.5
SO_3	1

The oxide compositions of Ordinary Portland cement are shown in Table 2.1 and undergo fusion process as follows:

$$8CaO + Al_2O_3 . 2S_1O_2 . 2H_2 \longrightarrow 2Ca_3S_1O_5 + Ca_2 Al_2O_3 + 2H_2O$$

Lime Clay Calcium silicate Calcium Aluminates

Finally, the clinker is cooled and mixed with about 3 to 4 percent of gypsum by mass which is subsequently ground to an exceedingly fine powder. This powder is the cement in the final form. The gypsum acts as retarder to prevent immediate setting and also improves the soundness of the cement. The fineness of grinding and the raw materials influence the reactivity of the cement, fine cement hardens more quickly than coarse cement of the same composition. Gambhir (1992) further explained that, high lime content generally increases the setting time and results in high early strengths. A decrease in lime content reduces the strength of concrete. High silica content prolongs the setting time and gives more strength. The presence of excess of burnt lime is harmful since the hydration takes place slowly and causes expansion (unsoundness). The iron oxide is not a very active constituent of concrete; it generally acts as a catalyst and helps the burning process.

Due to the presence of iron oxide the cement derives the grey colour. Magnesia, if present in large quantity causes unsoundness. As mentioned earlier, the constituents of cement are not just simple oxides but are in the form of complex compound having definite molecular structure. The major compounds in the ordinary Portland cement are shown in Table 2.2.

Table 2.2 Compound and chemical composition of Portland cement

Chemical Name	Chemical formula	Short hand notation	Percentage by weight
Tricalcium Silicate	$3CaO \times S_1O_2$	C_3S	50
Dicalcium Silicate	$2CaO \times S_1O_2$	C_2S	25
Tricalcium Aluminate	$3CaO \times Al_2O_3$	C_3A	12
TetracalciumAluminofersite	$4CaO \times Al_2O_3 \times FeO_3$	C_4 AF	8
Gypsum	$C_aSO_4 \times H_2O$	CSH_2	3.5

source: (Mindess and Young, 1981)

In Gambhir (1992), C_3S and C_2S constitute about 70 to 80 percent of the Portland cement and contribute to its strength. They enhance the durability by making the cement resistant to acid and alkali attack, C_3S hydrates rapidly and hence contributes to the early and ultimate strength of cement, C_3A hydrates rapidly contributing to early strength but reducing ultimate strength. This compound is liable to be attacked by salts and alkalis. C_4AF is the most undesirable compound and does not contribute to the strength. By changing slightly the chemical composition, it is possible to obtain cements exhibiting different properties.

2.5.1.1Physical properties of cement

Gambhir (1992) postulated that, the cement to be used in construction must have certain given qualities in order to play its part effectively in the structure. When these properties lie within certain range, the engineer is confident that in most of the cases the cement performance will be satisfactory. Also based on these properties it is possible to compare the quality of cement from different sources. The important physical properties of cement are:

- **Fineness**

  Kando (1972) said the term fineness or fineness of grinding refers to the coverage size of the cement particles. A higher fineness means a more finely ground cement, smaller particles. The significance of fineness lies in the fact that it affects several technically important properties of cement and concrete. For instance the higher the fineness, the higher compressive strengths are developed at early age.

- **Setting time**

  Gambhir (1992) said when cement is mixed with water it forms a slurry which gradually becomes less plastic and finally a hard mass is obtained. In this process of setting, a stage is obtained when the cement paste is sufficiently rigid to withstand a definite amount of pressure. The time to reach this stage is called setting time.

  Cement paste setting time is affected by a number of items including: cement fineness, water cement ratio, chemical content (especially gymsum content) and admixtures. Setting tests are used to characterize how a particular cement paste sets. Normally, two setting times are defined by Mindess and Young (1981):

  i. Initial set occurs when the paste begins to stiffen considerably.

  ii. Final set occurs when the cement has hardened to the point at which it can sustain some load.

- **Compressive strength of cement**

  It is one of the important properties of cement. The strength tests, generally carried out in compression on samples of neat cement, are of doubtful value as an indication of ability of the cement only make concrete strong in compression. Therefore, these are largely being superseded by the mortar cube crushing tests and concrete compression tests. These are conducted on standardized aggregates under carefully controlled conditions and therefore give a good indication on strength qualities of cement. Cement mortar cubes (1:3) having an area of 5000mm^2 are prepared and tested in compression testing machine. For ordinary Portland cement the compressive strength at 3 and 7 days curing should not be less than 16N/mm^2 and 22N/mm^2 respectively (Gambhir, 1992).

- **Normal consistency**

  In several standard tests concerning the quality of Portland cement, such as in the soundness time of setting and tensile strength tests, the amount of mixing water specified is related to the water condition needed to bring the paste to a standard condition of wetness, called normal consistency (Reed et al. 2008)

2.5.2 Aggregates

Aggregate is a more or less inert, granular, usually inorganic material consisting normally of stones or stone like solids. Typical examples are sand, gravel, crushed stone and crushed slag. The use of aggregate in concrete greatly reduces the needed amount of cement, which is important both from technical and economic standpoint (Sandor, 1992). The coarse aggregate is used primarily for the purpose of providing bulk to the concrete. To increase the density of resulting mix, the coarse aggregates are frequently used in two or more sizes. The most important function of the fine aggregate is to assist in producing workability and uniformity. The fine aggregate also assists the cement paste to hold the coarse aggregate particles in suspension. This action promotes plasticity in the mixture and prevents the segregation of the paste and coarse aggregate, particularly when it is necessary to transport the concrete some distance from the mixing plant to the point of placement.

The aggregate provides about 75 percent of the body of concrete and hence its influence is extremely important. The physical, thermal and also sometimes chemical properties of aggregates greatly affect the performance of the concrete. The properties influence the workability, strength, durability and economy. As the aggregate are cheaper than cement, it is economical to add into concrete as much of the aggregate as possible (Gambhir, 1992).

2.5.2.1 Classification of aggregate

Gambhir (1992) stipulates that the aggregate for concrete varies in size, but in any mix, particles of different sizes are used. The particle size distribution is called grading of the aggregate.

Two types of aggregates are:

- **Fine aggregate**

  Fine aggregate is often termed as sand-size aggregate. Sand or fine aggregate size is classified as less than 4mm or 4.75mm. The material between 0.06mm and 0.02mm is classified as silt and smaller particles are termed clay. Loam is a soft deposit consisting of sand, silt and clay in about equal proportions. In contrast to coarse aggregate type, the fine aggregate types do not appear to influence the concrete strength significantly. Fine aggregate in concrete fills the voids existing in the coarse aggregate. It reduces shrinkage and cracking of concrete. It also helps in hardening of cement by allowing the water through its voids.

- **Coarse aggregate**

Coarse aggregate is defined as an aggregate most of which retained on 4.75mm IS sieving (Gambhir, 1992). The aggregates are formed due to natural disintegration of rocks or by artificial crushing of the rock into gravels. Thus the aggregate derives many of their properties from the parent rocks. These properties are: chemical and mineral composition, petrography description, specific gravity, hardness, strength, physical and chemical stability, pore structure and colour. Some of the other properties of the aggregates which are not possessed by the parent rock particles are shape and size, surface texture, and absorption etc. All these properties may have a considerable effect on the quality of concrete in fresh and hardened states. To identify the particular lot of aggregates, the following classifications are used:

i. Classification based on petrological character of aggregates: This is based on the nature of rocks, sedimentary rocks, metamorphic rocks etc.

ii. Classification based on physical characteristics of the aggregate: This is based on the characteristics such as the particle shape, surface texture etc. is of great importance. Based on the shape, the aggregate can be described as:

- Rounded aggregate e.g. river or seashore gravel.
- Irregular or partly rounded e.g. pit-sand and gravels, cuboids rocks etc.
- Flaky aggregates: the aggregate whose dimensions are least e.g. laminated rocks. Angular aggregate possessing well defined edges formed at the intersections of roughly planner surfaces, e.g. that obtained by crushing the rocks etc.
- Classification based on the weight, normal weight, light weight aggregate etc. Gambhir (1992) further said coarse aggregate in concrete makes solid and hard

mass of concrete with cement and sand. It increases the crushing strength of concrete. It reduces the cost of concretes, since it occupies major volume.

2.5.3 Water

Gambhir (1992) states that water is the most important and least expensive ingredient of concrete. Its functions in concrete are to react chemically with cement to form the binding matrix in which the inert aggregates are held in suspension until the matrix hardens. Water in concrete also serves as vehicle or lubricant between the fine and coarse aggregates in order that the concrete may be more readily placeable in forms.

In Gambhir’s (1992)explanation minimum water cement ratio required is 0.3 but water quantity in this mix proportion will be very harsh and difficult to place. Additional water is required to lubricate the mix, which makes the concrete workable but too much water also reduces the strength of the concrete. Gamblir said water used in mixing concrete should be clean and free from injurious amount of oils, acids, alkalies, organic materials or other deleterious substance. The presence of these impurities in the water may affect setting time of cement, strength of concrete and may cause corrosion of the reinforcement. If the water is fit for drinking it is generally accepted for making concrete production.

2.5.4 Steel

Steel in its various forms (low carbon steel, medium carbon steel, and high carbon) is a metal most used in building. Steel is an alloy of iron and carbon, though other alloying are also found in many steels (Reynolds, 1972). Perhaps the most dramatic property of steel is that some alloys can be strengthened by quench hardening.

According to Reynolds (1972), red hot metal is rapidly cooled by plunging it into a liquid. These alloys can thus be good for fabrication and much stronger as a finished product. Steels are loosely grouped by carbon content into low carbon steels (< 0.35% carbon by weight), medium carbon steels (0.35% - 0.5% carbon by weight), and high carbon steels (0.5%-1.5% carbon by weight). These numbers may seem to be small, but they reflect the fact that carbon is a small, light element, while iron is a much larger, heavier atom.

When metallurgists look at the detailed structure of steels, they are concerned about the presence, and particularly the shape, on the carbide Fe_3C. This compound is 25% carbon by atom fraction, but only 6.7% carbon by weight.

Steel bars are used to reinforce concrete and pre-stressed concrete. According to Reynolds (1972), concrete is strong in compression but weak in tension, that is, it is liable to crack at those points that are under tensile stress. Tensile forces are forces that tend to pull something apart, as opposed to compressive forces which tend to push something together.

Steel, on the other hand, is strong in both tension and compression and is used to reinforce concrete which is under tensile stress; the concrete protects the steel from the effects of fire and corrosion. Chudley (1987) explained that tensile stress in concrete are greatest at the bottom of suspended slabs at the mid span where it rest on support. Steel bars are placed as near as possible to these positions while ensuring that they have sufficient cover concrete. When friction between the concrete and steel is low, the ends are hooked, making the reinforcement beams more secure.

2.5.4.1 Types of steel

Reynolds (1972) described the three types of steel as follows:

- Low carbon steel: This category of steel contains by far the largest tonnage of steel produced, as it includes the structural steels of bridges and buildings. These steels usually have only small amounts of other alloying elements. They are not quench hardened, as ductility in the final products is desired. Low carbon steels are sometimes referred to as mild steels. Low carbon steels may also be surface treated for corrosion resistance, using processes of galvanizing, electroplating, as well as just plain painting.
- Medium carbon steel: steel in this category are also medium alloy steels. Up to about 3% by weight might be comprised of varying proportions of manganese, nickel, chromium, molybdenum, or sometimes other elements. Medium alloy steels can be quench hardened, and the added alloying elements are primarily to improve hardening ability.
- High carbon steel: These are also high alloy steel, with approximately 5%-10% by weight consisting of alloying elements other than carbon. Though high carbon steels are used in the smallest amounts, these are specially steels often referred to as tool steels. They are the steels used for hammers, pick axes, and cutting tools like knives and chisels. They are the steels used at the highest temperatures. The tools steels are generally heat treated.

2.5.4.2 Types of steel used for reinforcement

Reynolds (1972) described the five main categories of steel materials used in reinforcement as:

- Plain round and Plain Square: These include mild steel, having ultimate stress of 432-510 N/mm^2; medium-tensile steel, having ultimate stress of 586 N/mm^2; and high-tensile steel of between 571 N/mm^2 and 664 N/mm^2.
- Wire: This is usually cold-drawn from mild steel so as to have ultimate stress 571-649 N/mm^2. Wires are used for binding the main rods in a reinforcement network. Thicker wires are also used in shaping reinforcement before they are dropped into formwork.
- Deformed bars: These may be either square or twisted or twin twisted round bars. The bars have an ultimate stress of 478 N/mm^2 or more. Deformed bars are used as main reinforcement frames in a network. They are sometimes selected because of their low cost. They bond better with concrete than plain bars.
- Steel fabrics: These are hand drawn steel wire fabric with the wire electrically welded together at all junctions. They have ultimate stresses of about 478 N/mm^2. They serve the same purpose in reinforcement as ordinary steel wires.
- Proprietary materials: These are expanded metals used for spanning formwork in small projects and in the construction of slabs for covering drains.

2.5.4.3 Uses of iron and steel.

According to Reynolds (1972), the main use of iron in buildings is as steel in reinforcement. Steel is also used in roofing, as members in girder construction and trusses and to make frames for some types of buildings.

2.6 Beams

Beams are structures placed across long openings to carry loads and transmit them to columns and walls (Chudley, 1987). Beams can be constructed of timber, steel or concrete. They must be strong enough to resist failure by compression, tension, shear and deflection. Beams are classified according to their sections as rectangular shaped, I- shaped, L- shaped and T-shaped. Depths range normally from 1/25 to 1/10 of the span of the beam and with a minimum of two rods at the bottom according to the load the beam is carrying and the span.

2.6.1 The use of concrete beams

Concrete beams are used substantially for several purposes including commercial, residential and industrial usage. A concrete beam is satisfactory to serve its purpose if it is able to withstand the loads imposed on it without any defect or failure throughout its life span. Concrete beams must be constructed of durable materials, which will improve upon its durability for as long as the beam continues to serve its purpose (Bour-Frimpong, 2008).

Mass concrete in common with other brittle materials has a greater crushing or compressive strength. The actual ratio varies but mass concrete is generally considered to be ten times stronger in compression than in tension. If a mass concrete member is loaded so that tension is induced, it will fail in tension. If this weakness in tension can be reinforced in such a manner that the tension resistance is raised to a similar value as its compressive strength, the member will be able to support a load ten times that of mass concrete or alternatively for any given load a smaller section can be used if concrete is reinforced (Chudley, 1987). This means that any material specified for use as reinforcement to concrete must fulfill certain requirements if an economical beam is to be constructed. These requirements are:

1. Possess tensile strength or stress
2. Be a material that can be easily bent to any required shape
3. Its surface must be capable of developing reinforcement to ensure that the required design tensile strength is obtained.
4. Must be capable of achieving this tensile strength without undue strain. (Dua Agyemang, 2008)

2.6.2 Types of beams

- Simple supported beams: In simple supported beams, the compressive stress is at the top and the tensile stress is at the bottom. The steel should be placed at the lower part of the beam.
- Cantilever Beam: In cantilever beams or slabs, the steel should be placed at the upper part of each concrete unit. This is because the tensile stress acts at the top of the beam.
- Semi-cantilever beam: Beams fixed at one end and free at the other are employed to support projecting galleries. Such beams act as levers and tend to overturn the wall above. To maintain equilibrium, sufficient weight of wall must be arranged above the built-in end of cantilever to balance the weight on the free end with enough in reserve to render the structure free (Dua Agyemang, 2008).
- Deep Beams: Deep beams are structural elements loaded as simple beams in which a significant amount of load is carried to the support by a compression force combining the load and the reaction. As a result the strain distribution is no longer considered linear, and the shear deformations become significant when compared to pure flexure. They are structural members with clear spans equal or less than four times the overall member depth

of regions of beams that are loaded on one face with concentrated loads within twice the member depth from the support and supported on the opposite face so that compression struts can be. Deep beams are beams having large depth/ thickness ratio and shear span-depth ratio less than 2.5 for concentrated load and less than 5.0 for distributed load (Haseeb, 2017).

2.7 Materials used as reinforcement in concrete

2.7.1 Fiber- Reinforcement concrete

Fiber-reinforcement is mainly used in normal concrete. Fiber- reinforced normal concretes are mostly used for ground floor slabs, small chamber covers and pavements, but can be considered for a wide range of construction part (beams, pillars, foundation etc.) either alone or with hand tied rebars. Concrete reinforced with fibers (which are usually glass or plastic) is less expensive than hand- tied rebar, while still increasing the tensile strength many times. Shape, length and dimension of fiber are important. A thin and short fiber, for example short hair-shaped glass fiber, will only be effective the first hours after pouring the concrete (reduces cracking while the concrete is stiffening) but will not increase the concrete tensile strength (Kankam, 2003).

A normal size fiber for European concreting (1mm length, 45mm length- steel or plastic) will increase the concrete tensile strength.

2.7.2 Steel or Iron Fiber- Reinforced Concrete

Reinforcing concrete is a means of incorporating an iron rod or steel in the concrete to give the concrete extra strength. Concrete is strong in compression but weak in tension, that is liable to crack at those points that are under tensile stress. Tensile forces are forces that tend to pull orstretch members. Steel, on the other hand, is strong in both tension and compression and is used to reinforce concrete which is under tensile stress (Reynolds, 1972). The spacing of rods is arranged to allow proper compaction of the concrete within the frame work. Good compaction can be achieved by using a mechanical poker vibrator. The minimum horizontal spacing should be the size of the maximum coarse aggregate usually 20mm – plus 5mm, and the minimum vertical should be two-third of maximum aggregate size. The maximum spacing of the main reinforcement is 300mm. The ends of the rods are usually bent into U-shape or L-shape hooks to anchor the main bars effectively. The breadth of the beam varies from 1/3 to ½ of the depth. Deep beams are more efficient than wide shallow beams. Concrete cover should be provided around the reinforcement bars to prevent the reinforcement rod from rusting and give protection against fire (Neville, 1996). To ensure this, spacer blocks of concrete or mort can be wired or threaded on to the steel rods, the spacers are then placed against the formwork and the rods held at the correct distance. The range of diameters for both round and deformed bars recommended are 6, 8, 10, 20, 25, 32 and 40 (mm), with a recommended maximum length of 12.0m. The steel bars must be clean, free from rust, grease and paint, all of which would reduce the bond between the steel and concrete. Great care should be taken to ensure that the reinforcement is not displaced during the placing and compacting of the concrete. To prevent bond failure, bars should be extended beyond the section where there is no stress in the bar. The length of the bar required will depend upon such factors as of grade concrete, whether the bar is in tension or compression and if the bar is deformed or plain. Hooks and bends can be used to reduce this anchorage length at the ends of bars and should be formed in accordance with the recommendations of BS 4466. Where a transfer of stress is required at the end of a bar, the bar may be welded and tapped. The hooks at the ends bars may be round or square (Neville, 1996).

Early research on steel fiber reinforcement in concrete was performed in the 1950's and 60s. The first commercial steel fibre reinforced concrete pavement in the US was placed in August 1971 at a truck station near Ashlan, Ohio. This was followed by two bridge deck overlays in Pennsylvania in 1972 that are still in service. Following those successful installations, steel fibers were used on a number of experimental concrete pavement projects in the 1970s and 80s, and have since been used primary in industrial floors, heavy-used pavements, beams, airfields, parking structures, and bridge decks.

The usual amount of steel fibers ranges from 0.25% to 2% by volume, or 20-157kg/m3. The benefits of steel fibers include up to 150% increase in flexural strength, reduced potential for cracking during concrete shrinkage, and increased fatigue strength. Significant research, testing, and application of steel fibers in concrete have occurred since the 1970s and have led to the primary use of steel fibers for increased strength and even thinner pavements designs (American Concrete Pavement Association, 2003).

Some steel fibers have hooked ends and are collected in bundles that break apart during mixing while others may be crimped in shape unattached as can be found in figure 2.1, 2.2 and 2.3. Steel fiber reinforced concrete is increasingly being used as a construction material. Studies have shown that steel fibers can be used to increase the bending moment capacity and shear strength of reinforced concrete beams. A study by Ezeldin and Hsu (1992) has outlined a computers algorithm that analyzes the combined contribution of steel fibers to flexural and shear strength of fiber reinforced concrete beams. The results of the evaluation indicate that the addition of steel fibers, especially those with a high aspect ratio in concrete improves flexural toughness, an indication of ductility and crack resistance. Steel fibers also increase splitting tensile strength.

It has been proved that addition of super plasticizers enhances these qualities further and also increases compressive and flexural strength which were not increased through the use of fibers alone. With the addition of fibers in concrete, no properties were adversely affected but no significant improvements over non-fiber reinforced concrete where noted in modulus of elasticity, Poison's ratio, shrinkage or durability over non-fiber reinforced concrete.



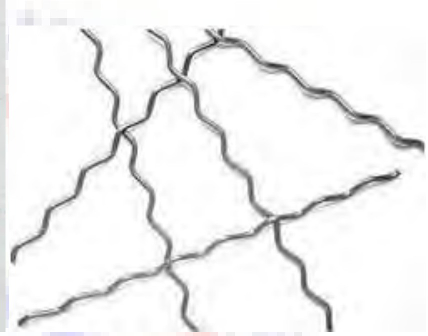

Figure 2.1 Steel Iron Rods **Figure 2.2 Hook end steel fiber** **Figure 2.3 Steel fiber**

2.7.3 Natural fiber- reinforced Concrete

The addition of fiber to plain concrete is intended to improve both the materials ductility and that of structure in which it is used (Construction Engineering Research Lab; 1992). In recent years, improving concrete properties such as strength and durability by adding fiber to the mix has become a common practice. Recent advances in fiber reinforced concrete (FRC) technology have increased its use in special construction areas, but their commercial applications are still limited due to FRC's cost. Kankam (2003) studied how the strength in the concrete slab could be achieved using natural fiber from palm kernel.

The purpose of that study was to investigate the impact resistance of palm kernel fiber- reinforced concrete beams due to falling and suddenly applied load. Palm kernel fibers were obtained from waste dump of a local palm oil processing mill. They ranged in length from19mm to 40mm and diameter of 0.2mm to 0.30mm. Nine different fiber contents of 0% 0.1%, 0.2%, 0.3%, 0.6%, 0.7%, 0.8%, 0.9% and 1.0% by weight of cement were used.

The results of the study showed that the maximum depth of cracks developed in the slabs were not significantly influenced by the fraction of fibers in the concrete; nevertheless, the inclusion of fiber reduced the maximum crack depth to about 15 to 40 percent. Based on the results and observations of the experimental investigations, it was found out that palm kernel fiber have significant influence in controlling crack formation in concrete due to impact loading (Kankam, 2003).

Adom- Asamoah (2003) studied how the impact and static loading in fiber concrete micro roofing tiles can be improved. Eighty- four (84) thin roofing tiles each of dimension 412mm x 250mm x 9.25mm were cast for various experimental tests. The concrete composition was varied using different percentages of palm kernel fibers to cement by weight. These were 0, 0.4%, 0.45%, 0.5%, 0.55%, 0.6%, 0.7% and 0.8%. The tiles were subjected to flexural and impact tests, the latter achieved by simply dropping a weight from rest in order to investigate the effects of fiber inclusion on the tensile strength and toughness of the tile in terms of crack behaviour. An optimum fiber content of 0.5% by weight of cement was to have improved the properties of the concrete roof tiles in terms of tensile strength and resistance to impact. Crack width and total crack length were reduced at 0.5% fiber content.

Other forms of natural fibers that have been investigated for reinforced concrete include sugarcane baggage, jute, coconut husk, palm stalk and feathers from consumed chicken which will contribute to cleaning the environment as they increase landfill waste.

2.7.4 Synthetic Fibers

Synthetic fibers are manufactured from materials such as acrylic, aramid, carbon, nylon, polyster, polyethylene or polypropylene.

The use of synthetic fibers has been increasing at a steady rate in the past couple of decades. Their primary use in concrete pavements to date has been in ultra-thin white topping, where 2 to 4 inches of concrete is bounded to an existing pavementsto form a composite pavement. They are normally used in concrete at a rate of at least 0.1% by volume. Ultrathin white topping utilizes 1.8kg/m3 of polypropylene fibers. The benefits of polypropylene fibers included reduced plastic shrinkage and subsidence cracking as well as increased toughness or post-crack integrity. In fresh concrete, polypropylene fibers also reduce the settlement of aggregate particles from the pavement surface, resulting in a less permeable end more durable (American Concrete Pavement Association, 2003).

Figure 2.4 Synthetic fibers

2.7.5 Carbon fiber Reinforced concrete.

The use of short pitch-based carbon fibers, together with a dispersant, chemical agent and silica fume in concrete with fine and coarse aggregates resulted in a flexural strength increase of 85% and a flexural toughness increase of 205%, a compressive strength increase of 22%, and a material price increase of 39%.

The slump was 4 in at a water/cement ratio of 0.50. The air content was 6%, so the freeze-thaw durability was increased, even in the absence of an air entrained. The aggregate size had little effect of the above properties. The optimum fiber length was such that the mean fiber length decreased from 12mm to 7mm after mixing using a Hobart mixer. The drying shrinkage was decreased by up to 90%. The electrical resistivity was decreased by up to 83% (Chung, 1992).

2.8 Particles

In the recent decade, nano-materials have shown great development due to their impact on construction materials (Sanchez and Soboleve, 2010). The use of nano technology products especially nano-powder has increased. Nano-powder can improve the mechanical properties of cement pastes due to accelerating the hydration, the formation of small-sized crystals such as Ca(OH), Atomic Force Microscopy (AFM) and the uniform clusters of C-S-H (Chen et al, 2012). Nano-powder can also improve the durability of cement-based composites due to filling of very small pores. The size of nano-powder is important as it has to be compatible with the pore structures of cement. According to Mehta (1999), cement particle size is important for its reactions with water (Diamond, 1986).

Nano particles are used either to replace part of cement, as a reinforcement material in concrete or as an admixture in the cement pastes (Li et al, 2004). In both cases, the addition of nano-scale particles improves the performance of concrete; for instance, an improvement of rheological properties has been observed in the fresh cement mixtures (Senff, et al 2010), whereas, the compressive strength was increased in the hardened state (Qing et al 2006).

2.8.1 Types of Particles

2.8.1.1 Nano-SiO_2 particles

Nano-SiO_2 particles lead to the chemical reaction between $SiO_2$and Ca $(OH)_2$ which is released during cement hydration. The previous mechanism can cause reduction of SiO_2 grain size contributing to increase the strength and reduce permeability. The great reactivity of particles is attributed to a high purity and a specific area in relation to its volume (Sobolev et al 2009). The effect of particles sizes has been studied by numerous studies as the nano particles cement mixture, tend to increase the demand for water for the same workability (Jo et al, 2007). In addition, particles tend to agglomerate, which can be avoided by using dispersing additives or applying different techniques during mixing (Porro et al 2005). Li recorded a dense, homogeneous structure in particles modified mortars and a compact transition zone between aggregates and paste. Sobolev et al (2009) reported that the nano-modified mixtures can reduce the initial strength with the curing age.

Li et al (2004) tested cement products with fly ash and concluded that the Pozzolanic reaction of fly ash is improved by adding nano-SiO_2 to the mixture.

2.8.1.2 Steel Particles

The making of steel and iron generates particles, namely by- products and waste. In Ghana, about 80% of the particles wastes are not used as raw materials for new steel production or other areas of application. In 2015, iron and steel production in Ghana generated over five million tones of particles. These particles were not used in any production venture but they were sent to landfills. Steel particles can be used in the areas of application such as metal industry, road construction, building industry and chemical industry (Regional Environmental protection agency Office report, 2016).

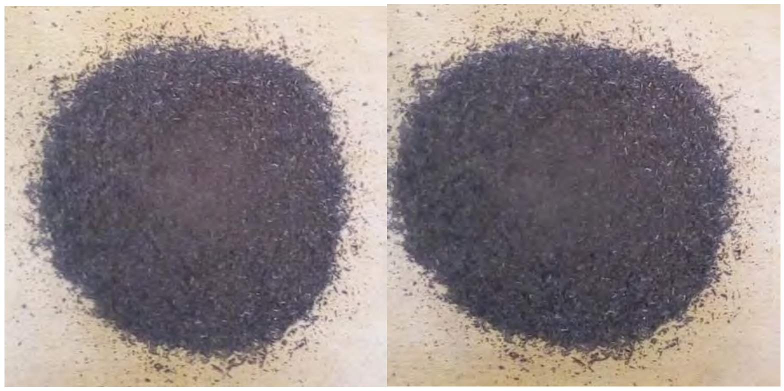

Figure 2.5 steel particles

2.8.2 Uses of Steel Particles

- Slag: Slag has several important functions in the production processes for iron and steel. Just over one and half of the residual products and metallurgical slags; with blast furnace slag being the largest item.
- Mill scale: Mill scale is the thin oxide coating formed when hot steel comes in contact with air and then flakes off during working of the steel. Mill scale consists of oxides of iron, but also the metal alloys that are included in the steel of which the mill scale is formed. Chemically, the mill scale can be compared with iron ore and can be used in similar applications, such as a raw material on production of pig iron, ferrous alloy and cement.
- Metal hydroxide sludge: The recycling of the metals from metals hydroxide sludge which is formed during pickling of stainless steel has engaged the interest of many researchers and companies. To find a good method has been shown to be difficult, despite the fact that the metal such as chromium and nickel have significant values.
- Shavings and fillings: These are obtained as a residual product on surface grinding of steel in order to remove surface defects.

2.9 Observation from the literature review

From the literature reviewed, it could be observed that numerous studies have been published to predict the compressive, flexural, and tensile strengths behavior of reinforced concrete members with different reinforcement materials such as steel fibers, natural fibers and synthetic fibers. Nevertheless, no studies have been done on steel particles as a reinforcement material for concrete elements. It is this fore- knowledge which serves as the strongest motivation for the current researcher to investigate the compressive, flexural and tensile strengths of concrete cubes and beams with steel particles.

CHAPTER THREE

3.0 EXPERIMENTAL STUDIES

This chapter reports on the experimental methods and procedures used in obtaining the objectives of the study. It also comprises experimental materials used in the various testing specimen for compressive, flexural, split tensile and water absorption resistance tests.

3.1 Materials

3.1.1 Cement

Ordinary Portland Cement of grade 32.5R from GHACEM which satisfies cement requirement BS 12: 1996 was used.

3.1.2 Water

Drinkable water from Ghana Water Company was used.

3.1.3 Aggregate

Granite of maximum size 12mm was used as coarse aggregate. Sand of maximum size of 2mm was used as fine aggregate.

3.1.4 Steel Particles

The steel particles used for the production of reinforced concrete specimen were obtained from steel shops at Cape-Coast Metropolis in the Central Region. The particles were from mild steel with particle size of 20um.

3.1.5 Moulds

A cube mould of size 150mm x 150mm x 150mm, beam mould of size 150mm x 750mm x 150mm and cylindrical mould of diameter 150mm and height of 300mm were used for casting of the specimens.

3.2 Experimental methods and procedure

3.2.1 Preliminary Test

A target strength of 25N/mm^{2}was predetermined. Based on that trial mixes were conducted to ascertain the targeted strength. The result of the preliminary test indicated that a mix ratio of 1:2:4/0.5 (cement: sand: stone)/w/c gave the targeted strength of 25 N/mm^2.

Details of the weight of component materials used for each specimen based on the results of the preliminary test are shown in Tables 3.1, 3.2, 3.3 and 3.4 below.

Table 3.1: Mix proportion of materials for compressive strength test specimen

Specimen	Water	Cement	Fine aggregate	Coarse aggregate	Steel particles composition	
	(g)	(g)	(g)	(g)	(g)	(%) out of concrete mix
A	3716	7431	14862	29724	0	0
B5	3716	7431	14862	29724	2601	5
B10	3716	7431	14862	29724	5202	10
B15	3716	7431	14862	29724	7803	15
B20	3716	7431	14862	29724	10403	20
B25	3716	7431	14862	29724	13004	25
	22296	44586	89172	178344	28610	

A- Control specimen, that is specimen without steel particles

B- Specimen with percentages of steel particles.

Table 3.2:Mix proportion of materials for flexural strength test specimen

Specimen	Water	Cement	Fine aggregate	Coarse aggregate	Steel particles composition	
	(g)	(g)	(g)	(g)	(g)	(%)out of concrete mix
A	18599	37199	74399	148799	0	0
B5	18599	37199	74399	148799	13020	5
B10	18599	37199	74399	148799	26040	10
B15	18599	37199	74399	148799	39060	15
B20	18599	37199	74399	148799	52080	20
B25	18599	37199	74399	148799	65100	25
	111594	223194	446394	892794	195300	

A- Control specimen, that is specimen without steel particles

B- Specimen with percentages of steel particles

Table 3.3: Mix proportion of materials for tensile split test specimen

Specimen	Water	Cement	Fine aggregate	Coarse aggregate	Steel particles composition	
	(g)	(g)	(g)	(g)	(g)	(%) out of concrete mix
A	5839	11678	23357	46714	0	0
B5	5839	11678	23357	46714	4087	5
B10	5839	11678	23357	46714	8175	10
B15	5839	11678	23357	46714	12262	15
B20	5839	11678	23357	46714	16349	20
B25	5839	11678	23357	46714	20437	25
	35034	70068	140142	280284	61310	

A- Control specimen, that is specimen without steel particles

B- Specimen with percentages of steel particles

Table 3.4:Mix proportion of materials for water absorption test specimen

Specimen	Water	Cement	Fine aggregate	Coarse aggregate	Steel particles composition	
	(g)	(g)	(g)	(g)	(g)	(%) out of concrete mix
A	3716	7431	14862	29724	0	0
B5	3716	7431	14862	29724	2601	5
B10	3716	7431	14862	29724	5202	10
B15	3716	7431	14862	29724	7803	15
B20	3716	7431	14862	29724	10403	20
B25	3716	7431	14862	29724	13004	25
	22296	44586	89172	178344	28610	

A- Control specimen, that is specimen without steel particles

B- Specimen with percentages of steel particles

3.2.2 Mixing of Concrete

A basic mix of 1:2:4 (cement: fine aggregate: coarse aggregate) with water/cement ratio of 0.5 was used to prepare all the specimens without particles. The cement and fine aggregates were mixed dry until thoroughly blended homogenous grey colour was achieved. Coarse aggregates were later added and the entire batch was mixed until a homogenous mix was obtained. About eighty percent (80%) of water was then added and the mixture were mixed thoroughly. The remaining percentage of water was finally added into the mixture and mixed for further 2 minutes in a concrete mixer. The same procedure was repeated for specimens with particles, except that the particles were gradually dispersed in the cement/sand mix, before the coarse aggregates were added.

In all, six batches were mixed. The control specimen was denoted as A while specimens with certain levels of steel particles were denoted Bi with i as percentage of steel particles (i %). The percentages of steel particles were 5, 10, 15, 20 and 25 by weight of cement.

3.2.3 Casting

One-third of the moulds were filled with concrete and compacted on compaction table. Another one-third was added again and compacted for 30 seconds. The moulds were finally filled with concrete and compacted further. Ten (10) cubes, five (5) each for compression test and water absorption test were cast for each batch. Five (5) beams for flexural strength test were cast for the batch. Five (5) cylindrical beams were also cast for split tensile strength test.

In all a total of sixty (60) cubes and sixty (60) beams were cast for the experiment.

3.2.4 Curing

The concrete cubes, concrete beams and concrete cylinders were demoulded after twenty-four hours and immersed in water and left for seven (7) and twenty-eight (28) days before testing.

3.2.5 Testing of Specimen

The main apparatus for testing the cubes, concrete beams and concrete cylinders were the dual compressive strength machine, flexural strength and split tensile strength machines. At the end of each curing period, the concrete cubes and beam specimens were first removed from water, cleaned and weighed using an electronic balance.

3.2.5.1 Test Methods

a. Compressive Strength Test

The compressive strength was determined by using compressive strength test machine. The cube samples were first placed in the compressive strength machine; and the machine was activated to incrementally apply compressive load to the concrete cubes until failure occurred.

Figure 3.1. Before crushing cubes **figure 3.2. After crushing of cubes**

b. Flexural Strength Test

The flexural strength test of the beam specimens were conducted on flexural chamber of the dual machines. The beam specimens were placed in the flexural dual machines. A centrally placed point load was applied to the specimens by turning the gear, until the beams failed under bending. The flexural strength of the beams was tested at ages 7 and 28 days. The average of five specimens was recorded for each testing age.

Figure 3.3 Before flexure of prism **Figure 3.4 After flexure of prism**

c. **Split Tensile Strength Test.**

The determination of the split tensile strength was done by conducting the splitting tensile test on the cylindrical specimens. The concrete specimen were placed horizontally between plates of the testing machine until the specimen split into two. In order to support the testing specimens, narrow strips of plywood were used to interpose between the specimens and the plates. The strips were usually a 3mm thick and a 25mm width.

Figure 3.5Before splitting of cylinder **Figure 3.6 After splitting of cylinder**

d. Water Absorption

Water absorption tests were conducted on the control concrete specimens and the concrete modified with the steel particles. In the test procedure, the specimens were fully immersed in the water tank for 7 and 28 days, and then they were taken out. Their faces were dried with a cloth and their weight were measured. Next, the specimens were dried in an oven at (100^0C – 110^0C) for 48 hours and then their masses were measured again. The percentage of water absorption was calculated from the following equation: Water absorption (%)= $(W_2-W_1)/W_1 \times 100$, where:W_1= average weight of dry sample (g) and W_2= average weight of the wet sample (g).

Figure 3.7 Cubes in the oven

In both operations, the crushing strength of the concrete specimens were studied, analyzed, compared and discussed. The raw data are in the appendix for cross reference.

CHAPTER FOUR

4.0 RESULTS

This chapter presents the test results on compressive, flexural, split tensile strengths and water absorption resistance obtained from the experimental studies.

4.1 Compressive Strength

The compressive strength of concrete is the most important property of the concrete that is considered in the structural designs. To know the strength development of concrete dosed with steel particles in comparison to concrete without steel particles, compressive strength tests were conducted on samples of each type of concrete at the ages of 7 and 28 days as detailed in appendix V and VI.

Table 4.1: 7 and 28 days compressive strength of concrete

Nano Particle		7 Days		28 Days	
Content (%)	N	Mean	StdDev	Mean	StdDev
0 (Control)	5	20.23	2.12397	25.28	2.65455
5	5	20.40	2.50366	25.61	3.19975
10	5	21.64	1.14539	27.05	1.42984
15	5	20.01	3.05653	25.01	3.82233
20	5	14.68	0.25165	15.85	0.31300
25	5	13.37	0.05983	14.21	0.07483

Table 4.2: ANOVA test results of compressive strength

		Sum of Squares	df	Mean Square	F	Sig.
Strength	Between Groups	1025.357	5	205.071	22.429	.000
	Within Groups	493.727	54	9.143		
	Total	1519.084	59			

The 7 days compressive strength in Table 4.1 recorded a mean strength of 20.23 N/mm^2 for 0% and 21.64 N/mm^2 when 10% of steel particles where added. At replacement of 15% and beyond specimens performed poorer than the control specimen. Also, the 28 days compressive strength recorded 25. 28 N/mm^2, 25.61N/mm^2, 27.05 N/mm2and 25.01 N/mm^2 which met the target strength of 25N/mm^2 for 0% to 15% of particles.

Addition of 20% to 25% steel particles resulted in poorer performance than the control specimens. The 10% replacement gave the highest compressive strength about 7% higher than the control. It could be seen that up to 10% replacement compressive strength increase with an increase in particles content. However, the compressive strength started decreasing with an increase in particles content. It was also observed that the compressive strength increase with an increased in the curing age, for all the levels

The ANOVA test results at 95% confidence interval in Table 4.2 indicate that the differences in the values among the different placement content are significant. There is therefore a statistically significant difference among the replacement content of concrete (F= 22.429; P= 0.000) in compressive strength.

4.2 Flexural Strength

The results of the flexural strength of the control concrete beams and the concrete beams modified by various percentages (5%, 10%, 15%, 20% and 25%) of steel particles at the curing days of 7 and 28 days are illustrated in Tables 4.3 and detailed in appendix VII and VIII

Table 4.3: 7 and 28 days flexural strength test results of beams

Nano Particle Content (%)	N	7 Days Mean	7 Days StdDev	28 Days Mean	28 Days StdDev
0 (Control)	5	1.02	0.22810	1.30	0.28606
5	5	1.05	0.18097	1.31	0.22742
10	5	1.22	0.01871	1.53	0.02302
15	5	0.74	0.15659	0.94	0.15849
20	5	0.66	0.02302	0.82	0.02739
25	5	0.54	0.34492	0.67	0.42991

Table 4.4: ANOVA test results of flexural strength.

		Sum of Squares	df	Mean Square	F	Sig.
strength	Between Groups	259.273	5	51.855	.952	.455
	Within Groups	2940.156	54	54.447		
	Total	3199.429	59			

The 7days flexural strength in Table 4.3 recorded a mean strength of 1.02 N/mm^2 for the control specimen. This increased to 1.22 N/mm^2 when 10% of particles was added. The 28days average flexural strength for the various steel particles recorded the highest value of 1.53 N/mm^2 when 10% was added to specimen as in Table 4.3. The specimen with particles higher than 10%

experienced reduction in flexural strength. The trend for that of the flexural strengths also increased with curing age.

The ANOVA test results in Table 4.4 prove that, the differences in the values among the different placement content are insignificant. This means that, there is no statistically significant difference (F= 0.952; P= 0.455) in flexural strength among the different placement content.

4.3 Split Tensile strength

The results of split tensile concrete beams without steel particles and concrete beams with various percentages (5%, 10%, 15%, 20% and 25%) of steel particles at the curing days of 7 and 28 days are presented in Table 4.5 and detailed in appendix IX and X

Table 4.5: 7 and 28 days Split tensile strength test results of beams

Nano Particle		7 Days		28 Days	
Content (%)	**N**	**Mean**	**StdDev**	**Mean**	**StdDev**
0 (Control)	5	0.82	0.40342	1.25	0.03507
5	5	1.05	0.03435	1.32	0.04301
10	5	1.37	0.34677	1.51	0.01924
15	5	1.38	0.05225	1.73	0.06325
20	5	1.15	0.03033	1.44	0.03808
25	5	1.00	0.06181	1.23	0.05683

Table 4.6: ANOVA test results of split tensile strength

		Sum of Squares	df	Mean Square	F	Sig.
Strength	Between Groups	1.443	5	.289	11.625	.000
	Within Groups	1.341	54	.025		
	Total	2.784	59			

The 7 days split tensile strength in Table 4.5 recorded a mean strength of 0.82N/mm^2, 1.05N/mm^2, 1.37N/mm^2, 1.38N/mm^2, 1.15 N/mm^2, and 1.00 N/mm^2 for 0%, 5, 10%, 15%, 20% and 25% accordingly.

The 28 days average split tensile strength for the various steel particles recorded values of 1.25N/mm^2 for 0%, 1.32N/mm^2 for 5%, 1.51N/mm^2 for 10%, 1.73 N/mm^2 for 15%, 1.44% for 20% and 1.23N/mm^2 for 25%. Per the results obtained the split tensile strength of the beams follows the same pattern of both compressive strength test and flexural strength test. The results indicate that the average split tensile strength with 15% recorded the highest 28days split tensile strength of 1.73N/mm^2 and started dwindling from 20% to 25% with their split tensile strength of 1.44N/mm^2 and 1.23N/mm^2 respectively.

An ANOVA test result at 95% confidence interval indicates that the differences in the values among the different placement content are significant. There is therefore statistically significant difference (F= 11.625; P= 0.000) in the split tensile strength among the different placement content.

4.4 Water Absorption

The water absorption test was conducted in order to study the effect of mixing steels particles with the concrete mixtures and compare them to concrete mixtures without steels particles. Water absorption tests were conducted on samples of each type of concrete at the ages of 7 and 28 days as detailed in appendix XI and XII

Table 4.7: 7 and 28days water absorption test results of cubes

		WA=$\frac{(W2-W1)}{W1} \times 100\%$	
Nano Particles content (%)		7days	28days
	N	Mean	Mean
0 (Control)	5	6.89	6.89
5	5	6.91	6.91
10	5	6.94	6.94
15	5	7.14	7.14
20	5	9.10	9.10
25	5	11.83	11.83

The 7 days water absorption resistance in Table 4.7 recorded a mean level of 6.89% for 0% particles. The mean level increased from 6.91% to 11.83% when 15% to 25% particles were added. The 28 days water absorption values in Table 4.7 also recorded the same values as 7 days. This shows that as the particles increased the water absorption values also increased.

CHAPTER FIVE

5.0 DISCUSSIONS

This chapter talks about the discussions of the results on compressive, flexural, split tensile and water absorption resistance obtained from the experimental studies.

5.1 Compressive Strength

From the findings in Table 4.1, the average compressive strength of concrete with 0% steel particles recorded the 28-days compressive strength of 25.28N/mm^2 for 0.5 water cement ratio. This was followed by the concrete with 5%, 10% and 15% with replacement of steel particles with strength above 25N/mm^2. These results indicate that particles admixture can therefore be used to produce structural concrete such as beams, slabs etc. especially with admixture up to 15%.

Average compressive strength of 15.85N/mm^2 and 14.21N/mm^2 were produced by 20% and 25% particles respectively. Research conducted by Senff et al (2010) stipulated that the addition of nano scale particles improves the performance of concrete: for instance an improvement of rheological properties which has been observed in the fresh cement mixtures. Qing et al (2006) also opined that compressive strength increases in the hardened state. All these researchers agree that particles can be used in place of steel rods and other fibers to produce reinforced concrete which will serve the same purpose as both reinforced and plain concrete.

It can be realized that, from the 0% replacement the initial strength development started increasing from 5% to 10% and started decreasing from 15% to 25% with particles replacement. Though the control specimen fall within the targeted value, the specimen with particles, percentages up to 15% of the strength produced is encouraging and met the standard set.

Beside, using 20% to 25% particles replacement can reduce the cost of reinforcement that is steel rods since the particles are waste residues obtained from construction sites, fitting shops, welders etc. with no cost or little cost which would bring down the cost of housing for the ever increasing population of Ghana, majority of whom cannot afford shelter because of increasing cost of construction materials as cost analysis detailed can be seen in appendix XIII.

This means 20% to 25% particles can be used for element of less structural importance such as lintel, aprons, drainage systems and blinding.

This stipulated that the compressive strength decreases with increasing amount of particles in the concrete and the more particles in the concrete, the lesser the relative strength. Nevertheless, with this, study has proved that particles up to 15% could be applied for reinforce concrete production for construction purposes. The findings also reveals that the compressive strength of the test cubes increases with strength as curing time increases. The results also indicate a pattern of strength development with ages from 7 days to 28 days after casting for both concrete without particles and particles replacement.

This assertion are in line with Sobolev et al (2009) which reported that nano-modified mixtures which can reduce the initial strength with the curing age.

This denotes that the addition of particles did not retard the development rate of the concrete strength. The 10% particles were enough to bond the concrete hence increasing compressive strength. Beyond 10% the excess made compaction difficult hence reduction in compressive strength.

The ANOVA test results at 95% confidence interval in Table 4.2 indicate that the differences in the values among the different placement content are significant. There is therefore a statistically significant difference among the replacement content of concrete (F= 22.429; P= 0.000) in compressive strength.

5.2 Flexural Strength

From the findings in Table 4.3, the average flexural strength with 10% was the highest at 28days being 1.53N/mm^2, and started decreasing for replacement levels of 15%, 20% and 25% to 0.94N/mm^2, 0.82N/mm^2 and 0.67N/mm^2 respectively. This shows that as the particles percentage increases, the flexural strength decreased. This result goes with the investigation by Perssons and Karendahl (1980) who states categorically that steel fibres and reinforcements bars are known to increase the flexural strength of concrete beams, slab lintels and columns where both flexural and impact strength are important. A study by Fiber Mesh Company (1989) also fellows with the same assertion, which opines that, the impact resistance of both plain and reinforced concrete contain steel fiber mesh and reinforcement bars also reveals remarkable increase in energy absorption of the latter.

Based on the results obtained, concrete with particles up to 10% achieved average flexural strength of 1.53N/mm^2 at curing age of 28 days can be used for reinforced concrete for light beams, lintels, slabs etc.

It can be found out that, flexural strength rises up to 10% and started decreasing from 15% to 25%. From Table 4.3, its clearly seen that 10% with flexural strength of 1.53N/mm^2 of 28days recorded the highest flexural strength. This also shows that 10% particle were enough to bond the concrete hence increasing flexural strength. Beyond 10% the excess made compaction difficult hence reduction in flexural strength.

The ANOVA test result in Table 4.4 proves that, the differences in the values among the different placement content are insignificant. This means that, there is no statistically significant difference (F= 0.952; P= 0.455) in flexural strength among the different placement content. This level of insignificants from ANOVA means that steel particles has no positive effect on flexural strength.

5.3 Split Tensile strength

From Table 4.5, the split tensile strength increased to a maximum as the steel particles increased from 0% to 15%. Thereafter the split tensile strength deceased with increase in the percentage of particles. This finding agreed with the findings by Perssons and Karendahl(1980) which stated clearly that steel fibres and reinforcement bars are known to increase tensile strength of concrete beams, slabs, lintels and columns where both tensile and impact are important. Fiber Mesh Company (1989) investigation also follows the same assertion of the impact resistance of both plain and reinforced concrete which contain steel fiber mesh and reinforcement bars also reveals remarkable increase in energy absorption. Table 4.5 shows the 7 days and 28days split tensile strength development of the concrete beams specimens. It can be found out that from 0% split tensile strength rises up to 15% and started dwindling from 20% to 25% respectively. From Table 4.5, its indicate clearly that 15% with split tensile strength of 1.73N/mm^2 of 28 days curing age recorded the highest split tensile strength. The split tensile strength also followed the same trend as the compressive and flexural strengths but changes from 10% to 15%. The 15% particles were enough to bond the concrete hence increasing split tensile strength. Beyond 15% the excess made compaction difficult hence reduction in tensile strength.

An ANOVA test result at 95% confidence interval indicates that the differences in the values among the different placement content are significant. There is therefore statistically significant difference (F= 11.625; P= 0.000) in the split tensile strength among the different placement content.

5.4 Water Absorption

From the results, water absorptions for the 0%, 5%, 10%, 15%, 20% and 25% for 7 days curing age were 6.89%, 6.91%, 6.94%, 7.14%, 9.10% and 11.83% respectively. The results were the same for 28days curing age. The results also show that as the particles percentages increase the water absorption values also increases as can be seen in Table 4.7. This follows the assertion of Gambhir, (1992) which explained that minimum water cement ratio required is 0.3 but water quantity in this mix proportion will be very harsh and difficult to place. He also added that water is required to lubricate the mix which make the concrete workable but too much water also reduces the strength of the concrete. This shows that 0.5 water ratio used for the mixture was quite good which has yielded recommendable uniform results for the tests.

Table 4.7 shows clearly that, as the percentage of particles of steel increases, the water absorption also increases. This shows that, water absorption for the study is uniform for both 7days curing age and 28 days curing age.

This denotes that the more particles percentages, the higher the absorption rate or level. This is due to difficulties in compaction.

The water absorption rate or level of the concrete cubes increases as the particles percentage increases for both 7days and 28 days. The water absorption rate for 7 and 28 days were the same because at the end of the 7 days, the pores were sealed hence the same absorption level. This stipulates that, the absorption rate increases with increasing amount of particles in the concrete and therefore the more particles in the concrete, the more the absorption rate of the concrete.

CHAPTER SIX

6.0 Summary of Findings, Conclusions and Recommendations

6.1 Summary of Findings

The uses of steel particles as a replacement of reinforcement bars in concrete have been extensively researched into in this study. It can be found that the compressive strength started increasing from 5% to 10% and decreased from 15% to 25% with particles. It can also be seen that flexural strengths rises up to 10% and started decreasing from 15% to 25%. The results also indicate clearly that 15% with split tensile strength of 1.73N/mm^2 of 28 days curing age recorded the highest split tensile strength. The water absorption level of the concrete cubes increases as the particles percentages increases for both 7 and 28 days. As in many other similar studies, the findings have been positive, indicating that it is possible to use steel particles as a replacement of reinforcement materials to produce concrete for construction activities in Ghana.

6.2 Conclusions

From the various tests conducted and analysis presented, the following conclusions were drawn:

- Steel particles of up to 15% produce concrete with compressive strength results above 25N/mm^2. This implies that steel particles replacements of up to 15% can be used to produce structural concrete based on standard target strength set.
- Also, steel particles replacement of up to 25% produces concrete with compressive results of approximately 15N/mm^2. This means that steel particles replacements of up to 25% can be used to produce medium grade concrete for non-structural works such as drainage systems, aprons and blindings.

- The compressive strength of the concrete decreases as the percentage replacement of steel particles increases i.e. From 20% to 25%, however, steel particles of 20% produces concrete of optimum strength and most economic grade for construction purposes.
- Flexural strength of steel particles up to 10% produces concrete with flexural strength of 1.53N/mm^2. This shows that steel particles replacement of up to 10% can be used for reinforced and plain concrete for short span beams, lintels, columns and slabs based on results achieved.
- The steel particles up to 15% also produces concrete with split tensile strength results of 1.73N/mm^2. This indicates that steel particles replacement up to 15% can be used to produce structural concrete.
- From the observations, it can be seen that as the steel particles increases, the water absorption values also increases.
- Indiscriminate dumping of steel particles in landfills will be minimized since people will know the benefit of the steel particles and also reduce the environmental pollution.

6.3 Recommendations

Based on the conclusions drawn above, the following recommendations were proposed:

- Steel particles replacements up to 15% can be used to produce structural concrete with compressive strength of 25N/mm^2
- Steel nanoparticle replacements up to 10% can be used for reinforced concrete with flexural strength of 1.53N/mm^2
- Particles percentages up to 15% can also be used to produce structural concrete with split tensile strength of 1.73N/mm^2
- Water cement ratio of 0.5 was good and can be used for the production of structural concrete with steel particles.
- Steel particles production must be undertaken on large grade to make it available on the market as a supplement for reinforcement bars.
- Based on the findings, steel particles should not be used as a replacement in high percentage for reinforcement bars if there is the need for high compressive and flexural strengths reinforcement bars. Reinforcement bars must still be used when higher compressive and flexural strengths are required.
- Curriculum planners will need this information to review the curriculum so as to help students to be introduced to this new knowledge and technology in Ghanaian Educational system.
- Educational seminars, in-service training and advertisement need to be organized by Ministry of Local Government and Rural Development and Ministry of Works and Housing to create awareness on the benefits of steel particles to the whole nation to

minimize the indiscriminate dumping of steel particles into the environment which is causing environmental pollution that might cause serious human health problems in future.

- Property test such as rusting, corrosion, resistance to sulphate attach etc. on the steel particles should be further investigated.
- Other levels (12% and 14%) of replacement with steel particles should be researched.

6.4. Recommendations for further study.

- Further studies should be conducted to find out the shear strength performance of concrete with steel particles.
- Curing ages of 14 and 21-days should also be performed to know the effects of 14 and 21-days strength performance of concrete with steel particles.

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APPENDICES

APPENDIX I

3.1Computation of weight of constituent materials of concrete for compressive strength.

Volume of concrete cube mould = L×B×H

=0.15× 0.15 × 0.15

=0.003375 m^3

Sample of cubes (6) =6× 0.003375

=0.02025 m^3

Density of concrete = 24 KN/m^3

Mass of concrete = Density × $Volume$

=24KN/m^3× 0.02025m^3

=0.486

$=\frac{0.486}{9.81} \times 1000$

=49.54 kg

=49540g

Add 5% waste and compaction $=\frac{105}{100} \times 49540$

Total mass required = 52017 g

Ratio of concrete mix = 1:2:4

Cement $=\frac{1}{7} \times 520\ 17$

=7431g

Sand $=\frac{2}{7} \times 52017$

= 14862 g

Stone $= \frac{4}{7} \times 52017$

=29724g

Water/ cement ratio = 0.5×7431

=3716 g

Percentages of steel particles:

5% $= \frac{5}{100} \times 52017$

=2601 g

10% $= \frac{10}{100} \times 52017$

=5202g

15% $= \frac{15}{100} \times 52017$

=7803g

20% $= \frac{20}{100} \times 52017$

=104034g

25% $= \frac{25}{100} \times 52017$

=13004g

APPENDIX II

3.2Computation of Weight of constituent materials of concrete for flexural strength.

Volume of concrete rectangular mould = L$\times b \times h$

= $0.15 \times 0.75 \times 0.15$

= 0.016875 m^3

No of sample specimen (6) = $6 \times 0.016875m^3$

=0.10125m^3

Density of concrete =24 KN/ m^3

Mass of concrete = Density × Volume

=24 KN/m^3× 0.10125 m^3

=2.43

=$\frac{2.43}{9.81} \times 1000$

=248 kg

=248000g

Add 5% of waste and compaction = $\frac{105}{100} \times 248000$

Total mass required =260400g

Ratio of concrete mix = 1:2:4

Cement = $\frac{1}{7} \times 260400$

=37199g

Sand =$\frac{2}{7} \times 260400$

=74399g

Stone $= \frac{4}{7} \times 260400$

=148799g

Water/ cement ratio = 0.5× 37199

=18599g

Percentages of steel particles

5% $= \frac{5}{100} \times 260400$

=13020g

10% $= \frac{10}{100} \times 260400$

=26040g

15% $= \frac{15}{100} \times 260400g$

= 39060g

20% $= \frac{20}{100} \times 260400g$

= 52080g

25% $= \frac{25}{100} \times 260\ 400g$

=65100g

APPENDIX III

3.3 Computation of weight of constituent materials of concrete for split tensile strength

Volume of concrete cylindrical mould = $\pi r^2 h$

$= \pi 75^2 h$

$= \frac{22}{7} \times 0.075^2 \times 0.3$

$= 3.143 \times 0.075^2 \times 0.3$

$= 0.005304\ m^3$

No of sample specimen (6) $= 6 \times 0.005304$

$= 0.031824\ m^3$

Density of concrete $= 24\ KN/m^3$

Mass of concrete $=$ Density $\times$ $Volume$

$= 24 KN/m^3 \times 0.031824$

$= 0.763776$

$= \frac{0.763776}{9.81} \times 1000$

$= 77.857 kg$

$= 77857 g$

Add 5% waste and compaction $= \frac{105}{100} \times 77857$

Total mass required $= 81749 g$

Ratio of concrete mix =1:2:4

Cement $=\frac{1}{7}\times 81749$

=11678g

Sand $=\frac{2}{7}\times 81749$

=23357g

Stone $=\frac{4}{7}\times 81749$

=46714g

Water/cement ratio =0.5 ×11678

=5839g

Percentages of steel particles:

5% $=\frac{5}{100}\times 81749$

=4087g

10% $=\frac{10}{100}\times 81749$

=8175g

15% $=\frac{15}{100}\times 81749$

=12262g

20% $=\frac{20}{100}\times 81749$

=16349g

25% $=\frac{25}{100}\times 81749$

=20437g

APPENDIX IV

3.4 Computation of weight of constituent materials of concrete for water absorption.

Volume of concrete cube mould = L×B ×H

=0.15× 0.15 × 0.15

=0.003375 m^3

Sample of cubes (6) =6× 0.003375

=0.02025 m^3

Density of concrete = 24 KN/m^3

Mass of concrete = Density × $Volume$

=24KN/m^3× 0.02025m^3

=0.486

$=\frac{0.486}{9.81} \times 1000$

=49.54 kg

=49540g

Add 5% waste and compaction $=\frac{105}{100} \times 49540$

Total mass required = 52017 g

Ratio of concrete mix = 1:2:4

Cement $=\frac{1}{7} \times 520\ 17$

=7431g

Sand $= \frac{2}{7} \times 52017$

$= 14862$ g

Stone $= \frac{4}{7} \times 52017$

=29724g

Water/ cement ratio $= 0.5 \times 7431$

=3716 g

Percentages of steel particles:

5% $= \frac{5}{100} \times 52017$

=2601 g

10% $= \frac{10}{100} \times 52017$

=5202g

15% $= \frac{15}{100} \times 52017$

=7803g

20% $= \frac{20}{100} \times 52017$

=10403g

25% $= \frac{25}{100} \times 52017$

=13004g

APPENDIX V

Table 4.1 The 7 days compressive strength test research of cubes

Steel nano particles %	A	B5	B10	B15	B20	B25
Date casted	28/06/18	28/06/18	28/06/18	28/6/18	28/06/18	28/6/18
Date tested	05/07/18	05/07/18	5/7/18	5/7/18	5/7/18	5/7/18
Age in days	7	7	7	7	7	7
Dimension	150× 150 × 150	150× 150 × 150	150× 150 × 150	150× 150 × 150	150× 150 × 150	150× 150 × 150
Weight (g)	5896 5888	6544 6962	6438 6614	6648 6748	6336 6127	6074 6343
	6087 5971	6242 6932	6389 6539	6519 6626	5893 6126	6118 6267
	6037	6246	6422	6653	6114	6093
Av. Weight (g)	5975.84	6585.28	6480.00	6638.72	6119.20	6179.04
Av. Density (kg/m^3)	2951.03	3251.99	3200.00	3278.38	3021.82	3051.37
Crushed load (KN)	383.2 257.76	265.230216	473.92 352.24	391.76 383.52	97.36 106.64	77.36 75.28
	283.28 302.56	493.76 352.16	470.08 399.60	250.48 341.12	112.80 108.96	74.64 75.36
	313.76	354.08	467.68	344.6	104.24	76.08
Av. crushed load (KN)	308.1	354.08	432.08	342.24	106.00	75.76
Comp. strength	19.46 17.03	19.78 21.42	21.06 20.90	17.42 17.05	14.3314.74	13.44 13.34
(N/mm^2)	20.59 22.59	21.94 16.38	23.66 21.16	19.14 23.71	15.02 14.59	13.32 13.42
	21.46	22.91	21.41	22.74	14.74	13.31
Av. Comp. strength (N/mm^2)	20.23	20.49	21.64	20.01	14.68	13.37

APPENDIX VI

Table 4.2 The 28 days compressive strength test results of cubes

Steel nano particles %	A	B5	B10	B15	B20	B25
Date casted	28/06/18	28/06/18	28/06/18	28/6/18	28/06/18	28/6/18
Date tested	26/7/18	26/7/18	26/7/18	28/7/18	28/7/18	28/7/18
Age in days	28	28	28	28	28	28
Dimension	150× 150 × 150	150× 150 × 150	150× 150 × 150	150× 150 × 150	150× 150 × 150	150× 150 × 150
Weight (g)	7370 7360	8181 8702	8048 8268	8310 8435	7920 7659	7592 7929
	7609 7464	7803 8665	7986 8174	8149 8282	7366 7658	7648 7834
	7546	7808	8028	8316	7642	7616
Av. Weight (g)	7469.80	8231.60	8100.00	8298.4	7649.00	7723.80
Av. Density (kg/m^3	3688.79	4064.98	4000.00	4097.97	3777.28	3814.22
Crushed load (KN)	479.0 322.2	331.5 377.7	592.4 587.6	489.7 479.4	121.7 133.3	96.7 94.1
	354.1 378.2	617.2 440.2	440.03 584.6	313.1 430.2	141.0 136.2	93.3 94.2
	392.2	442.6	499.5	426.4	130.3	95.1
Av. crushed load (KN)	385.1	442.6	540.1	427.8	132.5	94.7
Comp. strength (N/mm^2)	24.32 21.29	24.73 26.78	26.33 26.12	21.77 21.31	15.41 15.92	14.30 14.18
	25.74 28.24	27.43 20.48	29.57 26.45	23.92 29.64	16.27 15.74	14.15 14.28
	26.82	28.64	26.76	28.42	15.92	14.14
Av. Comp. strength (N/mm^2)	25.28	25.6	27.05	25.01	15.85	14.21

APPENEIX VII

Table 4.3: The 7 days flexural strength test results of beams

Steel nano particles %	A	B5	B10	B15	B20	B25
Date casted	5/07/18	5/07/18	5/07/18	5/7/18	5/07/18	5/7/18
Date tested	12/07/18	12/07/18	12/7/18	12/7/18	12/7/18	12/7/18
Age in days	7	7	7	7	7	7
Dimension	150× 750 × 150	150× 750 × 150	150× 750 × 150	150× 750 × 150	150× 750 × 150	150× 750 × 150
Weight (g)	30541 30484	32461 32077	32759 32209	30895 30897	31493 31573	32702 32675
	30546 30511	32418 32058	32119 32684	30814 30834	31157 31085	32627 32642
	30483	32333	32650	30835	31317	32677
Av. Weight (g)	30512.96	32269.12	32484.32	30855.04	31324.80	32664.64
Av. Density (kg/m^3	3013.62	3187.07	3208.32	3047.41	3093.80	3226.13
Crushed load (KN)	3.46 6.89	6.34 41.44	4.21 2.74	2.94 4.41	3.30 3.27	4.62 0.86
	5.10 5.16	6.27 4.37	4.19 2.71	2.92 4.42	3.26 3.31	2.50 2.45
	5.30	5.07	3.53	3.68	3.37	2.94
Av. crushed load (KN)	5.14	5.24	3.47	3.67	3.30	2.67
flex. strength (N/mm^2)	0.70 1.34	1.26 0.83	1.22 1.22	0.58 0.88	0.66 0.66	0.92 0.17
	1.02 1.07	0.90 1.17	1.23 1.24	0.66 0.83	0.69 0.64	0.77 0.65
	0.99	1.09	1.19	0.82	0.63	0.18
Av. flex. strength (N/mm^2)	1.02	1.05	1.22	0.75	0.66	0.54

APPENDIX VIII

Table 4.4: The 28 days flexural strength test results of beams

Steel nano particles %	A	B5	B10	B15	B20	B25
Date casted	5/7/18	5/7/18	5/7/18	5/7/18	5/7/18	5/7/18
Date casted	2/8/18	2/8/18	2/8/18	2/8/18	2/8/18	2/8/18
Age in days	28	28	28	28	28	28
Dimension	150× 750 × 150	150× 750 × 150	150× 750 × 150	150× 750 × 150	150× 750 × 150	150× 750 × 150
Weight (g)	38176 38105	40576 40522	40949 40149	38619 38518	39366 38946	40878 40 784
	38182 38139	40096 40416	40262 40812	38621 38544	39146 39466	40846 40844
	38104	40072	40855	38542	38856	40802
Av. Weight (g)	38141.2	40336.4	40605.4	38568.8	39156.0	40830.8
Av. Density (kg/m^3	3767.03	3983.84	4010.40	3809.26	3867.25	4032.67
Crashed load (KN)	4.33 8.36	7.92 5.18	5.26 3.42	3.67 5.51	4.13 4.09	5.77 1.08
	6.38 6.45	7.84 5.46	5.24 3.39	3.65 5.53	4.08 4.14	3.12 3.06
	6.63	6.34	4.41	4.60	4.21	3.68
Av. crushed load (KN)	6.43	6.55	4.34	4.59	4.13	3.33
Flex. strength (N/mm^2)	0.87 1.67	1.58 1.04	1.53 1.52	0.73 1.10	0.83 0.82	1.15 0.21
	1.28 1.34	1.12 1.46	1.54 1.55	0.82 1.04	0.86 0.80	0.96 0.81
	1.24	1.36	1.49	1.02	0.79	0.23
Av. flex. strength (N/mm^2)	1.28	1.31	1.53	0.94	0.82	0.67

APPENDIX IX

Table 4.5: The 7 days split tensile strength test results of cylindrical beams

Steel nano particles %	A	B5	B10	B15	B20	B25
Date casted	5/7/18	5/7/18	5/7/18	5/7/18	5/7/18	5/7/18
Date tested	12/7/18	12/7/18	12/7/18	12/7/18	12/7/18	12/7/18
Age in days	7	7	7	7	7	7
Dimension	3.143× 150 × 300	3.143× 150 × 300	3.143× 150 × 300	3.143× 150 × 300	3.143× 150 × 300	3.143× 150 × 300
Weight (g)	8983 93784 8999 9314 8979	9695 9637 9694 9688 9639	10186 9965 1009710162 9988	10508 10726 10514 10636 10722	10491 10483 10430 10436 10494	10153 10151 9906 10132 9913
Av. Weight (g)	9131	9670.6	10079.4	10621.3	10466.8	10051.04
Av. Density (kg/m^3	2869.12	3038.76	3167.22	3337.50	3290.25	3158.32
Crushed load (KN)	72.96 68.08 68.96 70.32 72.08	74.96 69.20 74.24 71.44 70.48	84.96 85.36 86.96 85.04 84.24	86.32 87.68 86.88 87.36 87.04	80.48 80.80 80.64 80.88 80.16	45.04 43.76 45.12 44.08 44.88
Av.crushed load (KN)	70.48	72.06	85.31	87.06	80.59	44.58
Split tensile strength (N/mm^2)	1.03 0.96 1.02 0.99 0.10	1.10 1.02 1.08 1.04 1.03	1.20 1.21 1.22 1.23 1.19	1.40 1.33 1.39 1.34 1.46	1.14 1.14 1.16 1.12 1.20	0.92 1.04 0.97 1.008 100
Av. Split tensile. strength (N/mm^2)	1.00	1.06	1.21	1.38	1.15	0.98

APPENDIX X

Table 4.6 The 28 days split tensile strength test results of cylindrical beams

Steel nano particles %	A	B5	B10	B15	B20	B25
Date casted	5/7/18	5/7/18	5/7/18	5/7/18	5/7/18	5/7/18
Date tested	2/8/18	2/8/18	2/8/18	2/8/18	2/8/18	2/8/18
Age in days	28	28	28	28	28	28
Dimension	3.143× 150 × 300	3.143× 150 × 300	3.143× 150 × 300	3.143× 150 × 300	3.143× 150 × 300	3.143× 150 × 300
Weight (g)	11229 11723 11249 11642 11224	12119 12046 12117 12110 12049	12732 12456 12621 12702 12485	13135 13408 13143 13295 13 402	13114 13104 13037 13118 13045	12691 12383 12689 12391 12665
Av. Weight (g)	11413.4	12088.2	12599.2	13276.6	13083.5	12563.8
Av. Density (kg/m^3	3586.40	3798.45	3959.02	4171.88	4112.77	3947.90
Crushed load (KN)	91.2 85.1 86.2 87.9 90.1	93.7 86.5 92.8 89.3 88.1	106.2 106.7 108.7 106.3 105.3	107.9 109.6 108.6 109.2 108.8	100.6 101.0 100.8 101.1 100.2	56.3 54.7 56.4 55.1 56.1
Av. crushed load (KN)	88.10	90.08	106.64	108.82	100.74	55.72
Split tensile strength (N/mm^2)	1.29 1.20 1.27 1.24 1.23	1.38 1.28 1.35 1.30 1.29	1.50 1.51 1.52 1.54 1.49	1.75 1.66 1.74 1.68 1.82	1.42 1.43 1.45 1.40 1.50	1.15 1.30 1.21 1.26 1.25
Av. Split tensile. strength (N/mm^2)	1.25	1.32	1.51	1.73	1.44	1.23

APPENDIX XI

Table 4.7: The 7 days water absorption test result of cubes

Steel nano particles %	A	B5	B10	B15	B20	B25
Date casted	28/6/18	28/6/18	28/6/18	28/6/18	28/6/18	28/6/18
Date tested	5/7/18	5/7/18	5/7/18	5/7/18	5/7/18	5/7/18
Age in days	7	7	7	7	7	7
Dimension	150× 150 × 150	150× 150 × 150	150× 150 × 150	150× 150 × 150	150× 150 × 150	150× 150 × 150
Wet Weight (g)	6264 5998 6142 6142 6120	6853 6451 6314 6592 6547	6789 65 40 6369 6672 6525	6618 6517 6399 6513 6503	6100 6127 6250 6096 6098	6159 6009 6222 6133 6131
Av. Wet weight (g)	6133	6551	6579	6510	6134	6131
Av. Wet density (kg/m^3)	3028.64	3235.06	3248.88	3214.81	3029.13	3027.65
Dry weight (g)	5582 5756 5870 6000 5480	6459 5946 6097 6215 6128	5979 6398 6173 6215 6150	6101 5959 6172 6079 6074	5700 5518 5514 5576 5578	5563 5345 5536 5525 5443
Av. Dry weight (g)	5738	6169	6183	6077	5577	5482
Av. Dry density (kg/m^3)	2833.58	3046.41	3053.33	3000.98	2754.07	2707.16
% $\frac{(w2-w1)}{w1} \times 100$	6.89	6.19	6.40	7.14	9.10	11.83

APPENDIX XII

Table 4.8: The 28 days water absorption test results of cubes

Steel nano particles %	A	B5	B10	B15	B20	B25
Date casted	28/6/18	28/6/18	28/6/18	28/6/18	28/6/18	28/6/18
Date tested	26/7/18	26/7/18	26/7/18	26/7/18	26/7/18	26/7/18
Age in days	28	28	28	28	28	28
Dimension	$150\times 150\times 150$	$150\times 150\times 150$	$150\times 150\times 150$	$150\times 150\times 150$	$150\times 150\times 150$	$150\times 150\times 150$
Wet Weight (g)	7830 7497 7677 7678 7650	8566 8064 7892 8240 8184	8486 8175 7961 8340 8156	8273 8146 7999 8141 8129	7625 7659 7813 7620 7622	7699 7511 7778 7666 7664
Av. Wet weight (g)	7666	8189	8224	8138	7668	7664
Av. Wet density (kg/m^3)	3785.67	4043.95	4061.23	4018.76	3786.66	3784.69
Dry weight (g)	6977 7195 7338 7500 6850	8074 7433 7621 7769 7660	7474 7978 7716 7769 7688	76267449 7715 7599 7592	7125 6897 6892 6970 6972	6954 6681 6920 6906 6804
Av. Dry weight (g)	7172	7711	7729	7596	6971	6853
Av. Dry density (kg/m^3)	3541.72	3807.90	3816.79	3751.11	3442.46	3384.19
% $\frac{(w2-w1)}{w1}\times 100$	6.89	6.19	6.40	7.14	9.10	11.83

APPENDIX XIII

COST ANALYSIS OF STEEL PARTICLES IN 1M³ OF 1:2:4 MIX PROPORTION.

A. Main Bars (R16 Ø)

The number of steel particles in the mixture is approximately 100 R16 Ø.

The equivalent cost savings on 15% replacement of reinforcement bars with steel particles for 1R16 Ø of reinforcement bar is presented below:

One (1) R 16 Ø of reinforcement bar cost GH¢ 40.00

Cost of 15% replacement of reinforcement bar with steel particles in 1R 16 Ø

$$=\frac{0.15}{1} \times 40$$

$$=0.15 \times 40$$

=Gh ¢ 6.00

Therefore 100R 16 Ø **=100**$\times 40$

=GH¢4000.00

If 15% replacement of reinforcement bars with steel particles is done for utilization in low cost housing:

Cost saving on 100 R16 Ø $=\frac{6}{40} \times 4000$

=GH¢600.00

B. Stirrups (R 8 ∅)

The number of steel particles in the mixture is approximately 100 R 8 ∅.

The equivalent cost savings on 15% replacement of reinforcement bars with steel particles for 1 R 8 ∅of reinforcement bar is presented below:

One (1) R 8 ∅ of reinforcement bar cost GH¢ 10.00

Cost of 15% replacement of reinforcement bar with steel particles in 1R8∅

$=\frac{\mathbf{0.15}}{\mathbf{1}} \times 10$

$=0.15 \times 10$

=Gh ¢1.5p

Therefore 100 R8 ∅ $= \mathbf{100} \times \mathbf{10}$

=Gh¢1000.00

If 15% replacement of reinforcement bar with steel particles is done for utilization in low cost housing:

Cost saving on 100 R8∅ $= \frac{1.5}{10} \times 1000$

$=1.5 \times 10$

=GH¢150.00

APPENDIX XIV

Preliminary laboratory visit at Sunyani Technical University

Testing of silt content in the fine aggregate

Testing of concrete workability using slump test method

Weighing of specimen materials

Oiling of concrete moulds






Casting of specimen

Demoulding of specimen

Curing of specimen

Removing of curing specimen from the water

Weighing and recording of cured specimen

Crushing and Recording of tested specimen

Putting all recordings together