Jimma University

School of Graduate Studies

Jimma Institute of Technology

Faculty of Civil and Environmental Engineering

Construction Engineering and Management Stream

WASTE MARBLE DUST POWDER AS AN ADDITION IN CONCRTE PRODUCTON

A Research thesis submitted to the School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering (Construction Engineering and Management)

By: Yodit Fekadu

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January, 2018
Jimma, Ethiopia

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DECLARATION

This research thesis is my original work and has not been presented for a degree in any other university.

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Signature Date

This research thesis has been submitted for examination with my approval as university supervisor.

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Advisor Date

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Co-Advisor Date

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ABSTRACT

Marble dust is a by-product of marble production facilities which creates large scale environmental pollution. The purpose of this work is to describe, the effects of using waste marble dust (WMD) as an admixture material on the performance of concrete. For this purpose four different series of concrete-mixtures were prepared by adding a dosage of (passing 0.25mm sieve) with WMD 5, 10,12.5 and 15% by weight. In order to determine the effect of the WMD on the compressive strength, flexural and split tensile strength with respect to the curing age.. The results indicate that using WMD as an admixture increases the compressive, split tensile and flexural strengths of concrete. And found out that the optimum percentage of addition of WMD is 10%

Keywords: Concrete, waste marble dust, Compressive Strengths, Flexural Strength and Tensile strength

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ABREVIATIONS

AASHTO	American Association State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
$CaCo_3$	Calcium carbonate
CaMg (CO3)2	Dolomite
Kg/m^3	kilogram per cubic meter
KN	kilo Newton
Lit	Liter
Lit/kg	Liter per kilogram
M	Maximum Moment
m^3	Meter cubic
OPC	Ordinary Portland cement
WMD	Waste marble dust

CHAPTER ONE

INTRODUCTION

1.1. GENERAL

It is generally known that, good quality concrete is the fundamental requirement for making concrete structures . Good quality concrete is produced by carefully mixing cement, water, and fine and coarse aggregate and combining admixtures as needed to obtain the optimum product in quality. It is now quite clear that admixtures can both solve technical problems and save substantial cost. However, they also have the potential to create technical problems if improperly selected or used.

Numerous benefits are available through the use of admixtures, such as: improved quality, acceleration or retardation of setting time, coloring, greater concrete strength, increased flow for the same water-to-cement ratio, enhanced frost and sulfate resistance, improved fire resistance, improved workability, cracking control and enhanced finishability. The specific effects of an admixture generally vary with the type of cement, mix proportion, ambient conditions (particularly temperature) and dosage [1].Recycling of industrial wastes has actually environmental, economic and technical benefits. These day marbles are widely used in construction work [1]. Marble dust can be used either to produce new products or as an admixture so that we can use admixture freely of cheaply available are used more efficiently and the environment is saved from dumpsites of marble waste Marble is a metamorphic rock produced from limestone from pressure and heat in the earth's crust due to geological process. Marble dust powder is an industrial waste produced from cutting of marble stone. The result is that the marble waste which is 20% of total marble quarried has reached as high millions of tons. Generally the marble wastes are being dumped in any nearby pit or vacant space near the marble processing industries, although notified areas have been marked for dumping the same. This leads to increased environmental risks as dust pollution spreads alongside for a large area. In the dry season, the dust dries up, floats in the air, flies and deposits on crops and vegetation. In addition, the deposition of such generated huge amount of fine wastes certainly creates necrotic ecological conditions for flora and fauna changing landscapes and habitats. The accumulated waste also contaminates the surface and underground water reserves.

Now a day's marble waste is one of the causes of environmental problems around the world. Therefore, there is max. Utilization of marble waste in various industrial sectors, especially the construction, agriculture, glass and paper industries would help to protect the environment. Concrete is the most widely used construction material in the civil construction work because of its high structural strength and stability[1].

When sand is replaced with marble waste dust in concrete production gives similar strength as of concrete mixes with 100% sand both at early and later ages. and, it shows that replacing of sand with marble dust up to a limit reduces the slump of concrete mixes, but when it replace with sand up to limit, it enhances the slump of the concrete mixes. Earlier experimental studies says the unit weight of concrete can be increased when waste marble dust is added into the concrete because the specific gravity of waste marble dust is extremely high. Marble dust also helps in increasing the physical and Mechanical properties of the cement when mixed in proper ratio. It also contributes in decreasing the porosity of concrete, whereas marble dust works as catalyst in hydration process. Which makes it playing an important role in it [19].

Many studies have been conducted in literature on the performance of the concrete containing waste marble dust or waste marble aggregate, such as its addition into self-compacting concrete as an admixture or sand. as well as its utilization in the mixture of asphaltic concrete and its utilization as an additive in cement production the usage marble as a coarse aggregate [8] and as a fine aggregate passing through 1 mm sieve[2] [3][5][6].

1.2. Statement of the problem

Concrete is one of the oldest construction materials in the construction industry and it is widely used throughout the world. It is suitable to almost all types of constructions starting from foundations, road pavements, dams, buildings of various types etc. However, the process involved in the production of concrete requires due care and attention [10]. Quality and strength are the heartbeat of concrete. To enhance the quality and strength. The construction industry and concrete manufactures have realized that they will need to use admixture. Admixture this days contractors will not use admixture in order to not increase the cost of construction. So we have to provide a cheap or free admixture so that every contractor can enjoy the benefit of admixture. Management and disposal of WMD is a worldwide concern to environmental safety [2]. This waste if dumped, will in addition to loss, raising the environmental concerns like Disposal of marble dust on ground causes loss of water permeability at dumpsites, MP slush leaves a surface residue upon drying which is main reason for enormous air contaminations nearby processing units and Rain water often take these waste deposits to close rivers, streams and reservoirs and results a great deal of water pollution [8].

To solve the problems, stone waste in different forms could be used in different industrial activities in particular construction industry. One of such wastes that can be used for admixture is waste marble dust that could be used in the production of concrete for specific purposes. Therefore, usage of the marble dust in various construction industry would help to protect the environment. In addition to this, due to fineness of the marble dust, it will easily mix, with aggregate so that excellent bonding is possible. These days the cost of building material is increasing so if we use the waste material in the production of the concrete so we decrease the price. So this paper seeks for ways of utilizing WMD as an admixture for concrete production to minimize disposal problems, environmental pollution and also enhance the economy.

1.3. OBJECTIVES

1.3.1. General objective

The main objective of study is to investigate the effect of WMD addition on concrete properties.

1.3.2. Specific Objectives

- ✓ To examine the fresh properties concrete when WMD is added

- ✓ To investigate the harden properties of concrete when marble dust is added.
- ✓ Comparing the properties of concrete with WMD with standards
- ✓ Investigating the optimum percentage of WMD in concrete production .

1.4. RATIONAL OF THE STUDY

The main purpose of this research is to investigate the possibility of utilizing waste marble dust as an admixture concrete generated during cutting and polishing process in marble factories in order to reuse it concrete production. The research will help to produce almost free admixture during concrete production. Owners, contractors and consultants will benefit from the study as a source of information for production of concrete. This research will also help to determine strength of concrete with waste marble dust. Hence it will be easy for engineers to specify in which project and in what proportion will be used to produce concrete. Other researchers also will use the findings as a reference for further research on properties of concrete. There is need for this research since waste marble dust has recently gained good attention to be used as an effective filler material.

CHAPTER TWO

LITERATURES REVIEW

2. Theoretical review

Concrete is the most widely used strongest construction material that forms the basis of our modern life. It is used in different structures, such as: dam, building, bridge, tunnels, highway etc. Starting from the past, concrete was produced by the combination of cementing materials, aggregate and water. However, when the concrete technology develops, additional materials known as admixture have produced. This additional material may be added to the basic mix to develop special properties of the concrete in fresh and hardened states [1].

Admixture

According to ACI 116R and ASTM C 125, admixtures are ingredients other than water, aggregates, hydraulic cement, and fibers that are added to the concrete batch immediately before or during mixing [3]. A proper use of admixtures offers certain beneficial effects to concrete, including: acceleration or retardation offsetting time, enhanced strength development, improved workability, improve concrete durability and enhanced finish ability [3]. Historically, admixtures are almost as old as concrete itself. They have been recognized as important components of concrete used to improve its performance. The original use of admixtures in cementations mixtures is not well documented. It would be a logical progression to use such materials, which imparted desired qualities to the surface, as integral parts of the mixture. It is known that the Romans used animal fat, milk, and blood to improve their concrete. Properties. Although these were added to improve workability, blood is a very effective air entraining agent and might well have improved the durability of Roman concrete; eggs during the middle ages in Europe; polished glutinous rice paste, lacquer, Tung oil, blackstrap molasses, and extracts from elm soaked in water and boiled bananas by the Chinese; and in Mesoamerica and Peru, cactus juice and latex from rubber plants[7]. The Mayans also used bark extracts and other substances as set retarders to keep stucco workable for a long period of time. In more recent times, calcium chloride was often used to accelerate hydration of cement. The systematic study of admixtures began with the introduction of air-entraining agents in the 1930s when people accidentally found that cement ground with beef tallow (grinding aid) had more resistance to freezing and thawing than a cement ground without it [7]. Nowadays, admixtures are important and necessary components for modern concrete technology. The concrete properties both in fresh and hardened states can be modified or improved by the addition of admixtures. Currently, admixtures are obtained as mineral and chemical admixtures which used to improve the short and long term properties of concrete [4].

2.1. Marble

Marble is a crystalline, compact variety of metamorphosed limestone, consisting primarily of calicle (CaCO3), dolomite (CaMg (CO3)2) or a combination of both minerals. Dimensional stones such a marble has been highly popular since time immemorial, being used on facades and interiors of houses and buildings. The term marble is loosely applied to any limestone or dolomite that takes a good polish and is otherwise suitable as a building stone or ornamental stone. Marbles range in color from snow-white to gray and black, many varieties being some shade of red, yellow, pink, green, or buff; the colors, which are caused by the presence of impurities, are frequently arranged in bands or patches and add to the beauty of the stone when it is cut and polished.[10]

2.2. Components of marble

Calcium carbonate appears in such natural materials as limestone, gypsum, chalk, and marble. The mineral content of marble results from the original makeup of its rock mass, which often includes manganese, magnesium, and iron. The level of these elements is partially what determines the hardness and whiteness of the marble, according to the Senoia Pigments website. Other ingredients that may be found in marble dust are alumina and silica [11].

2.3. Production of Waste Marble Dust

The production of fine particles (<2 mm) while cutting marble is one of the major problems for the marble industry. When 1 m^3 marble block is cut into 2 cm thick slabs, the proportion of fine particle production is approximately 25 % [12].

While cutting of marble blocks water is used as cooler. But, the fine particles can be easily dispersed after losing humidity, under atmospheric conditions, such as wind and rain. Thus, fine particles can cause more pollution than other forms of marble waste [13].

Figure 2.1: Views from waste marble dust disposed site (captured on 4/06/2017)

2.4. Literature on the waste marble dust

Studied the use of the marble powder by product to enhance the properties of brick ceramic [14]. The ornamental stone industries have fine rock powder as by-product that might be suitable to be used in civil engineering construction purposes. Bouziani Tayeb, Benmounah Abdelbaki, Bederina Madani and Lamara Mohamed found that the increase of Marble Powder (MP) content in Self Compacting Sand Concrete, from 150 kg/m3 to 350 kg/m3, improves the properties at fresh state by decreasing v-funnel flow time (from 5s to 1.5s) and increasing the mini-cone slump (from 28cm to 34cm)[13].

In other hand, the 28 days compressive strength decreases with an increase of MP content Therefore, this work intends to discuss about technical aspects concerning the use of this material, which derives from sawing operation of marble blocks, in the ceramic raw material (clayey matrix). The study has been carried out using clayey soils from the municipal district of Campos in Rio de Janeiro, Brazil, where more than 130 ceramic industries are settled, which are potential consumers C.A Study has been conducted by V. M. Sounthararajan et.al(2013) have done their research on Effect of the Lime Content in Marble Powder for Producing High

Strength Concrete [16]. and also explained in their paper that the effect of marble dust was studied by replacing it partially with mortar and other components of concrete. By partial replacing the components of concrete it came to know that waste marble dust increases the compressive strength, flexural strength and workability of mortar and concrete[17]. He also wrote that in proper grading and excess silt of natural sand results in less popularity of find sand. Because of its non-desired fineness and gradation. Due to this marble dust powder came in consideration and importance. Due to its fineness it is used as filler and helps in reducing the total void content in concrete.[18] found out that Marble waste is a solid waste material generated by processing the marble. It is than can be used as a filler material in cement concrete [19]. Concluded that as per the study it, marble dust when replacing with sand up to certain percentage shows almost same strength. Marble dust is easily available so it might be cost effective.

Use of waste as aggregates has greater potential because 75% of concrete is composed of aggregates. Investigation show that these industrial wastes are capable of improving hardened concrete performance. Thus, we found out the optimum percentage for replacement of sand with marble dust in concrete is almost 50%. Adding the waste marble dust unto 10% replace by weight of fine sand can increase the tensile strength and compressive strength of concrete and They found that the waste marble They found that the waste marble powder up to 10% by weight of cement was investigated for hardened concrete properties. D. A Study has been conducted and have done their research on Periodic Research, The Significance of Partial Replacement of Cement With Waste of such a waste marble powder. They found that the effect of using marble powder as constituents of fines in mortar or concrete by partially reducing quantities of cement has been studied in terms of the relative compressive, tensile as well as flexural strengths. Partial replacement of cement by varying percentage of marble powder reveals that increased waste marble powder (WMP) ratio result in increased strengths of the mortar and concrete [20].

Leaving the waste materials to the environment directly can cause environmental problem. Hence the result The Compressive strength of Cubes are increased with addition of waste marble Powder up to 12.5 % replace by weight of cement and shows any further addition of waste Marble powder affect the compressive strength negatively. Characterization laboratory tests were carried out on samples that were conformed in a laboratory extruder, simulating, thus, the actual industrial process. These samples were molded with different marble powder contents, fired at temperatures varying from 750°C to 950°C were evaluated for its mechanical property. This range of temperature was considered representative because most of ceramic industries in this region of Brazil make use of Hoffman kiln type, where temperatures above 900°C, is difficult to be obtained. Results have shown that the use of 15–20 % of waste content in the red ceramic raw material could be considered the best proportion. However the water absorption is one of the most critical properties of ceramic brick, and the values for 20 % of waste content are higher than allowed for civil construction purpose. Thus, a raw-material composition of 15 % of waste content fired at 850°C might be used in industrial scale for commercial use of the ceramic body. However, this temperature magnitude is quite difficult to be reached using a common Hoffman kiln that is the most usual kind of kiln in the studied region. On the other hand, if the ceramic industry possesses kiln with a capacity for firing the material at temperatures above 950°C, a higher content of waste material can be used, without loss of quality[20].

The most advantage to use this kind of waste is the low temperature required to dissociate the calcite and dolomite, improving somewhat the strength of the ceramic body. However, mechanical behavior of this material shall be 15 determined for a long period of time in order to assess the lifetime of the ceramic brick with waste incorporated in its raw material. The results depict the possibility of using this by-product in the paste composition of ceramic bricks for the use in civil engineering construction industry, without impairment of their mechanical properties. In several cases, some of these properties have been improved [9]. Investigated the Durability of concrete made with granite and marble as recycled aggregates. The ornamental stone industries in Turkey produces vast amount of by-product rock waste (marble, granite) that could be used in concrete production suitable for construction purposes. Also investigated the preliminary concrete mix design for SCC with marble powders. The marble has been commonly used as a building material since ancient times [3].

Disposal of the waste materials in the marble industry, consisting of very fine powders, is one of the environmental problems worldwide today. However, these waste materials can be successfully and economically utilized to improve some properties of fresh and hardened self-compacting concrete (SCC). The aim of this study is to find some relationship between properties of the fresh SCC 17 and the hardened SCC containing marble powder. For this purpose, the mix design approach based on monogram developed by Montero and co-workers for normal vibrated concrete was adapted to SCC mixes. In order to obtain this monogram, a series of SCC mixes with different water/cement ratios and water/powder ratios were prepared. Several tests such as slump-flow, T500 time, L-box, V-funnel and sieve segregation resistance were applied for fresh concrete and tests such as compressive strength and split-tension strength at 7,28 and 90 days were performed for hardened concrete [21]. Studied the effect of waste marble dust content as filler on properties of self-compacting concrete. Day by day, the amount of the marble dust (MD) as a waste material is significantly of increasing in Turkey.[22] studied the Utilization of waste marble dust as an additive in cement production. In this experimental study, the usability of waste marble dust (WMD) as an additive material in blended cement has been investigated. For this purpose, waste marble dust added cements (WMDCs) have been obtained by inter grinding WMD with Portland cement clinker at different blend ratios: 2.5, 5.0, 7.5 and 10% by weight. 40×40×160 mm mortar prisms has been produced with the obtained cements.

Strength tests have been carried out on mortar specimen at 7, 28, and 90 days. WMDCs have been compared to standard and thus 10 % WMD can be used as an additive material in cement manufacturing. The Characterization of marble powder for its use in mortar and concrete. From the physical and chemical point of view they have characterized the marble powder using it in mortar and concrete production. A powder obtained as a by-product of marble sawing and shaping was characterized from a chemical and physical point of view in order to use it as a mineral addition for mortars and concretes, especially for self-compacting concrete. This marble powder showed a very high Blaine fineness value of about 1500 m2/kg, with 90 % of particles finer 20 than 50 micron and 50 % under 7 micron [2].

For rheological studies, several cement pastes were prepared using marble powder, In terms of mechanical performance, 10 % substitution of sand by the marble powder in the presence of a super plasticizing admixture provided maximum compressive strength at the same workability level, comparable to that of the reference mixture after 28 days of curing. Moreover, an even more positive effect of marble powder is evident at early ages, due to its filler ability. Results obtained show that 10% substitution of sand by the marble powder provided maximum compressive strength at about the same workability [23]. Examined the possibility of using granite powder as replacement of sand and partial replacement of cement with fly ash, silica fume, slag and superplasticiser in concrete. The percentage of granite powder added by weight was 0, 25, 50, 75 and 100 as a replacement of sand used in concrete and cement was replaced with 7.5 % silica fume, 10 %fly ash, 10 % slag and 1 % superplasticiser. With the inclusion of Marble powder the strength of concrete gradually increases up to a certain limit but the gradually decreases. With the inclusion of Marble powder upto10% the initial strength gain in concrete is high. At 10% there is 27.4% increase in initial Split Tensile strength for 7 days. At 10% there is 11.5% increase in initial Split Tensile strength for 28 days. The initial strength gradually decreases from 15%. It was found out that the optimum percentage for replacement of marble powder with cement and it is almost 10% cement for both cubes and cylinders The effects of water ponding temperatures at 26°C and 38°C with 0.4 water-to-binder (w/b) ratios on 21 mechanical properties, plastic and drying shrinkage strain of the concrete were studied and compared with natural fine aggregate concrete. The test results obtained indicate that granite powder of marginal quantity as partial sand replacement has a beneficial effect on the mechanical properties such as compressive strength, split tensile strength, modulus of elasticity and also considerable advantages in plastic and drying shrinkage [24].

Investigated the use of waste marble powder in concrete and also Today we are faced with an important consumption and a growing need for aggregates because of the growth in industrial production, this situation has led to a fast decrease of available resources. On the other hand, a high volume of marble production has generated a considerable amount of waste materials; almost 70 % of this mineral gets wasted in the mining, processing and polishing stages which have a serious impact on the environment. The processing waste is dumped and threatening the aquifer. Therefore, it has become necessary to reuse these wastes, particularly in the manufacture of concrete products for construction purposes.

Demonstrate the possibility of using marble wastes as a substitute rather than natural aggregates in concrete production. The paper presents the study methodology, the characterization of waste marble aggregates and various practical formulations of concrete. This experimental investigation was carried out on three series of concrete mixtures: sand substitution mixture, gravel substitution mixture and a mixture of both aggregates (sand and gravel). The concrete formulations were produced with a constant water/cement ratio. The results obtained show that the mechanical properties of concrete specimens produced using the marble wastes were found to conform to the concrete production standards and the substitution of natural aggregates by waste marble aggregates up to 75 % of any formulation is beneficial for the concrete resistance. [25] experimentally investigated the effect of mineral admixtures on mechanical properties, chloride ion permeability and impermeability of self-compacting concrete. The objective of this study was to evaluate the effectiveness of various mineral admixtures in producing self-compacting concrete (SCC). For this purpose, fly ash (FA), granulated blast furnace slag (GBFS), limestone powder (LP), basalt powder (BP) and marble powder (MP) were used. Workability of SCC was determined using slump flow, T50 time, and L-box and V-funnel tests. The hardened properties that were determined included ultrasonic pulse velocity and compressive strength determined at 7 and 28 days. It was concluded that among the mineral admixtures used, FA and GBSF significantly increased the workability of SCC.

Durability properties of SCC mixtures such as, chloride Waste material in different proportions was mixed with industrial brick mortar starting amount of 0 % wt. up to 80 % wt. in 41×8×8 mm rectangular prisms for testing of physic-mechanical properties of the samples having different marble dust composition. These prepared prisms were pressed and sintered at three different temperatures 900, 1000 and 1100°C. Flexural strengths of the test samples were given at three different temperature values of 900, 1000 and 1100°C. An Archimedes water displacement test was conducted with different water absorption percentage 23 values at 900, 1000 and 1100°C temperatures. Analyses have been carried out for the additives which contain mainly calcite and small amount of dolomite minerals. It was found that the amount of marble dust additive had a positive effect on the physical, chemical and mechanical strength of the produced industrial brick.[26] experimentally investigated the use of locally available granite powder as fine aggregate and partial replacement of cement with admixtures in the production of HPC with 28 days strength to the maximum of 60 MP.

The influence of the water cement ratio and curing days on mechanical properties for the new concrete mixes were premeditated. The percentage of granite powder added by weight was 0, 25, 50, 75 and 100 % as a replacement of sand used in concrete and cement was replaced with 7.5 %silica fume, 10 % fly ash, 10 % slag and the dosage of superplasticiser added 1 % by weight of cement. The test results show clearly that granite powder as a partial sand replacement has beneficial effects on the mechanical properties of high performance concrete. Of all the six mixtures considered, concrete with 25 % of granite powder (GP25) was found to be superior to other percentages of granite powder concrete as well as conventional concrete and no admixtures concrete for all operating conditions. Hence the following conclusions are made based on a comparison of GP25 with the control concrete, C.Chem. Mechanical properties like the compressive strength, split tensile strength, modulus of elasticity and flexural strength, particularly for all ages higher than that of the reference mix, CC as mentioned below. There was an increase in strength as the days of curing increased. Compressive strengths 6.12 to 22.14 % greater than that of CC. Split tensile strength is 14.88 to21.95 % higher than that of CC. Modulus of elasticity is 8.85 to 18.89 % higher than that of CC. Flexural strength is 12.5 to 22.22 % higher than that of CC. The water absorption was about 8 to 14.2 % less than that of conventional concrete mixture [27].

Thus the present experimental investigation 24 indicates that the strength properties of the concrete could enhance the effect of utilization of granite powder obtained from the crusher units in place of river sand in concrete. In general, the behavior of granite aggregates with admixtures in concrete possesses the higher properties like concrete made by river sand.[27] carried out an experimental investigation on use of granite powder as an alternative material for fine aggregate in concrete production. The percentages of granite powder added by weight to sand by weight were 0, 5, 10, 15, 20 and 25. To improve the workability of concrete 0.5 % Superplasticiser was added. This attempt has been done due to the exorbitant hike in the price of fine aggregate and its limited availability due to the restriction imposed by the government of Tamil Nadu. Fifty four cubes and The aim of this study is to find some relationship between properties of the fresh concrete and the hardened concrete containing marble powder. For this purpose, the mix design approach based on monogram developed by Monteiro and co-workers for normal vibrated concrete was adapted to concrete mixes [28].

Studied the use of the marble powder by product to enhance the properties of brick ceramic. In general, the ornamental stone industries have fine rock powder as by-product that might be suitable to be used in civil engineering construction purposes. Therefore, this work intends to discuss about technical aspects concerning the use of this material, which derives from sawing operation of marble blocks, in the ceramic raw material (clayey matrix). Cement and concrete similar to that used today. They mixed slaked lime with a pozzolanic volcanic ash from Mt. Vesuvius to produce hydraulic cement that hardened under water and would not deteriorate when exposed to moisture. Some pipelines and aqueducts constructed using this concrete are still in use today. Generally, in literature waste marble dust has been replaced with either all of the fine aggregate and cement. The requirement for locally manufactured building material has been emphasized in many countries. Environmental problems can be issued due to dumping of waste materials. Waste can be used for production of new products as an admixture so that natural resources are used more efficiently and the environment is protected from waste deposits [29].

Marble waste utilization

Table 2.1. Marble waste utilization

No.	Utilization area	Utilization %
1	Structural, fill, Soil stabilization, and road embankment work	10-15
2	Cement	10-12
3	Aggregates	2-5
4	Bricks , Blocks, Tiles	11-13
5	Paint ,Binder ,Plaster	2-5
6	Concrete roofing sheets	5-10
7	Ceramic Products	10-12
8	Particle Board, Panels	10-12

2.3. Effect of waste marble dust on Concrete

The effect of waste marble dust on concrete depends on type, dosage, and time of addition, w/c ratio, nature and amount of cement, aggregate, temperature. Generally, waste marble dust will have some effect on fresh and hardened concrete. [30]

2.3.1. Effect of waste marble dust on Fresh Concrete

Waste marble dust have different effects on the fresh concrete and the effects can observe on the following parameters, such as: water reduction, workability, slump loss, bleeding and segregation, air content and finishing[14].

Workability: - Workability of concrete is will not well improved when waste marble dust are incorporated in the mixture at given water content. The ability of waste marble dust to increase the slump of concrete depends on the type, dosage, and time of addition of the dust, w/c ratio, nature and amount of cement, aggregate, etc. The time when the west marble is added to concrete affects the slump values. By adding the waste marble dust with the mixing water, the slump value is increased considerably. Even higher slump values are possible by the addition of dust a few minute sifter the concrete is mixed with water. In the temperature range of 5-30°C, there is no radical difference in the slump values attained by addition of a marble dust [30].

Bleeding and Segregation: - Indy, no undue segregation or bleeding occurs. Generally, the bleeding decreases because of the decreased w/c ratio. When repeated dosages of super plasticizers are used to control the loss of slump, bleeding and segregation may occur if the repeated dosing exceeds two or three times [38].

2.4. Health and Safety Effect of waste marble dust

Johnson and found also hyperplasia and hypertrophy of alveolar epithelium in response to silica exposure in rats [39]. They explained this because silica increase secretion of the product of alveolar type II cells, surfactant in exposed mice. These finding supports the need to further investigate of marble dust exposure as possible carcinogenic particulate. The data of the present study, demonstrated that long period of chronic exposure to dust induced progressive atrophic changes in the alveoli, the alveolar ducts are lined with interrupted flat epithelial cells, even collapse of the alveoli. The interim-alveolar setae showed C.T increase in thickness. Similar changes have been reported [40].

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Study Design

The study was an experimental study for many purpose as a material composed of cement, sand as fine aggregate, crushed rock as coarse aggregate, water and admixture. It's obvious that, concrete can be produced by anybody through mixing of concrete ingredients, but the important point bear in mind is producing acceptable concrete quality with a reasonable economy. To produce acceptable quality, it's important to make physical characteristic tests on materials used for the investigation before any concrete experiments are carryout. So, this chapter elaborates concrete making materials used for the research, mix design, proportion, and concrete production process.

3.2. Material Preparation

The physical characteristics of concrete making materials (Cement, fine aggregate, Coarse aggregate, Water and Waste marble dust) used for the research were examined and appropriate mix design was made.

3.2.1. Cement used for the study

Ordinary Portland cement (OPC) produced as per CEM-I-42.5 grade contains 95% clinker and 5% gypsum produced by Capital Cement PLC was used throughout the experiment. The reason to select only one cement type is due to financial and time limitation to perform experiments. According to the tests result, the normal consistency of this hydraulic cement was of 27%. This test is used to determine the amount of water required to prepare a standard cement paste. The initial and final setting time was 2:13 hr. and 3:00 hr. respectively.

3.2.2. Sand used for the study

This Aggregates are materials basically used as filler with binding material in the production of concrete. Aggregates form the body of the concrete, reduce the shrinkage and affect economy. Therefore, it is significantly important to obtain right type and quality of aggregates on site. They should be clean, hard, strong, and durable and graded in size to achieve utmost economy from the paste. Therefore, to judge the quality of the aggregate physical characteristics tests have to be conducted.

3.2.5. Course aggregate used for the study

The aggregate used for the study was purchased from local supplier and their sources are from GAMBELA.

3.2.4. Water used for the experiment

Mixing water used in this research was drinkable water supplied by Addis Ababa Water and Sewerage Authority found in the laboratory area.

3.2.5. Marble Dust used for the experiment

The specific gravity of marble is 2.6. Local available Marble powder used as an admixture concrete.

Table 3.1 Physical properties of Marble powder

Color	White
Form	Powder
Odor	Odorless
Specific gravity	2.60gm/cm

Table 3.2. Chemical properties of marble powder

S.No.	Materials	Marble powder %
1	Loss of Ignition	40.63
2	CaO	32.23
3	Fe	1.09
4	Al_2O_3	1.09
5	SiO	4.99
6	MgO	18.94
7	SO	0.02
8	K_2O	0.91
9	Na_2O	0.63

Source: Ethiopian marble industry

3.3. Engineering property of materials

The engineering property of all materials necessary for describing the type of materials used and also properties that can affect the production concrete were determined prior to production. The test methods used for the aggregates are listed below in Table 3.3.

Table 3.3 Material property test

No.	Laboratory procedures	Standard used
1	Sieve analysis for fine and coarse aggregate	ES C.D3.201
2	Unit weight of aggregate	ASTM C-29
3	Specific gravity and water absorption for CA	ASTM C-127
4	Specific gravity and water absorption for FA	ASTM C-128
5	Moisture content	ASTM C-0566
6	Silt content for FA	Abebe D. lab. guide

No.	Laboratory procedures	Standards used
1	Consistency of cement	ASTM C-187
2	Setting time of cement	ASTM C-191
3	Mix design procedure	ACI Mix design
4	Slump test of concrete	ASTM C-143
5	Compressive strength of concrete	ASTM C 192

3.4. Concrete Mix design and Materials Proportion

The ACI Method of concrete mix design was used to design C-25. For C-25 the target mean strength was $38N/mm^2$, and the water to cement ratio was 0.53 and In addition to this, the slump was 24 to 30 mm for C-25. The quantity of concrete materials was calculated by using the physical properties of the materials and table show the quantity of materials for one cubic meter for C-25. The Standard cast iron molds of size 15x15x15cm are used in the preparation of concrete cubes for compressive strength and permeability tests. Whereas, for flexural strength the standard cast iron molds of size 50 x 10 x 10cm are used.

Table 3.4: Quantity of materials in kg for $1m^3$ C-25 concrete grade production

For C-25 concrete grade; W/C = 0.53				
Materials	Cement (kg)	Water(It)	Fine aggregate (kg)	Course aggregate(kg)
Quantities per m^3	359	190	840	931

3.5. Specimen production process

For the normal strength concrete an ACI Mix design Method is used as starting point and two trial mixes were done to arrive at this mix proportion. Each mix batch was 51 liter C-25 in volume and was subjected to 1 minute dry mixing and 2 minutes wet mixing. Regarding placing and compaction, placing was started immediately and was done in two layers and compacted in table vibrator for 30 seconds for single 15 cms cube mold and for 45 seconds for couple of 15 cms cube molds. Compaction and placing were completed within 15 minutes. For the Intermediate Strength concrete, literature review for recommended practices and trial mixes are the methods used to arrive at this mix proportion. Each mix batch was 51 liter in volume and was subjected to 1 minute dry mixing and 2 minutes wet mixing. After deducting the volume the admixture from the mixing water, the admixture was added to the water and stirred thoroughly. Regarding placing and compaction, placing was started immediately and was done in two layers and compacted in table vibrator for 30 seconds for single15 cms cube mold and for 45 seconds for couple of 15 cms cube molds. Compaction and placing were completed within 15 minutes. For the high strength concrete, literature review for recommended practices and trial mixes are the methods used to arrive at this mix proportion. Each mix batch was 34 liter in volume and was subjected to 1.5 minutes dry mixing and 3 minutes wet mixing. After adding of WMD by percent, and stirred thoroughly. Regarding placing and compaction, placing was started immediately and was done in two layers and compacted in table vibrator for 45 seconds for single 15 cms cube mold and for 60 seconds for couple 15 cms cube molds. Compaction and placing were completed within 15 minutes. To minimize error each sample should be mixed at a time. However, the capacity of the mixer at the Faculty's Material Test Laboratory is 60 liters but each sample required thirty units of 15cm cubes which correspond to about 110 liters. Hence, mixing was done in two or three batches and of course this may contribute some errors among the test result of each cube with in a sample. The concrete molds and mixer were cleaned from all dust and coated with releasing agent (oil) to smooth the surface and to prevent sticking of mixed concrete with the mold and mixer. The ingredients, such as; cement, fine aggregate (sand), coarse aggregate water and admixture were measured by weight balance. After that the weighted coarse aggregate was first added to the mixer and the cement was added after the coarse aggregate and then the fine aggregate is added next to cement and dry mixed for a minute. Then, water and marble dust powder was added to the dry mixed concrete ingredients mixture and thoroughly mixed for two more minute. The mixed concrete was checked for workability by filling the standard slump cone with three layers by rodding each layer with 25 times. Then, after checked the slump the mixed concrete was placed in the mound and was well compacted in two layers with the help of a table vibrator for 45 and 30 seconds for double and single cast iron molds respectively. The concrete molds are kept for 24 hours and then the casted concrete cubes were removed from the mold and placed inside water for curing to take place until the testing age was reached

3.6. SAMPLING PROCEDURE AND SAMPLE SIZE

The sampling procedure was purposive sampling, therefore the sample size was determined accordingly to the test specimen number required to conduct compressive strength, flexural, split tensile strength for concrete. Therefore there were 3 samples for compressive strength, flexural and split tensile strength tests in each % addition and age.

Table 3.5: Number of samples

% of marble dust addition	Number of Sample					Total
	For compressive strength			For flexural and split tensile strength		
	7th	14th	28th	7th	28th	
0	3	3	3	3	3	15
5	3	3	3	3	3	15
10	3	3	3	3	3	15
12.5	3	3	3	3	3	15
15	3	3	3	3	3	15

3.7. STUDY VARIABLES

- Dependent Variable:

  Compressive strength
  Flexural strength
  Split tensile strength

- Independent variable

  Percentage of WMD addition
  Mix proportion
  Water cement ratio

3.8. DATA COLLECTION PROCESSS

The data for this research was collected from laboratory results. In the study analytical data will be collected.

3.9. DISSIMINATION PLAN

These researches are going to carry out for the partial fulfillment of master's degree of civil engineering in construction engineering and management, therefor the research finding should be presented for the construction engineering and management department and will be submitted both in hard and soft copy to the department and for all interested body.

CHAPTER FOUR

Result and discussion

4.1. Engineering property of materials

4.1.1. Properties of fine aggregate

- **Sieve Analysis**

According to ES C.D3.201, the gradation result of the original sample sand is out of range on 300µm and 150µm sieve size. So, it is blended with finer sand to make within the range. The grading requirements for fine aggregates according to ES C.D3.201 and, the particle size distribution of original and blended aggregate used for the experiment is shown in Table 3.1 and Figure 3.1 below. Therefore, based on BS specification as shown in Table 3.2 below, the grading of the blended aggregate has failed under zone one.

Table 4.1. The particle size distribution for fine aggregate

Sieve size	Cumulative passing ES C.D3.201 (%)	Cumulative Passing (Original Sand) (%)	Cumulative Passing (blended Sand) (%)
9.5mm	100	100	100
4.75mm	95-100	97.8	97.8
2.36mm	80-100	88.4	88.4
1.18mm	50-85	66.8	66.8
600µm	25-60	28.6	29.8
300µm	10-30	3.8	10.0
150µm	2-10	0.4	2.0

Fineness Modules = $\sum \frac{Cummilative\ courser(\%)}{100} = \frac{305.2}{100}, 3.05$ this can be interpreted that the third sieve, i.e. 600µm is the average size. However, depending upon their size, sand can be classified as coarse sand when a fineness modulus is between 2.90 to 3.20; medium sand with a fineness modulus of 2.60 to 2.90 and; fine sand with a fineness Modulus of 2.20 to 2.60. So, the sample was classified as coarse sand.

Table 4.2. BS and ASTM grading requirements of fine aggregate

Sieve size	Percentage by weight passing sieves				
	BS882:1973				ASTM standards (C33-78)
BS	Grading Zone 1	Grading Zone 2	Grading Zone 3	Grading Zone 4	
9.5mm	100	100	100	100	100
4.75mm	90-100	90-100	90-100	95-100	95-100
2.36mm	60-95	75-100	85-100	95-100	80-100
1.18mm	30-70	55-90	75-100	90-100	50-85
600µm	15-34	35-59	60-79	80-100	25-60
300µm	5-20	8-30	12-40	15-50	10-30
150µm	0-10	0-10	0-10	0-15	2-10

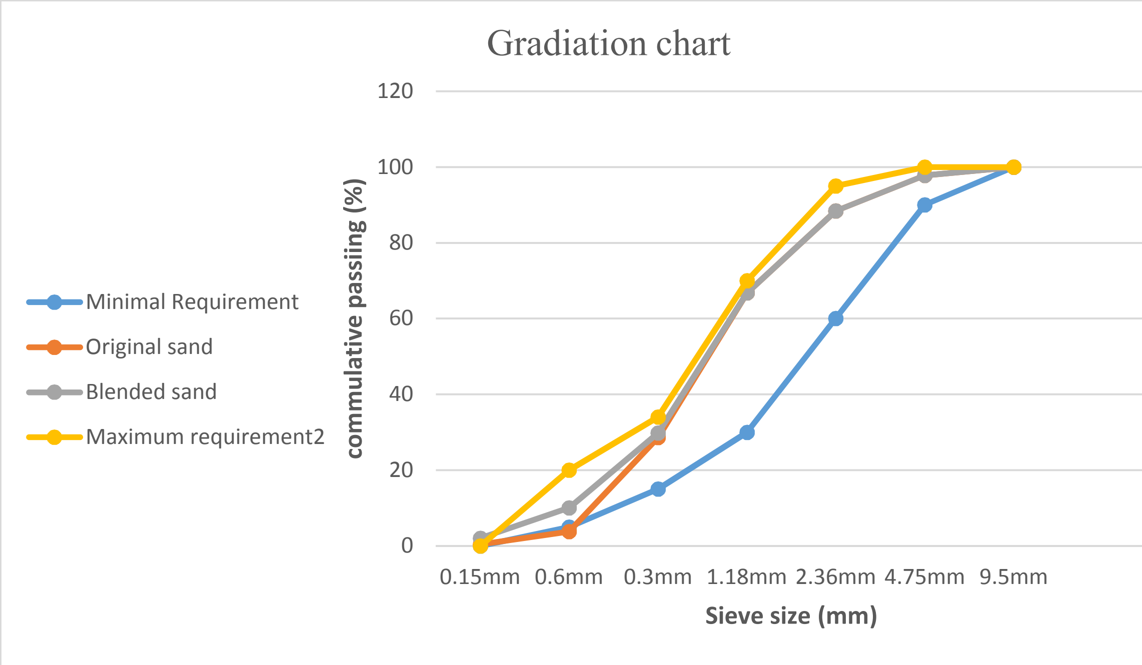


Figure 4.1: Fine aggregate gradation chart

Silt Content

According to the Ethiopian Standard it is recommended to wash the sand or reject if the silt content exceeds a value of 6% [11]. From the test result obtained, the silt content of the sand used for this experiment before washing was 8.35%, which is above the maximum requirement of Ethiopian standard. For this reason, it was washed thoroughly and the result becomes 2.85%.

Unit weight of Aggregates

The unit weight is simply measured by filling a container of known volume and weighing it. Then, dividing the aggregate weight by the volume of the container provides the unit weight of the aggregate. The compacted and loose unit weight of this sample fine aggregate was 1504 kg/$m^3$and 1410 kg/m^3

Specific Gravity and Absorption Capacity of fine aggregate

Since aggregates generally contain pores, both permeable and impermeable, the meaning of the term specific gravity has to be carefully defined, and there are indeed different types of specific

Figure 4.2: Pycnometer

Gravity, like: apparent specific gravity and bulk specific gravity. Bulk specific gravity refers to total volume of the solid including pores of the aggregate, and apparent specific gravity refers to the volume of the solid is consider to include the impermeable pores but not the capillary ones. The bulk specific gravity, bulk specific gravity (saturated- surface dry) and apparent specific gravity results obtained from the experiment are 2.41, 2.47 and 2.56 respectively. And, the absorption capacity was 2.46%.

➢ Moisture Content of Aggregate

The moisture content of fine aggregate was determined by Oven dry 500gm of fine aggregate (sand) for about 24hrs with a temperature of 105 °C to 110 °C and cool for an hour. Then, dividing the weight difference by oven dry weight and multiplying by hundred provide the moisture content. Therefore, the moisture content of the sample fine aggregate was 2.04%.And, the absorption capacity was 2.46%.

Table 4.3: Summarized test result for fine aggregate

No	Physical test for fine aggregate		Result
1	Silt content	Before washing	7.14%
		After washing	2.9%
2	Finess modulus		3.05
3	Unit weight	Compacted unit weight	1501 kg/m
		Loose unit weight	1410kg/m3
5	Specific Gravity	Bulk specific gravity	2.41
		Bulk specific gravity(SSD)	2.47
		Apparent specific gravity	2.56
6	Absorption capacity		2.46%
7	Moisture content		2.04%

4.1.2. Properties of coarse aggregate

The coarse aggregate used for this research was basaltic crushed rock from local market the aggregate comes from the market was washed thoroughly and dried in air inside the laboratory room. The size of coarse aggregate used for experimental investigation was a mixture of 20mm and 10mm diameter aggregate sizes and it was sieved and stored in different grades for blending. In this study a maximum size of 19 mm diameter aggregate was used in all the concrete mix design. The physical properties of coarse aggregate test results are shown in the Table 4.4 and 4.5 below. The value of coarse aggregate grading is shown as a Figure in Figure 3.2 below.

Table 4.4. Sieve analysis for course aggregate

Sieve Analysis (mm)	Cumulative passing ES C.D3.201	Cumulative passing (Original coarse aggr.)	Cumulative passing (Blended coarse aggr.)
19 mm	95-100	97.3	97.3
12 mm	-	37.8	66.3
9.5 mm	25-55	8.7	34
4.75 mm	0-10	0.27	0.27

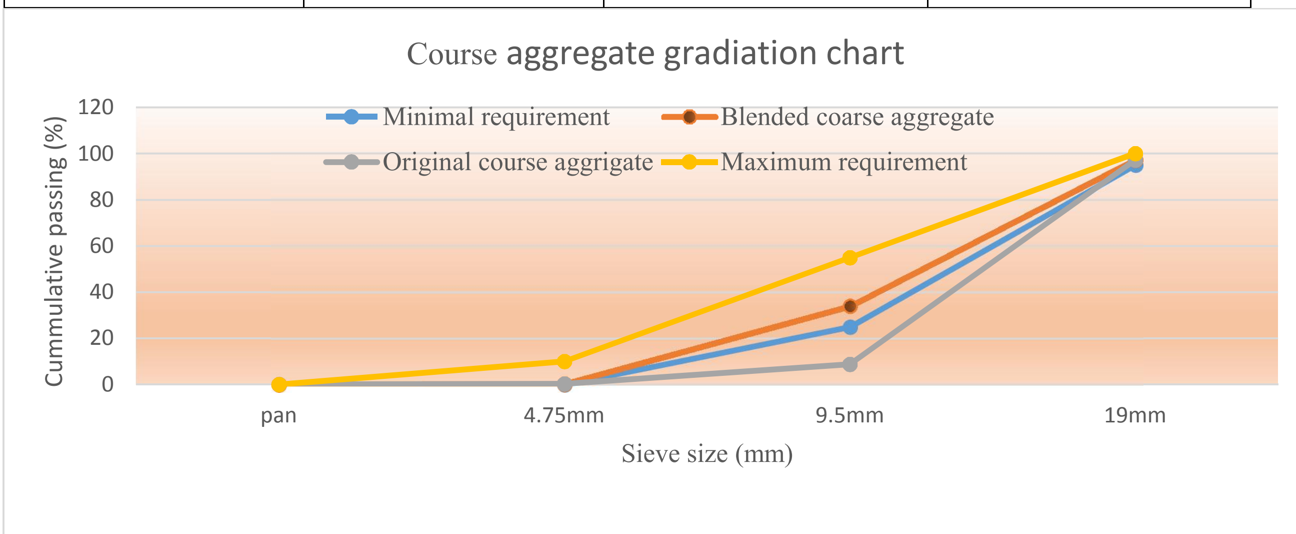


Figure 4.3: Course aggregate gradation chart

Table 4.5: Summarized result for course aggregate

No	Physical test for course aggregate		Result
1	Unit weight	Compacted unit weight	1435.4 kg/m^3
		Loose unit weight	1382.1 kg/m^3
2	Specific gravity	Bulk specific gravity	2.47
		Bulk specific gravity (SSD)	2.53
		Apparent specific gravity	2.61
3	Absorption Capacity		2.1 %
4	Moisture Content		2.4 %
5	Aggregate Impact value		12.9 %
6	Aggregate		17.9 %

According to the research objectives and methodology, effect of waste marble dust on the properties of concrete, such as: workability and strength of concrete have been studied at dosages of 0%, 5 %, 10 %, 12.5% and 15 %.

4.2. Properties of fresh concrete

For this investigation experiments are carried out for fresh concrete with and without the presence of waste marble dust for C-25 grade. For fresh concrete property, slump tests were conducted to assess the workability of the concrete mix.

4.2.1. Slump

The test was performed by following ASTM C 143/C Standard Test Method for Slump of Hydraulic-Cement Concrete. A 30CM. tall slump cone was filled with concrete in 3 equal layers. Each layer was ridded 25 times by a 5/8-in. tamping rod. After the cone was filled, all excess concrete was stricken from the top. The cone was then lifted straight up and the vertical displacement of the concrete was measured from the original top of the cone.

For the C-25 concrete, workability tests were conducted. The slump test results were conducted to investigate the impact of waste marble dust dosage on workability. While, the strength development, and strength of mix with dosage of waste marble dust to determine the hardness of mix. Figure 4.4 Based on the observed slump measurements, the concrete mix produced without Waste marble dust a slump 25mm was observed. Similarly, the observed slump for a dosage of 5% waste marble dust added concrete was 27mm. The observed difference between the two slumps was 2mm. However, according to ASTM C143 standard the variability for a slump of 25mm is about 17mm. If the analysis is based on the recommendation of ASTM C143 standard, 5% dosage of waste marble dust does not bring a significant workability improvement. However, given the fact the experiments are carried under controlled situations, the actual variability of slump is expected to be lower, thus though not significant the 5% waste marble dust shows tendency of workability decrement. For a dosage of 10% WMD added concrete, the observed slump was also measured 27mm. The observed difference between the two slumps, which is produced by without adding WMD and 10% WMD added concrete was 2mm. This shows addition of 10% WMD have not brought any improvement over the reference concrete and has not provided a higher result than ASTM C143 standard recommendation. The no increment of slump value was observed by addition of 15% waste marble dust, which was measured 1mm. This shows the workability of 15% waste marble dust added concrete was improved by 24mm from reference concrete and provided very low slump difference than ASTM C143 standard recommendation.

According to the test observation, the slump of 0%,5%,10%,12.5%,15% waste marble dust added on concrete were within the range and produced true slump. Waste marble dust will help to obtain workable concrete for a longer time, and this will reduce the quick slump loss during the transportation and placing of concrete on site. However, over dosage of admixtures leads to high slump, which will not give the desired slump as expect. Therefore, it will affect the strength of produced concrete. This does not mean too much slump will no longer relevant, it will be preferable to use in congested areas with steel reinforcement as a self-compacted concrete, and this can reduce wastage of time and money incurred for compaction.

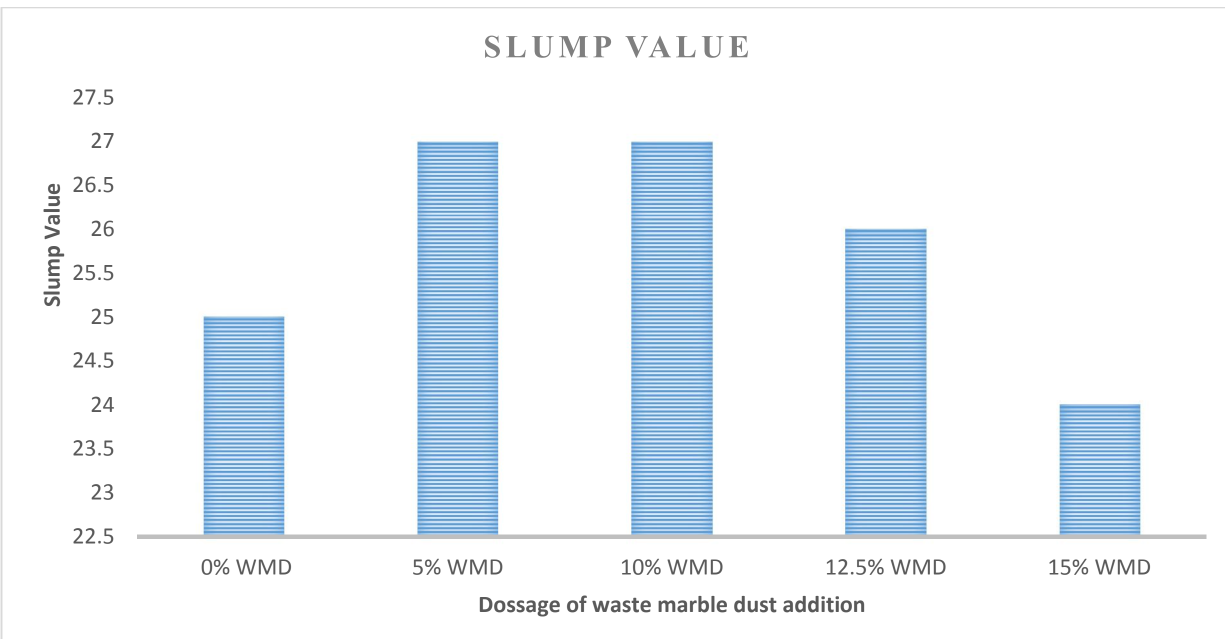


Figure 4.4. Slump value

4.3. Hardened concrete

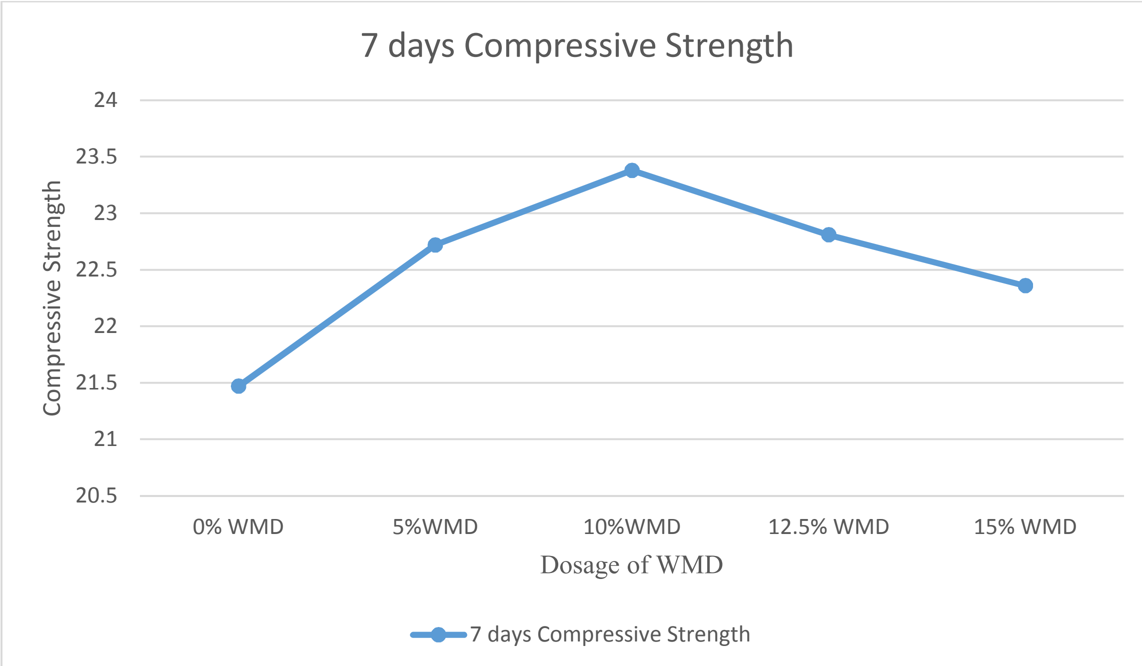
4.3.1. Compressive strength

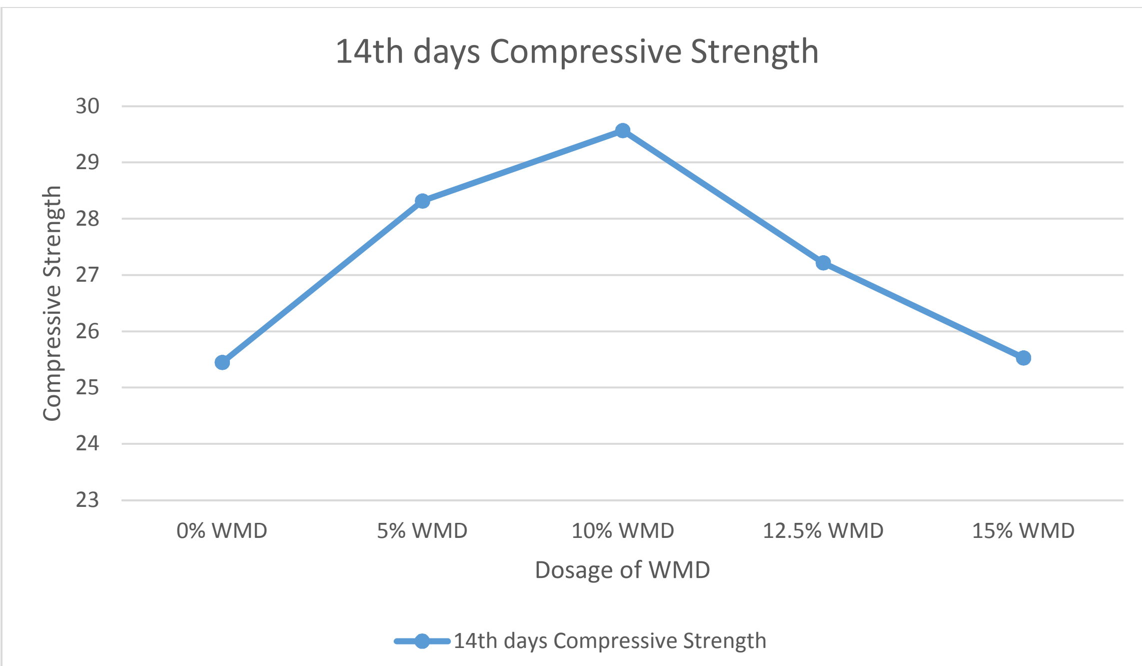
Table 4.5 below illustrates a typical concrete cube sample ready for testing and after testing. The compressive strength of concrete was determined by testing the cubes in a compression testing machine at a rate of 0.28MPa/s. For every cube the compressive strength is recorded in MPa and, then the mean values of three samples were taken as their compressive strength value for 7th, 14th and 28th days. Table 4.1 below shows slump and rate of compressive strength development test results for C-25 concrete grade with different dosage of waste marble dust.

Figure 4.5: Sample ready for testing

Table 4.6. Workability and compressive strength results for C-25

Effect of waste marble dust on compressive strength of concrete mix								
Waste marble dust	W/C Ratio	Slump (mm)	7th days		14th days		28th days	
			Failure Load (kN)	Comp. strength (MPa)	Failure Load (kN)	Comp. strength (MPa)	Failure Load (kN	Comp. strength (MPa)
0%	0.53	25	338.97	21.06	483.13	25.45	733.4	32.60
5%	0.53	27	348.1	22.72	511.13	28.32	761.6	33.84
10%	0.53	27	360.6	23.88	537.7	29.57	898.45	39.93
12.5%	0.53	26	340.5	22.81	513.2	27.22	846.5	37.62
15%	0.53	24	330.65	22.36	501.3	25.53	743.6	33.63


7 days Compressive Strength
Compressive Strength
24
23.5
23
22.5
22
21.5
21
20.5
0% WMD
5%WMD
10%WMD
12.5% WMD
15% WMD
Dosage of WMD
7 days Compressive Strength


14th days Compressive Strength
Compressive Strength
30
29
28
27
26
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24
23
0% WMD
5% WMD
10% WMD
12.5% WMD
15% WMD
Dosage of WMD
14th days Compressive Strength

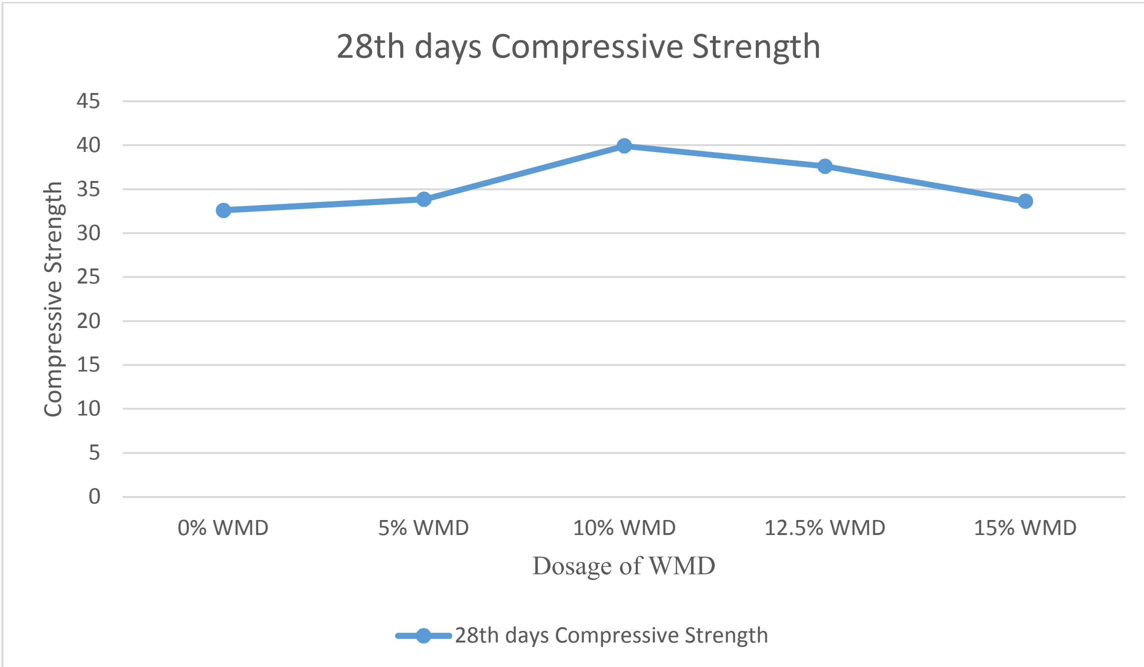

Figure 4.6: Effects of waste marble dust on compressive strength

The mean rate of compressive strength development of concrete at the age of 7th, 14th, and 28th with those percentages are also discussed as follows.

At the age of seventh day, the observed rate of compressive strength development of control point concrete was 21.06MPa. Similarly, for 5% waste marble dust added concrete the observed rate of compressive strength development was 22.72MPa. This indicates the rate of compressive strength development was increased by 1.66 MPa or 2.7% from 0% waste marble dust added concrete. For 10 % waste marble dust added concrete the observed rate of compressive strength development was 23.88MPa, which was increased by 2.82MPa or 6.04%, 1.16 MPa from 0 and 5%, waste marble dust added concrete. For 12.5 % waste marble dust added concrete the observed rate of compressive strength development was 22.81Mpa. It was increased by 1.75Mpa and 0.09 from control point and decreased by 1.07Mpa from 10%. For 15% waste marble dust he observed rate of compressive strength development was 22.36Mpa it was increased by 1.3Mpa from control point but decreased by 0.36Mpa, 1.5Mpa and 0.45Mpa from 5%, 10% and 12.5%waste marble dust admixture added concrete respectively.

At the age of fourteen day, the observed rates of compressive strength development of 0, 5, 10 12.5 and 15% of waste marble dust added concrete were 25.45Mpa, 28.32Mpa, 29.57Mpa, 27.22Mpa and 25.53MPa respectively. This indicates the observed rate of compressive strength development of 5% was increased by 2.87MPa from 0% waste marble dust added concrete. For 10% waste marble dust added concrete the observed rate of compressive strength development was increased by 4.12MPa, 1.25MPa, 2.35Mpa and 4.24MPa from 0, 5, 12.5 and 15% waste marble dust added concrete respectively.

At the age of twenty eight day, the observed rates of compressive strength development of 0, 5 10, 12.5 and 15% waste marble dust added concrete were 32.6MPa, 33.84MPa, 39.93MPa 37.62Mpa and 33.63MPa respectively. This shows the rate of compressive strength development of 5% was increased by 1.24MPa from 0% waste marble dust added concrete. 10% waste marble dust added concrete was increased by 7.33MPa and 6.09MPa from 0%, 5% waste marble dust added concrete. Whereas, 12.5% was increased by 5.02MPa, 3.78MPa and 3.99Mpa from 0%, 5% and 15% waste marble dust added concrete and reduced by 2.31Mpa from 10% waste marble dust added concrete.

According to ASTM C 192 standard, the 7-day compressive strength results of properly conducted tests on two trial batches made in the same laboratory should not differ by more than 574 psi (4MPa). If the analysis is based on the recommendation of ASTM C192 standard, all added dosage of waste marble dust does not bring a significant change on strength. However, based on the test observed results, concrete casted with the addition of waste marble dust has been shown a difference on the rate of compressive strength development at all ages than the reference concrete. This indicates, the rate of compressive strength development of concrete can be improved by the addition of waste marble dust, but based on the observed result, addition of WMD not always increases the compressive strength of concrete, on the other hand, it can reduces the strength significantly and become worse when the dosage is beyond the optimum amount. For this reason, there is an optimum limit for the usage of dust. According to the test observation the optimum dosage of waste marble dust admixture which produce better strength is 10%.

Therefore, optimum dosage of WMD is found based on the highest ultimate strength that they provide at age 28 days. i.e., 10% WMD added concrete was provided the highest optimum compressive strength. Dosage with lower or higher than this optimum value will reduce the strength. Since, the compressive strength of concrete is improved by the addition of WMD admixture by the reduction of cement; it's possible to conclude that a better improvement can also be obtained on flexural strength and split tensile strength. In this case it is possible to save at least 1.33%, 2.12%, 2.9% of cement by the addition of WMD admixture. For this reason, it possible to call WMD is a cement replacement material.

4.3.2. Flexural Strength of Concrete

The flexural strength test is used to determine the tensile strength of the concrete. When point load is applied at the center of the sample concrete, the member is subjected to bending moment. In this test, the concrete sample to be tested was supported at 4cm towards its both ends and loaded at the interior (center) location by a gradually failure load as illustrated in the figure 4.10 below. The failure load at which the concrete cracks was then recorded in ken as follows and by using formula, calculations were carried outdo determine the flexural strength in MPa.

Then, the flexural strength for center point loading has been calculated by using the following

General formula.

Flexural strength = $\frac{3FL}{2bd}$

Where:

F= the total load

L = the distance between the lower supporting rollers

b= breadth of the beam

d= depth of the beam

This test was performed for seven and twenty eight days for 0 %, 5%, 10% and 12.5% ,waste marble dust added concrete. Table 4.6 show the quantity of materials used to produce an m^3concrete by reducing mixing water. The results obtained from the experiment and through calculation are recorded in table 4.3 below.

Table 4.7: Quantity of materials in kg for 1m3C-25 concrete grade production

For C-25 concrete grade 0% WMD					
Materials	Cement (kg)	Water(lt)	WMD(Kg)	fine aggregate (kg)	Coarse aggregate(kg
Quantities per m^3	359	190	-	840	931
For C-25 concrete grade with 5% WMD					
Materials	Cement (kg)	Water(lt)	WMD(kg)	fine aggregate (kg)	Coarse aggregate(kg
Quantities per m^3	354.6	190	1.63	840	931
For C-25 concrete grade with 10% WMD					
Materials	Cement (kg)	Water(lt)	WMD (kg)	fine aggregate (kg)	Coarse aggregate(kg
Quantities per m^3	352	190	9.21kg	840	931
For C-25 concrete grade with 12.5% WMD					
Materials	Cement (kg)	Water(lt)	WMD (kg)	fine aggregate (kg)	Coarse aggregate(kg
Quantities per m^3	350.28	190	12.35kg	840	931
For C-25 concrete grade with 15% WMD					
Materials	Cement (kg)	Water(lt)	WMD (kg)	Fine aggregate (kg)	Coarse aggregate(kg
Quantities per m^3	348.4	190	14.67kg	840	931

Table 4.8: Effect of waste marble dust on Flexural strength of concrete

Waste marble dust	W/C Ratio	Slump Value	7^{th} days		28^{th} days	
			Failure Load (kN)	Flexural Strength (MPa)	Failure Load (kN)	Flexural Strength (Mpa)
0%	0.53	25	4.2	2.65	6.8	4.31
5%	0.53	26	4.6	2.9	7.3	4.65
10%	0.53	27	6.05	3.8	8.4	5.48
12.5%	0.53	27	6.55	4.13	8.65	5.36
15%	0.53	24	6.33	4.10	8. 21	5.20

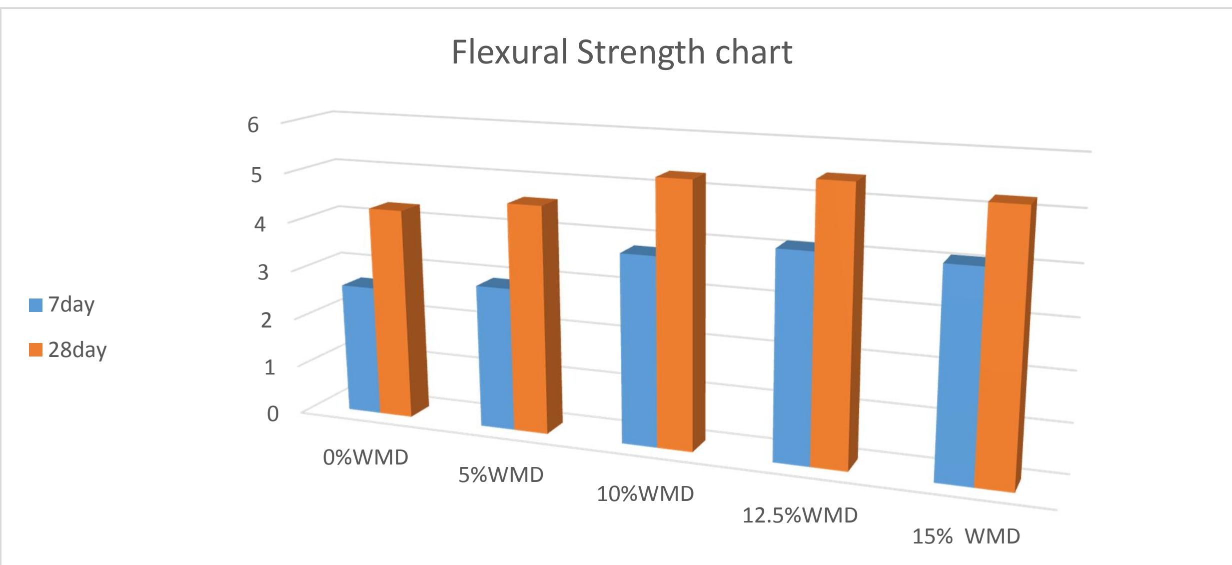

Figure 4.7. Flexural strength test

Development at the age of 7^{th} and 28thdays are discussed as follows. At the age of seven days, the rate of flexural strength development of 0%, 5%, 10%,12.5% and 15% of waste marble dust added concrete was 4.65MPa, 2.9MPa, 3.8MPa and 4.13MPa respectively. This indicates the rate of flexural strength development of 5% waste marble dust added concrete was improved by 0.251MPa or 9.4% from 0%. For 10% waste marble dust added concrete the rate of flexural strength development was improved by 1.15MPa or 43.4% and 0.9 MPa or 31% from 0% and

5%, but it was reduced by 0.33Mpa or 7.99% from 15% waste marble dust added concrete. For 15% waste marble dust added concrete the rate of flexural strength development was improved by 1.48Mpa or 55.84 %, 1.23MPa or 42.4% and 0.33MPa or 8.7% from 0%, 5% and 10% waste marble dust added concrete. At the twenty eight days, the rate of flexural strength development of 0%, 5%, 10%, 12.5% and 15% of waste marble dust added concrete was 4.31MPa, 4.65MPa, 5.36MPa, 5.48MPa and 5.20MPa respectively. This indicates the rate of flexural strength development of 5% waste marble dust added concrete was improved by 0.34MPa or 7.5% from 0%. For 10% waste marble dust added concrete the rate of flexural strength development was improved by 1.05MPa or 23.9% and 0.7 MPa or 15.2% from 0% and 5%, but it was reduced by 0.15Mpa or 2.8% from 15% waste marble dust added concrete. For 15% WMD added concrete the rate of flexural strength development was improved by 1.16Mpa or 27 %, 0.83MPa or 18% and 0.15MPa or 2.8% from 0%,5% and 10% waste marble dust added concrete. According to the reference discussed in the literature part, the flexural strength of waste marble dust added concrete can improve about 10% from the reference concrete. This research have also shown that the flexural strength of 5,10 and 12.5% dust added concrete at the 28day have been shown 7.2,23and 27% from the reference concrete. Therefore, based on the test results, the flexural strength has been well improved when the dosage of waste marble dust increase by increasing the amount of mixing water.

4.3.3. Experimental Results and Discussion on split tensile strength of concrete

Split Tensile strength of concrete is tested on cylinders at different percentage of marble powder Content in concrete. The strength of concrete has been tested on cylinder at 7 days curing and 28 days. 7days test has been conducted to check the gain in initial strength of concrete. 28 days test gives the data of final strength of concrete at 28 days curing .Compression testing machine is used for testing the Split Tensile strength test on concrete along with two wooden boards. At the time of testing the cylinder taken out of water and dried and then tested.

Then, the split tensile strength for center point loading has been calculated by using the following

General formula.

Split Tensile Strength = $\frac{2P}{\pi l d}$

Where:

T= Splitting tensile strength of the specimen

P = maximum applied load indicated by testing machine

l= length

d= diameter

This test was performed for seven and twenty eight days for 0 %, 5%, 10% ,12.5% and 15% ,waste marble dust added concrete. The results obtained from the experiment and through calculation are recorded in table 4.9. Below.

Figure 4.8: Sample ready for testing

Table 4.9: split tensile strength of concrete

Addition of marble powder (%)	Split tensile strength	
	7 days	28 days
0	2.10	2.78
5	2.37	3.23
10	3.56	4.86
12.5	3.45	3.54
15	3.75	3.89

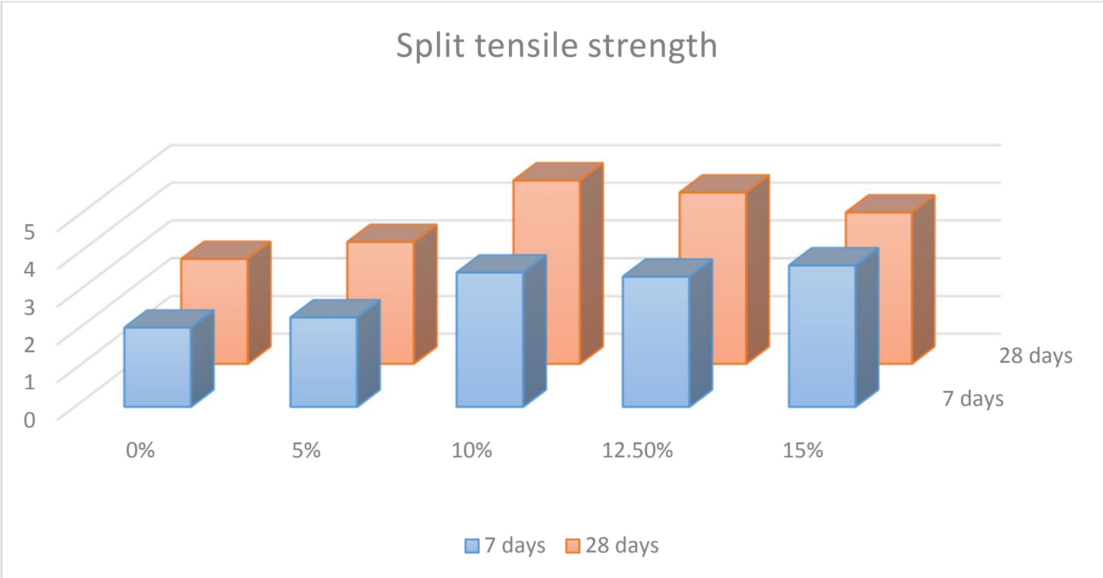

Figure 4.9. Split tensile strength

As an additive, WMD presence in concrete affects the results. Table 4.9 summarizes 7 and 28 days strength against various replacement conditions. The optimum value is reached at 10%WMD content in concrete sample. Due to the fine filler effect of WMD powder, maximum packing density of the mass is achieved with WMD grains filling up the vacant space.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

Based on the conducted laboratory results by using waste marble dust, conclusions and recommendations are forwarded on the effect of WMD admixture on the properties of concrete

5.1. CONCLUSIONS

This research was investigated the effect of addition of waste marble dust on concrete properties, such as: workability, strength (compressive and flexural and tensile) and. The results obtained from the study are summarized as follows:

According to earlier experimental studies, it concludes that use of wastes as a partial replacement of concrete constituents had a great prospective. The workability of the concrete did it show much difference as the percentage of WMD addition increased The Compressive strength of Cubes are increased with addition of waste marble powder up to 10% further any addition of waste marble powder the compressive strength decreases. The Split Tensile strength of Cylinders are increased with addition of waste marble powder up to 10% addition and further any addition of waste marble powder the Split Tensile strength decreases. The flexure strength of prisms are increased with addition of waste marble powder up to 10% addition and further any addition of waste marble powder the flexural strength decreases. There is a decrease in workability as the dosage of addition increases. It has been put forth a simple step to minimize the costs for construction with usage of marble powder which is freely or cheaply available.

Thus it is found out that optimum percentage for addition of marble powder is 10% for cubes, cylinders and prisms

.

RECOMMENDATION

Based on the research study, the following recommendations have forwarded

1. This research studied only on 0, 5, 10, 12.5 and 15% of waste marble dust admixture. So, further studies are required in different dosages of WMD admixture on different properties of concrete to obtain the maximum benefit.
2. In this investigation M25 grade of concrete is tested further work can be carried out by testing higher grades of concrete i.e.M30, M40 etc.
3. Further researches should have to be done on effects of WMD as an admixture.
4. Contractors and construction company can use waste marble dust as an addition to enhance the properties of concrete

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APPENDIX 1

MATERIALS TEST RESULTS

1. Properties of cement

1.1. Normal consistency of cement

Wt of (gm)cement	500	500	500	500	500	500	500	500
% of water	26	27	28	29	30	31	32	33
Wt of water (gm)	130	135	140	145	150	155	160	165
Penetration depth (mm)	5	11	21	-	-	-	-	-

1.1.2.

Time (min)	8:10	8:40	8:50	9:00	9:10	9:20	9:30	9:40	9:50	10:00	10:10	10:20	10:30	10:40	10:50	11:00	11:10
Penetration (mm)	-	40	40	39	40	39	38	35	36	34	34	28	15	13	10	5	0

1.2. Properties of fine aggregate

1.3.1. Silt content

Silt content Before washing			
Sample	Amount of silt deposit	Amount of clear sand	Silt content
Sample 1	6	22ml	7.9
Sample2	7	22ml	8.8
		Mean	8.35

Silt content after washing			
Sample	Amount of silt deposited(ml)	Amount of clear sand(ml)	Silt content
Sample 1	6	150ml	3.3
Sample2	7	290ml	2.4
		Mean	220

1.2.2. Sieve Analysis

1.2.2.1. Sieve analysis for original sand

Sieve size(mm)	Wt. of sieve (gm)	Wt. of sieve and aggregate (gm)	Wt. retained (gm)	Percentage retained (%)	Cumulative coarser (%)	Cumulative passing (%)
9.5 mm	585	585	0	0	0	100
4.75 mm	429	440	11	7	7	97.8
2.36 mm	383	430	47	11.5	18.7	88.4
1.18 mm	354	462	108	18.5	37.2	66.8
600 µm	326	511	185	33.75	70.95	28.6
300 µm	304	403	99	13.25	84.2	3.8
150 µm	460	500	40	12	96.2	0.4
Pan	255	265	10	1.5	1.5	0

1.2.2.1. Sieve analysis for blended aggregate

Sieve size(mm)	Wt. of sieve (gm)	Wt. of sieve and aggregate (gm)	Wt. retained (gm)	Percentage retained (%)	Cumulative coarser (%)	Cumulative passing (%)
9.5 mm	585	585	0	0	0	100
4.75 mm	429	440	11	7	7	97.8
2.36 mm	383	430	47	11.5	18.7	88.4
1.18 mm	354	462	108	18.5	37.2	66.8
600 µm	326	511	185	33.75	70.95	29.8
300 µm	304	403	99	13.25	84.2	10.0
150 µm	460	500	40	12	96.2	2.0
Pan	255	265	10	1.5	1.5	0

1.2.2. Unit Weight

1.2.2.1. Compacted Unit weight

Compacted Unit weight							
Sample	Wt of cylindrical metal(kg)	Wt of container + aggregate (kg)	Height of cylinder (m)	Dia. of cylinder (m)	Wt of aggregate (kg)	Volume of container (m3)	Compacted unit eight (kg/m3)
Sample 1	0.57	5.005	0.28	0.255	4.435	0.0142925	1515
Sample 2	0.57	5.115	0.28	0.255	4.545	0.0142925	1520
Sample 3	0.57	5.060	0.28	0.255	4.490	0.0142925	1518
						mean	1518

1.2.2.2. Loose unit weight

Compacted Unit weight							
Sample	Wt of cylindrical metal(kg)	Wt of container + aggregate (kg)	Height of cylinder (m)	Dia. of cylinder (m)	Wt of aggregate (kg)	Volume of container (m3)	Compacted unit eight (kg/m3)
Sample 1	0.57	5.005	0.28	0.255	4.435	0.0142925	1515
Sample 2	0.57	5.115	0.28	0.255	4.545	0.0142925	1520
Sample 3	0.57	5.060	0.28	0.255	4.490	0.0142925	1518
						mean	1518

1.3.3. Specific gravity

Weight of pycnometer = 291g

Weight of sand = 500 g

V_a = Volume of water added to pycnometer = 797cm^3

V = Volume of pycnometer = 1000cm^3

A = weight of oven-dry sample in air, [g] = 488g

Formula

C = 0.9976Va + 500 + W

Where:

C = weight of pycnometer filled with sample plus, water, [g]

Va = volume of water added to pycnometer, [cm^3]

W = weight of the pycnometer,[g]

C = 0.9976Va + 500 + W

C = 0.9976*797 + 500 + 291

C = 1586.09

B=0.9976V + W

Where:

B = weight of flask filled with water, [g]

V = volume of flask, [cm^3]

W = weight of flask empty, [g]

B=0.9976V + W

B = 0.9976 *1000 + 291

B = 1288.6

Bulk specific gravity

Bulk sp gr = $\frac{A}{B+500-C}$

Bulk sp gr = $\frac{493}{1555+500-1858}$ = 2.49

Bulk specific gravity (saturated- surface dry)

Bulk sp. gr. (saturated- surface dry) = $\frac{500}{B+500-C}$

Bulk sp. gr. (saturated- surface dry) = $\frac{500}{1555+500-1858}$ = 2.54

Apparent specific gravity

Apparent sp. gr. = $\frac{A}{B+A-C}$

Apparent sp. gr. = $\frac{493}{1555+493-1858}$

Apparent sp. gr. = $\frac{493}{190}$ = 2.59

Absorption capacity

Absorption capacity (%) = $\frac{500-A}{A} * 100$

Absorption capacity (%) = $\frac{500-493}{493} * 100$ = 1.42

1.3.1. Moisture content

A = weight of original sample = 500gm

B= weight of oven dry sample = 490gm

W= moisture content (%)

$$W = \frac{A-B}{B} * 100$$

$$W = \frac{500-490}{490} * 100 = 2.04\%$$

1.3. Properties Coarse aggregate

1.3.1. Sieve analysis

1.3.1.1. Sieve analysis for original coarse aggregate

Sieve size(mm)	Wt. of sieve (gm)	Wt. of sieve and aggregate (gm)	Wt. retained (gm)	Percentage retained (%)	Cumulative coarser (%)	Cumulative passing (%)
28 mm	535	1540	**535**	6.35	6.35	93.65
20 mm	4070	4370	4070	41.7	48.05	51.95
14 mm	2940	2735	2940	33.2	81.25	18.25
10 mm	1035	1630	1035	12.35	93.6	6.4
5 mm	380	1075	380	5.8	99.4	0.6
Pan	45	970	45	0.60	100	0

1.3.2.1. Sieve analysis for blended coarse aggregate

Sieve size(mm)	Wt. of sieve (gm)	Wt. of sieve and aggregate (gm)	Wt. retained (gm)	Percentage retained (%)	Cumulative coarser (%)	Cumulative passing (%)
28 mm	535	1540	**535**	6.35	6.35	93.65
20 mm	4070	2832	4070	41.7	48.05	51.95
14 mm	2940	2908	2940	33.2	81.25	18.25
10 mm	1035	2994	1035	12.35	93.6	6.4
5 mm	380	1075	380	5.8	99.4	0.6
Pan	45	932	45	0.60	100	0

1.3.2. Unit Weight

1.3.2.1. Compacted unit weight

Compacted Unit weight							
Sample	Wt of cylindrical metal(kg)	Wt of container + aggregate (kg)	Height of cylinder (m)	Dia. of cylinder (m)	Wt of aggregate (kg)	Volume of container (m3)	Compacted unit eight (kg/m3)
Sample 1	0.57	5.005	0.28	0.255	4.435	0.0142925	1515
Sample 2	0.57	5.115	0.28	0.255	4.545	0.0142925	1520
Sample 3	0.57	5.060	0.28	0.255	4.490	0.0142925	1518
						mean	1518

1.3.2.2. Loose unit weight

Compacted Unit weight							
Sample	Wt of cylindrical metal(kg)	Wt of container + aggregate (kg)	Height of cylinder (m)	Dia. of cylinder (m)	Wt of aggregate (kg)	Volume of container (m3)	Compacted unit eight (kg/m3)
Sample 1	0.57	5.005	0.28	0.255	4.435	0.0142925	1515
Sample 2	0.57	5.115	0.28	0.255	4.545	0.0142925	1520
Sample 3	0.57	5.060	0.28	0.255	4.490	0.0142925	1518
						mean	1518

1.3.4. Specific gravity

- Weight of oven dry sample in air (mass A) = 4886g
- Weight of saturated surface dry sample in air (massB) = 4989g
- Weight of saturated sample in water (mass C) = 3014g

Bulk specific gravity

Bulk sp. gr. = $\frac{A}{B-C}$

Bulk sp. gr. = $\frac{4886}{4989-3014} = 2.47$

Bulk specific gravity (saturated surface dry basis)

Bulk sp. gr. (saturated surface dry basis) = $\frac{B}{B-C}$

Bulk sp. gr. (saturated surface dry basis) = $\frac{4989}{4989-3014} = 2.52$

Apparent specific gravity

Apparent sp gr = $\frac{A}{A-C}$

Apparent sp gr = $\frac{4886}{4886-3014} = 2.61$

Absorption capacity

Absorption capacity (%) = $\frac{B-A}{A} * 100$

Absorption capacity (%) = $\frac{4989-4886}{4886} * 100$

Absorption capacity (%) = 2.11

1.3.4. Moisture Content

A = weight of original sample = 2000gm

B= weight of oven dry sample = 1953gm

W= moisture content (%)

W = $\frac{A-B}{B} * 100$

W = $\frac{2000-1953}{1953} * 100 = 2.41$

1.3.5. Determination of Aggregate Impact Value

A= the mass of surface dry sample aggregate = 324.6gm

B= the mass of the fraction passing on 2.36mm sieve= 41.8 gm

C = the mass of the fraction retained on 2.36mm sieve = 282.74 gm

Total fraction of passing and retained = 41.8gm + 282.74gm = 324.54gm

The total aggregate loss = 324.6gm - 324.54gm = 0.06gm

Percentage fines = $\frac{B}{A} * 100$

Percentage fines = $\frac{41.8}{324.6} * 100$ =12.9

APPENDIX 2

EXPERIMENTAL RESULTS

Zero % waste marble dust on workability and compressive strength for C-25												
No	Test age [days]	Dimensions (cm) L	W	H	w/c ratio	Slump (mm)	Weight (gm)	Volume (cm^3)	Failure load(kN)	Comp. Strength (MPa)	Rate of loading (MPa/s))	Unit weight (gm/cm^3)
1	7	15	15	15	0.53	26	8605	3375	339.1	15.07	0.280	2.550
2		15	15	15			8740	3375	334.6	14.87	0.280	2.590
3		15	15	15			8015	3375	343.2	15.25	0.280	2.375
						Mean	8453	3375	338.97	15.06	0.280	2.50
1	14	15	15	15	0.53	25	8008	3375	494.6	21.98	0.280	2.373
2		15	15	15			8660	3375	496.4	22.06	0.280	2.566
3		15	15	15			8036	3375	458.4	20.37	0.280	2.381
						Mean	8235	3375	483.13	21.47	0.280	2.440
1	28	15	15	15		27	8055	3375	738.6	32.83	0.280	2.387
2		15	15	15			8053	3375	760.1	33.78	0.280	2.386
3		15	15	15			8579	3375	701.6	31.18	0.280	2.542
						Mean	8229	3375	733.43	32.59	0.280	2.438

5% waste marble dust on workability and compressive strength for C25												
No	Test age [days]	Dimensions (cm)			w/c ratio	Slump (mm)	Weight (gm)	Volume (cm^3)	Failure load(kN)	Comp. Strength (MPa)	Rate of loading (MPa/s)	Unit weight
		L	W	H								
1	7	15	15	15	0.53	26	8605	3375	339.1	15.07	0.280	2.550
2		15	15	15			8740	3375	334.87	14.87	0.280	2.590
3		15	15	15			8579	3375	701.6	15.25	0.280	2.542
						Mean	8229	3375	733.4	32.60	0.280	2.542
1	14	15	15	15	0.53	25	7420	3375	750.3	27.4	0.280	2.542
2		15	15	15			7865	3375	761.4	28.1	0.280	2.542
3		15	15	15			7530	3375	762.1	27.8	0.280	2.542
						Mean	7605	3375	761.6	28.3 2	0.280	2.542
1	28	15	15	15	0.53	27	7780	3375	740.56	32.88	0.280	2.590
2		15	15	15			7620	3375	820.43	33.24	0.280	2.590
3		15	15	15			7980	3375	802.31	32.90	0.280	2.590
						Mean	7793	3375	787.77	33.84	0.280	2.590

10% waste marble dust on workability and compressive strength for C-25

No	Test age [days]	Dimensions (cm) L	W	H	w/c ratio	Slump (mm)	Weight (gm)	Volume (cm^3)	Failure load(kN)	Comp. Strength (MPa)	Rate of loading (MPa/s))	Unit weight (gm/cm^3)
1	7	15	15	15	0.53	26	8605	3375	339.1	15.07	0.280	2.550
2		15	15	15			8740	3375	334.6	14.87	0.280	2.590
3		15	15	15			8015	3375	343.2	15.25	0.280	2.375
						Mean	8453	3375	338.97	15.06	0.280	2.50
1	14	15	15	15	0.53	25	8008	3375	494.6	21.98	0.280	2.373
2		15	15	15			8660	3375	496.4	22.06	0.280	2.566
3		15	15	15			8036	3375	458.4	20.37	0.280	2.381
						Mean	8235	3375	483.13	21.47	0.280	2.440
1	28	15	15	15	0.53	27	8055	3375	738.6	32.83	0.280	2.387
2		15	15	15			8053	3375	760.1	33.78	0.280	2.386
3		15	15	15			8579	3375	701.6	31.18	0.280	2.542
						Mean	8229	3375	7334	32.59	0.280	2.44

12.5 % waste marble dust on workability and compressive strength for C-25

No	Test age [days]	Dimensions (cm) L	W	H	w/c ratio	Slump (mm)	Weight (gm)	Volume (cm^3)	Failure load(kN)	Comp. Strength (MPa)	Rate of loading (MPa/s))	Unit weight
1	7	15	15	15	0.53	26	8288	3375	869.7	38.65	0.280	2.456
2		15	15	15			8291	3375	867.9	38.57	0.280	2.457
3		15	15	15			8315	3375	889.3	39.52	0.280	2.464
						Mean	8298	3375	875.6	38.9	0.280	2.459
1	14	15	15	15	0.53	25	8256	3375	513.34	27.32	0.280	2.456
2		15	15	15			7980	3375	540.4	28.8	0.280	2.457
3		15	15	15			7544	3375	532.5	28.4	0.280	2.464
						Mean	7927	3375	527.8	27.6	0.280	2.439
1	28	15	15	15		27	8380	3375	804.6	35.76.	0.280	2.483
2		15	15	15			8574	3375	791.2	35.17	0.280	2.483
3		15	15	15			8235	3375	806.6	35.85	0.280	2.483
						Mean	83.96	3375	800.8	35.58	0.280	2.483

15% waste marble dust on workability and compressive strength for C-25

No	Test age [days]	Dimensions (cm)			w/c ratio	Slump (mm)	Weight (gm)	Volume (cm^3)	Failure load(kN)	Comp. Strength (MPa)	Rate of loading (MPa/s))	Unit weight (gm/cm^3)
		L	W	H								
1	7	15	15	15	0.53	26	7605	3375	449.1	21.07	0.280	2.550
2		15	15	15			7740	3375	404.6	20.87	0.280	2.590
3		15	15	15			7015	3375	353.2	22.25	0.280	2.375
						Mean	7453	3375	338.97	22.36	0.280	2.50
1	14	15	15	15	0.53	25	7008	3375	494.6	21.98	0.280	2.373
2		15	15	15			7660	3375	496.4	22.06	0.280	2.566
3		15	15	15			7036	3375	458.4	20.37	0.280	2.381
						Mean	7235	3375	483.13	21.47	0.280	2.440
1	28	15	15	15		27	7055	3375	738.6	32.83	0.280	2.387
2		15	15	15			7053	3375	760.1	33.78	0.280	2.386
3		15	15	15			7579	3375	701.6	31.18	0.280	2.542
						Mean	72.29	3375	733.43	32.66	0.280	2.438

Effect of 0 % WMD on flexural strength of concrete										
No	Test Age [days]	Dimention(cm)			Wt (gm)	W/C ratio	Water reduction (%)	Slump (mm)	F [kN]	σ[MPa]
		L	B	D						
1	7	50	50	50	12234	0.53	5.65	27	4.3	2.84
2		50	50	50	12332				4.5	2.42
								Mean	4.2	2.63
1	28	50	50	50	12566	0.54	5.65	25	7.4	4.66
2		50	50	50	1436				7.2	4.54
								Mean	6.8	4.31

Effect of 5 % WMD on flexural strength of concrete										
No	Test Age [days]	Dimention(cm)			Wt (gm)	W/C ratio	Water reduction (%)	Slump (mm)	F [kN]	σ[MPa]
		L	B	D						
1	7	50	50	50	12234	0.53	5.65	27	4.5	2.84
2		50	50	50	12332				4.7	2.96
								Mean	4.6	2.9
1	28	50	50	50	12566	0.54	5.65	25	7.4	4.66
2		50	50	50	1436				7.2	4.54
								Mean	7.3	4.6

Effect of 10% WMD on flexural strength of concrete										
No	Test Age [days]	Dimention(cm)			Wt (gm)	W/C ratio	Water reduction (%)	Slump (mm)	F [kN]	σ[MPa]
		L	B	D						
1	7	50	50	50	12234	0.53	5.65	27	6.2	3.12
2		50	50	50	12332				5.9	2.96
								Mean	6.05	3.05
1	28	50	50	50	12566	0.54	5.65	25	7.4	5.66
2		50	50	50	1436				7.2	5.33
								Mean	7.3	5.48.

Effect of 12.5% WMD on flexural strength of concrete										
No	Test Age [days]	Dimention(cm)			Wt (gm)	W/C ratio	Water reduction (%)	Slump (mm)	F [kN]	σ[MPa]
		L	B	D						
1	7	50	50	50	12234	0.53	5.65	27	4.5	2.84
2		50	50	50	12332				4.7	2.96
								Mean	6.55	2.9
1	28	50	50	50	12566	0.54	5.65	25	8.4	5.33
2		50	50	50	1436				8.75	5.40
								Mean	8.65.	5.36

Effect of 15 %WMD on flexural strength of concrete										
No	Test Age [days]	Dimention(cm)			Wt (gm)	W/C ratio	Water reduction (%)	Slump (mm)	F [kN]	σ[MPa]
		L	B	D						
1	7	50	50	50	12234	0.53	5.65	27	5.8	2.84
2		50	50	50	12332				4.7	2.96
								Mean	4.6	2.9
1	28	50	50	50	12566	0.54	5.65	25	8.41	5.06
2		50	50	50	12345				8.10	5.34
								Mean	8.21	5.20

APPENDIX 3

SAMPLE PHOTO GALLERY TAKEN DURING THE RESEARCH

Photo: Sample marble dust used

Photo: Riffle Box for quartering course aggregates and sieves Shaker with series of sieves

Photo: Photo: Riffle Box for quartering fine aggregates and sieves Shaker with series of sieves

Photo: Unit weight tests

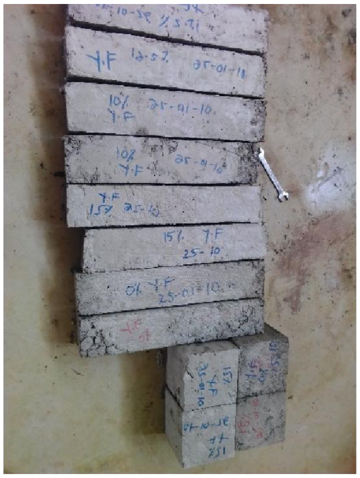

Photo: Flexural test concrete sample